·Clinical Research·

A new specialized visual acuity chart for amblyopic children aged 3-5 years old: development and its clinical applications

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Abstract

• AIM: To introduce a new specialized visual acuity chart for amblyopic children aged 3-5 years old and its clinical applications.

• METHODS: The new visual acuity chart and notations were designed based on Weber-Fechner law. The optotypes were red against a white background and were specially shaped four basic geometric symbols: circle, square, triangle, and cross. A regular geometric progression of the optotype sizes and distribution was employed to arrange in 14 lines. The progression rate of the optotype size between two lines was 1.2589 and the testing distance was 3m. Visual acuity score could be recorded as logMAR notation or decimal notation. Age-stratified diagnostic criteria for amblyopia established by consensus statement on diagnosis of amblyopia (2011) among members of the Strabismus and Pediatric Ophthalmology Group, Ophthalmology Society, Chinese Medical Association (SPOGOSCMA) were illustrated in the new visual acuity chart.

• RESULTS: When assessing visual acuity in children aged 3-5 years old, this new visual acuity chart that consists of four symmetrical shapes (triangle, square, cross, and circle) overcame an inability to recognize the letters of the alphabet and difficulties in designating the direction of black abstract symbols such as the tumbling ´E´ or Landolt ´C´, which the subjects were prone to lose interest in. The visual acuity score may be recorded in different notations: decimal acuity and logMAR. These two notations can be easily converted each other in the new eye chart. The measurements of this new chart not only showed a significant correlation and a good consistency with the international standard logarithmic visual acuity chart (r=0.932, P<0.01), but also indicated a high test-retest reliability (89% of retest scores were within 0.1logMAR units of the initial test score).

• CONCLUSION: The results of this study support the validity and reliability of distance visual acuity measurements using the new eye chart in children aged 3 to 5 years over a wide range of visual acuities, and the new eye chart is great for early detection of amblyopia. It can be applied in various clinical settings.

• KEYWORDS: amblyopic children; Weber-Fechner law; international standard logarithmic visual acuity chart
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INTRODUCTION

In pediatric practice, vision screening is intended to identify those preschool children who have visual impairment or eye conditions that are likely to lead to visual impairment so that a referral can be made to an appropriate eye care professional for further evaluation and treatment. The main goal of pediatric vision screening is to identify preschool children who have or are at risk to develop amblyopia, which can lead to permanent visual impairment unless treated in early childhood [1]. There are a number of methods used to screen a child's vision. The method chosen is largely dependent on the age of the child and the clinical experience of the examiner. In most cases, amblyopia can be found even in infants aged from several months after birth to 3 years through objective visual acuity testing, such as preferential looking, visual evoked potentials and optokinetic nystagmus, *etc* [2]. By age 3, pediatric vision screening with acuity measurements is the most widely used method because most children are able to cooperate for subjective visual acuity testing using an eye chart [3]. In the case of preschool children, the best time to correct amblyopia is during infancy or early childhood [4]. The earlier that amblyopia is detected, the better the visual recovery and the long-term prognosis. For these reasons, it is important that an appropriate eye chart be selected to improve accuracy and precision of pediatric vision screening for the earlier discovery of amblyopia and visual acuity must be accurately documented. In addition, it is critical that child be tested at the appropriate distance for the eye chart [5]. Historically, although a variety of pediatric acuity testing targets have been developed, the most frequently used are the Snellen letter, tumbling E, hand gesture, HOTV and Lea symbols chart which require some degree of skills in visual perception and spatial orientation, such as laterality and directionality, and may not be suitable for children aged 3-5 years old [6]. Recent investigations of children's cognitive development suggest that infants often learn to distinguish the outline of a geometrical figure before they begin to discriminate the orientation during visual perception development because asynchrony between visual and mental development in early childhood is always present [7]. Generally speaking, infants first learn to tell up from down, then they learn to recognize left from right; finally, they learn to distinguish the front and back, and furthermore it is easier for infants to indicate the directions of up, down, front, back than they do about left and right[8]. Thus it is quite difficult to determine accurately the best possible visual acuity that a amblyopic child (3 to 5 years of age) can achieve by using a visual acuity chart currently used in clinical settings. Controlled clinical trials showed that cone cells in the foveal region of the children's retina are most sensitive to wavelengths of the light around 640nm (red)[9]. The overall cooperation rate and the extent of cooperation for visual acuity testing using 5m children visual acuity chart in pediatric practice are not only relatively lower, but also there isn't enough living space for visual acuity testing in most Chinese families. Therefore, it is desirable for all ophthalmic personnel to develop a specialized visual acuity chart which is suitable for both the detection of amblyopia risk factors in children (3-5 years of age) and the national conditions in China. In this study, a new visual acuity chart and notations based on Weber-Fechner law are designed for use in preschool children (3-5 years of age) to overcome the perceived inadequacies of conventional eye charts, and its primary clinical applications are evaluated.

MATERIALS AND METHODS

Criteria for Visual Acuity Charts The new visual acuity chart and notations were designed based on Weber-Fechner law. Optotypes were specially shaped four geometric symbols (circle, square, triangle, and cross) shown by symmetrical plane figures for easy recognition in the sequence of children's cognitive development, and represented as red symbols against a white background in the new eye chart. The order in which the symbols were presented on each line was randomized in compliance with ISO 8596:2009 [10]. The stroke width of each optotype was one point perspective and was equal to 1/5 of side-length of a square that was circumscribed around an optotype figure. The new chart conformed to the design principles used in the international standard logarithmic visual acuity chart, in terms of visual angle, visual record, intersymbol spacing and interline spacing. The testing distance was 3m.

Methods of Visual Acuity Testing The measurement of visual acuity in children (3-5 years old) is usually from right to left eye, with each eye tested independently. Visual acuity in each eye is tested as the opposite eye is covered with a solid object. Take care not to press on the eye itself. Test chart background luminance is from 200 to 320cd/m^2. When an optometrist points to the optotypes displayed on the chart using an indicator rod, and the child subject is asked to read out loud the outlines of all indicated pictorial optotypes, starting with large rows and continuing to smaller rows until the optotypes cannot be reliably recognized anymore. All optotypes on each line have to be identified in the new chart.

Optometry By convention, A line of optotypes is generally considered to have been read correctly when more than half of the optotypes presented have been read correctly on the new chart. The recorded acuity score shall identify the size of the smallest optotype that can be recognized. The result of the visual acuity measurement can be recorded as logMAR notation or decimal notation. The following formula is defined to convert a visual acuity record from logMAR notation to decimal notation: $L=\lg\alpha=\lg 1/V$, where the capital letter 'L' and 'V' are the convenient form of the logMAR and decimal visual acuity value respectively. The conversion between visual angle, logMAR, and decimal notation of the new chart is shown in Table 1.

Clinical Trials A total of 150 subjects were randomly selected from preschool children (3 to 5 years of age; mean 4.1±0.8 years), recruited in ophthalmology outpatient service. Strabismus, ametropia, and any organic eye disease were excluded. Then a definite diagnosis of amblyopia was made on the basis of consensus statement on diagnosis of amblyopia (2011) among members of the Strabismus and Pediatric Ophthalmology Group, Ophthalmology Society, Chinese Medical Association (here-in-after called 'SPOGOSCMA') [11]. Visual acuity was measured under the following conditions: 1) illumination for interior lighting, 500lux; 2) testing distance, 3m; 3) only data from the right eyes were used except when vision screening for the detection of amblyopia risk factors was performed.

Statistical Analysis Data are expressed as $\bar{x}\pm s$. Statistical analysis was performed using the SPSS for one-way analysis of variance. Bland-Altman analysis for paired data was performed[12].

Table 1 Conversion table for visual angle, logMAR notation and decimal notation

Visual angle(α)	logMAR notation(L)	Decimal notation (V)
10.0	1.0	0.1
7.9	0.9	0.12
6.3	0.8	0.15
5.0	0.7	0.2
4.0	0.6	0.25
3.2	0.5	0.3
2.5	0.4	0.4
2.0	0.3	0.5
1.6	0.2	0.6
1.3	0.1	0.8
1.0	0.0	1.0
0.8	-0.1	1.2
0.6	-0.2	1.5
0.5	-0.3	2.0
		1/α

RESULTS

Description of the Chart As shown in Figure 1, the new chart consists of four basic symmetrical shapes (triangle, square, cross, and circle) printed on a white background in red color. It had 14 rows and the visual acuity values ranged from 0.1 to 2.0 (logMAR grade notion 1.0 to -0.3) at 3m. The symmetrical shapes were getting smaller as they descended the chart. The spacing between adjacent borders on each row was equal to the width of a symbol. The progression rate of optotype size between two lines was 1.2589 and distance between lines was 24mm. Different shapes for testing vision were arranged in a random order and used with identical quantities. Adjacent optotypes were different in the new chart. The visual acuity score could be recorded as logMAR notation or decimal notation.

Statistical Analysis for Assessing Agreement The mean value of visual acuity measured using international standard logarithmic visual acuity chart in the right eyes of 150 subjects was (0.2390±0.1550)logMAR, the mean value of visual acuity measured using the specialized visual acuity chart for amblyopic children aged 3-5 years old was (0.1960±0.1433)logMAR. For 150 subjects, the difference in the two acuity measurements was 0.043logMAR, and the linear regression equation between measurements from international standard logarithmic visual acuity chart and the new specialized visual acuity chart was y=-0.01+0.862x, and the correlation between the acuity results obtained from the two charts was high (r=0.932, P<0.01). As shown in Figure 2, no statistically significant differences can be observed in acuity scores obtained from the two charts in clinical trials (P>0.05). The 95% confidence interval for the difference in mean acuity level between the new chart and international standard logarithmic visual acuity chart was (-0.177logMAR, 0.263logMAR).

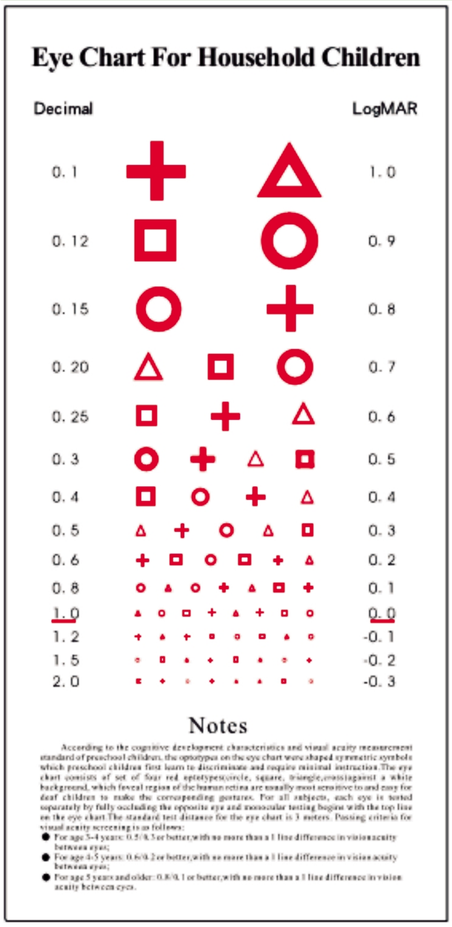

Figure 1 Specialized visual acuity chart for amblyopic children aged 3−5 years old.

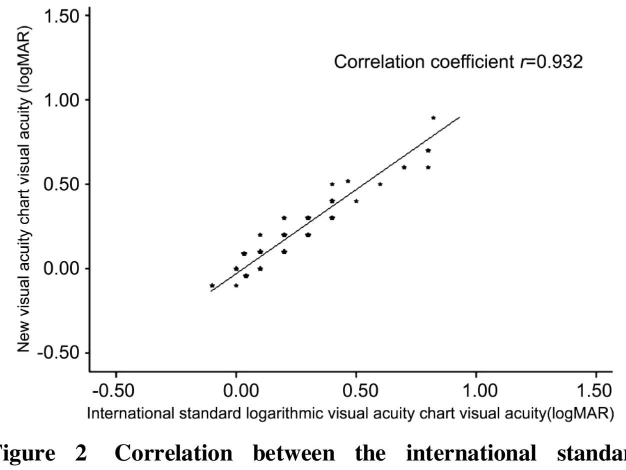

Figure 2 Correlation between the international standard logarithmic visual acuity chart and the new specialized visual acuity chart for amblyopic children aged 3−5 years old visual acuity chart.

Visual acuity data obtained with the new specialized visual acuity chart for amblyopic children aged 3-5 years old visual acuity chart are plotted against equivalent data for the international standard logarithmic visual acuity chart.

Statistical Analysis for Test −Retest Reliability The correlation between the initial and the retest visual acuity scores was 0.914, with 89% of retest scores within being 0.1logMAR units of the initial test score. For a change

Table 2 Comparison of the response rate, the means of binocular visual acuity and the number of children who showed an interocular difference of more than one line concerning those of different age groups cooperating in both tests

Group (month)	36-47 (n=50)			48-59 (n=50)			60-71 (n=50)		
Screening test	Means of binocular visual acuity	Response rate (%)	Difference >1line	Means of binocular visual acuity	Response rate (%)	Difference >1line	Means of binocular visual acuity	Response rate(%)	Difference >1line
I	0.31±0.10 logMAR	44	1	0.23±0.11 logMAR	72	2	0.18±0.19 logMAR	94	2
II	0.25±0.09 logMAR	96	3	0.21±0.09 logMAR	96	3	0.16±0.18 logMAR	98	2

Table 3 Comparison of amblyopia screening results between screening tests I and III

Screening test I	Screening test III: Amblyopic subjects, Age group (month) 36-47	48-59	60-71	Nonamblyopic subjects, Age group (month) 36-47	48-59	60-71	Total
Amblyopic subjects	1	2	2	1	1	1	8
Nonamblyopicsubjects	2	2	1	18	31	43	97
Total	3	4	3	19	32	44	105

between two acuity scores, the 95% confidence interval was the difference ±0.2logMAR units (Figure 3).

Comparison of the Screening Accuracy and Validity for the Detection of Amblyopia Vision screening tests for the detection of amblyopia risk factors were conducted in 150 subjects who had none of strabismus and organic eye disease in thorough ophthalmological examination. The 150 subjects were divided into three groups according to their month ages: 36-47 months (n=50), 48-59 months (n=50), and 60-71 months (n=50). For screening test I with international standard logarithmic visual acuity chart, substantial variations were observed among the three age groups.

In the 36-47 months age group, the means of binocular visual acuity, response rate and the number of children who had an interocular difference of more than one line were (0.31±0.10)logMAR, 44%, and 1 (Table 2), respectively. 2 in 50 children were found to have amblyopia risk factors based on the current referral criteria ,but one of them was confirmed by screening test III based on consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA to have amblyopia; while 2 in 48 nonamblyopic children were confirmed by screening test III to suffer from amblyopia (Table 3).

In the 48-59 months age group, the means of binocular visual acuity, response rate and the number of children who had an interocular difference of more than one line were (0.23±0.11)logMAR, 72%, and 2 (Table 2), respectively. Three in 50 children were found to have amblyopia risk factors based on the current referral criteria, but one of them was confirmed by screening test III based on consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA to suffer from amblyopia; while 2 in 47 nonamblyopic children were confirmed by screening test III to have amblyopia (Table 3).

In the 60-71 months age group, the means of binocular visual acuity, response rate and the number of children who had an interocular difference of more than one line were

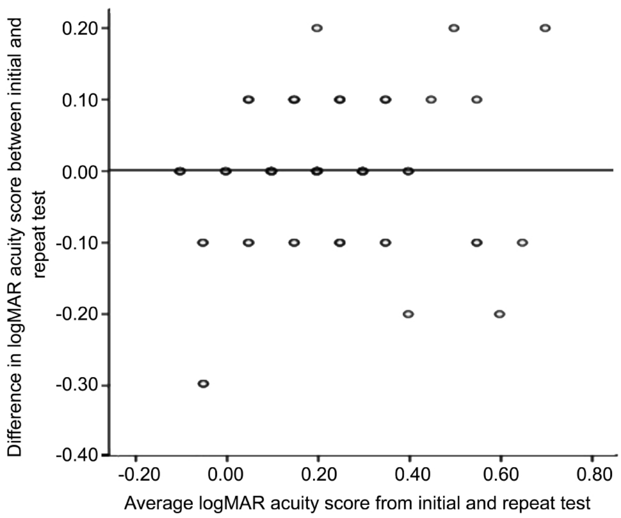

Figure 3 Bland-Altman plot of test-retest difference versus average test-retest acuity. Data plotted as the test-retest difference versus the mean test-retest acuity suggest that the test-retest reliability did not vary with the level of visual acuity. A negative difference indicates that the repeat acuity test score was worse than the initial score[13].

(0.18±0.19)logMAR, 94%, and 2, respectively (Table 2). Three in 50 children were found to have amblyopia risk factors based on the current referral criteria , but one of them was confirmed by screening test III based on consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA to have amblyopia; while 1 in 47 nonamblyopic children were confirmed by screening test III to have amblyopia (Table 3). For screening test II with new visual acuity chart, substantial variations were slightly higher than the suitability previously found in the same age range.

In the 36-47 months age group, the means of binocular visual acuity, response rate and the number of children who had an interocular difference of more than one line were (0.25±0.09)logMAR, 96% and 3, respectively (Table 2). Three in 50 children were found to have amblyopia risk factors based on the current referral criteria ,but one of them was confirmed by screening test III based on consensus statement

Table 4 Comparison of amblyopia screening results between screening test II and III

Screening test II	Screening test III						Total
	Amblyopic subjects Age group (month)			Nonamblyopic subjects Age group (month)			
	36-47	48-59	60-71	36-47	48-59	60-71	
Amblyopic subjects	2	2	2	1	1	1	9
Nonamblyopic subjects	2	1	1	43	44	45	136
Total	4	3	3	44	45	46	145

Table 5 Comparing the screening accuracy for the prediction of amblyopia between the two different visual acuity charts

Age group (month)	Screening test									
	I					II				
	Sensitivity (%)	Specificity (%)	Youden index	Positive predict value (%)	Negative predict value (%)	Sensitivity (%)	Specificity (%)	Youden index	Positive predict value (%)	Negative predict value(%)
36-47	33.3	94.7	0.277	50.0	90.0	50	97.7	0.477	66.7	97.9
48-59	50	96.9	0.469	66.7	93.9	66.7	97.8	0.645	66.7	97.8
60-71	66.7	97.7	0.644	66.7	97.7	66.7	97.8	0.645	66.7	97.8

I: visual acuity chart specialized for amblyopic children aged 3-5 years old; II: international standard logarithmic visual acuity chart; III: consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA.

on diagnosis of amblyopia (2011) among members of SPOGOSCMA to suffer from amblyopia; while 2 in 47 nonamblyopic children were confirmed by screening test III to have amblyopia (Table 4).

In the 48-59 months age group, means of binocular visual acuity, response rate and number of children who had an interocular difference of more than one line were (0.21 ± 0.09)logMAR,96% and 3, respectively (Table 2). Three in 50 children were found to have amblyopia risk factors based on the current referral criteria, but one of them was confirmed by screening test III based on consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA to suffer from amblyopia; while 1 in 47 nonamblyopic children were confirmed by screening test III to have amblyopia (Table 4).

In the 60-71 months age group, means of binocular visual acuity, response rate and number of children who had an interocular difference of more than one line were (0.16 ± 0.18)logMAR, 98% and 2, respectively (Table 2). Three in 50 children were found to have amblyopia risk factors based on the current referral criteria, but one of them was confirmed by screening test III based on consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA to suffer from amblyopia; while 1 in 47 nonamblyopic children were confirmed by screening test III to have amblyopia (Table 4).

As Table 2 shows the response rates for monocular testing of both eyes in two different screening tests increased with age. The difference in response rate between two screening tests was statistically significant only for 3-year-old children, more of whom were cooperative with the new visual acuity chart (96%) than with the international standard logarithmic visual acuity chart (44%). Although the means of binocular visual acuity obtained from the new visual acuity chart had been found to be about 11.5 lines higher than those obtained from the international standard logarithmic visual acuity chart, a difference that was even more evident in amblyopic eyes, there were no statistically significant differences between the screening test results for any age group. To compare the accuracy and validity of vision screening tests for the detection of amblyopia using two different visual acuity charts in children (3-5 years old), we calculated the sensitivity, specificity, Youden index, the positive predictive value and the negative predictive value for each test. As shown in Table 5, the efficacy (including specificity, sensitivity, Youden index, the positive and negative predictive values) was better with screening test II than with screening test I. The largest differences in efficacy were in the 36-47 month age group, where the sensitivity, specificity, Youden index, the positive and negative predictive values for amblyopia were 33.3% , 94.7% , 0.277, 50% , 90% , respectively, for the international standard logarithmic visual acuity chart and 50% , 97.7% , 0.477, 66.7% , 97.9% , respectively, for the new visual acuity chart. Overall, the screening tests showed an increase of sensitivity and corresponding Youden index with age, while specificity remained basically unchanged in all age groups. When specificity was equally high for both screening tests, the sensitivity and corresponding Youden index of screening test II were slightly higher than those of screening test I in the same age group. Comparison of visual acuity screening results between the two tests indicated that visual acuity screening using the new visual acuity chart appeared to be more accurate than the international standard logarithmic visual acuity chart in the detection of amblyopia in children aged 3-5 years.

DISCUSSION

Theoretical Basis The new visual acuity chart and notations are designed based on Weber-Fechner law. When optotypes are being arranged in the form of charts, a previous study shows that crowed symbols should be preferred because of higher sensitivity for amblyopia [14]. Compared with other commonly used visual acuity charts, the above mentioned statistic data suggests that the new eye chart presented in figure 1 has the following advantages:

Firstly, following the normal patterns of the visual acuity development in infants and young children up to the age of five, the optotypes on the new eye chart are shaped symmetric symbols that children of 3 to 5 years first learn to discriminate and require minimal instruction [15]; and what's more, age-stratified diagnostic criteria are proposed for the detection of amblyopia risk factors according to consensus statement on diagnosing amblyopia (2011) among members of SPOGOSCMA; hence using the new eye chart may result in increased sensitivity and a lower false-negative rate.

Secondly, the new eye chart symbols combine the advantages of optotypes and pictures. These optotypes are well-standardised, calibrated against the Landolt C which is the international reference optotype in decadic logarithmic steps (lines) from 0.1 to 2.0 at a distance of 3m, and similar in discriminability. They blur equally at threshold to reduce chances of guessing and culturally neutral [16]. The new eye chart uses three symbols: a triangle, a cross and a square, which differ in few critical details from the fourth symbol (a circle). Below the threshold of recognition, each symbol appears as a small circle.

Thirdly, by definition, visual acuity refers to the measure of the eyes' ability to distinguish object details and shape in a given distance in the fovea centralis. Because fovea centralis contains only cones that are sensitive to the red light (L cones, 65%), the green light (M cones, 33%), and the blue light (S cones, 2%) without rods, it contributes to providing the best possible vision screening for amblyopic children of 3-5 years old by stimulating cone cells in the foveal region of the children retina using the new eye chart, which consists of set of red optotypes whose hue values range between 630nm and 650nm[17].

Fourthly, the new chart is designed for vision testing at 3m. It is not only suitable for the use in a small space like a living room or bedroom, but also more convenient for examiners to communicate with subjects, and helpful to improve response rates by reducing the test distance in the pediatric practice.

Finally, the visual acuity results obtained from children using the new visual acuity chart are expressed as logMAR notation or decimal notation. These two alternative notations for indicating the visual acuity can be easily converted each other.

Standardization The new near-vision chart may also be referred to as a standardized visual acuity chart because the visual characteristics of the new chart conforms with design principles for international standard logarithmic visual acuity chart in terms of optotype, visual angle, increasing rate of optotype size, and notation, which are in compliance with the requirements defined in GB11533-2011 [18]. Analysis of the agreements made available shows that there are no statistically significant differences between acuity results obtained with the two charts.

Analysis of Statistical Results In the case of children aged 3-5 years, the statistical results of this study support the validity and reliability of the new eye chart which is used as a primary visual acuity measuring tool in children of 3 to 5 years over a wide range of visual acuities, and is especially suitable for vision screening test for the detection of amblyopia. The overall response rate from using the new visual acuity chart is higher than that from using the international standard logarithmic visual acuity chart. This conclusion may be explained by various factors. Younger children are more interested in optotype symbols on the new visual acuity chart than in capital letter E on the international standard logarithmic visual acuity chart because they prefer red to black [19]. When reaching visual acuity threshold, children who get the same prompt provided by the inspector are willing to continue to identify the optotypes on the new visual acuity chart while they run out of patience with visual acuity testing when the international standard logarithmic visual acuity chart is adopted. Although there is a significant correlation between visual acuity scores of the new visual acuity chart and the international standard logarithmic visual acuity chart, the new visual acuity chart may overestimate the acuity score determined by the international standard logarithmic visual acuity chart in children of 3-5 years old. This difference may be attributed to the fact that it is easier for the child to identify and name geometric shapes of optotypes on the new acuity chart instead of the direction which an optotype faces on the international standard logarithmic visual acuity chart. Based on the previous studies, optotypes on the new visual acuity chart include more recognition and interpretation clues than the international standard logarithmic visual acuity chart. The capital letter E is seen as a dim C and the direction of capital E can be guessed by estimating which side of the capital letter is lighter when the capital letter E is blurred to the point of being barely perceptible. The symmetrical symbols on the new visual acuity chart, when blurred, are recognized by the number of corners pointing either out or into the dim ring, a visual task quite different from the recognition of the capital letter E [20]. The relationship between age and visual acuity is measured numerically and the results show that the means of binocular visual acuity obtained from using the new acuity chart and international standard logarithmic visual acuity chart increase with age, whereas the mean paired acuity difference between the two visual acuity charts will be gradually reduced. This may be in part because there is an expected improvement in recognition acuity with the increasing age. For amblyopic children aged 3-5 years old, recognition acuity is more severely reduced than grating acuity or detection acuity [21]. Symmetric symbols such as circle, square, triangle, and cross are very favorable for measuring recognition acuity in preschool children. Therefore, in cooperative subjects, the new visual acuity chart is more sensitive to interocular acuity differences than the national standard logarithmic near vision chart. Although sensitivity obtained with the new visual acuity chart is slight higher than those obtained with the international standard logarithmic visual acuity chart, with the largest difference between acuity results on the two tests occurring in 36-47 months age group when their corresponding specificities are equal to each other, no statistically significant difference was found between them (P>0.05). In this case, the positive and negative predictive values for amblyopia still remain relatively low. The improvements of diagnostic capabilities of visual acuity chart in children aged 3-5 years old are related to age-stratified diagnostic criteria which the new visual acuity chart proposed for visual acuity screening based on consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA.

In conclusion, the new eye chart and notations, conforming to physiological and psychological characteristics of children (3-5 years), are developed in compliance with GB11533-2011 Chinese national standard for logarithmic visual acuity charts. Compared with the national standard logarithmic visual acuity chart, the response rate, especially for preschool children aged 3-4 years old using the new eye chart, is higher. The new near vision chart not only provides a better measure of interocular acuity differences that is similar to that obtained from the national standard logarithmic visual acuity chart, but may also increase the precision of the measured acuity and sensitivity of interocular acuity differences. And thus it will increase the efficiency and sensitivity of amblyopia screening; meanwhile, considering these factors that affect age-matched normal values of visual acuity including cognitive and motor development, the new eye chart employs symmetric red symbols against a white background as optotypes, and provides age-matched passing criteria for vision screening[22]. Because the new eye chart secures validity of amblyopia screening among children of 3-5 years old based on the consensus statement on diagnosis of amblyopia (2011) among members of SPOGOSCMA, it may represent an ideal alternative to the national standard logarithmic visual acuity chart for the vision screening in children aged 3-5 years, especially under the age of 4 years. The new eye chart shows great potential for use in routine clinical practice. Having established the potential of this design, further investigations are optimising the chart design in terms of line spacing, spacing of optotypes, number of optotypes for each size, and specification of the measured visual acuity.

REFERENCES

1 YS Bradfield. Identification and treatment of amblyopia. *Am Fam Physician* 2013;87(5):348-352

2 Hoyt CS. Objective techniques of visual acuity assessment in infancy. *Aust N Z J Ophthalmol* 1986;14(3):205-209

3 Committee on Practice and Ambulatory Medicine, Section on Ophthalmology. American Association of Certified Orthoptists; American Association for Pediatric Ophthalmology and Strabismus; American Academy of Ophthalmology. Eye examination in infants, children, and young adults by pediatricians. *Pediatrics* 2003;111(4):902-907

4 Pan JP. Child Health Care. Xi'an: Shanxi Science & Technology Publishing House 1998:233

5 Tingley DH. Vision screening essentials: Screening today for eye disorders in the pediatric patient. *Pediatr Rev* 2007;28(2):54-61

6 Huang RZ. Design of visual acuity chart for preschool children. *Anhui Medical Journal* 1983;4(3):184-185

7 Changqing. Psychology of preschool children. Nanchang: Jiangxi Universities Associated Press 2009:91-95

8 Wang YX, Yue HL. Psychological and behavioral observations of children Shanghai: Shanghai Science & Technology Publishing House 2011:127

9 Cicerone CM, Nerger JL.The relative numbers of long-wavelength-sensitive to middle-wavelength-sensitive cones in the human fovea centralis. *Vis Res* 1989;29(1):115-128

10 International Organization for Standardization (ISO). Ophthalmic optics visual acuity testing standard optotype and its presentation. Geneva, Switzerland, ISO, 2009; (ISO 8596:2009)

11 Members of the Strabismus and Pediatric Ophthalmology Group, Ophthalmology Society, Chinese Medical Association. Consensus statement on diagnosis of Amblyopia. *Chi J Ophthalmol* 2011;47(8):768

12 Beck RW, Moke PS, Turpin AH, Ferris FL3rd, SanGiovanni JP, Johnson CA, Birch EE, Chandler DL, Cox TA, Blair RC, Kraker RT. A computerized method of visual acuity testing: adapt-ation of the early treatment diabetic retinopathy study testing protocol. *Am J Ophthalmol* 2003;135(2):194-205

13 Moke PS, Turpin AH, Beck RW, Holmes JM, Repka MX, Birch EE, Hertle RW, Kraker RT, Miller JM, Johnson CA. Computerized method of visual acuity testing: adaptation of the amblyopia treatment study visual acuity testing protocol. *Am J Ophthalmol* 2001;132(6):903-909

14 Gräf MH, Becker R, Kaufmann H. Lea symbols: visual acuity assessment and detection of amblyopia. *Graefes Arch Clin Exp Ophthalmol* 2000;238(1):53-58

15 Miller JM, Dobson V, Harvey EM, Sherrill DL. Comparison of preschool vision screening methods in a population with a high prevalence of astigmatism. *Invest Ophthalmol Vis Sci* 2001;42(5):917-924

16 Bach M, Kommerell G. Determining visual acuity using European normal values: scientific principles and possibilities for automatic measurement. *Klin Monatsbl Augenheilkd* 1998;212(4):190-195

17 Robert J. Snowden, Peter Thompson, Tom Troscianko. Basic vision: an introduction to visual perception. Oxford University Press 2006:218

18 National Standard of the People's Republic of China GB11533-2011, Standard for logarithmic visual acuity charts. beijing: China Zhijian Publishing House 2011:1-10

19 Wu LJ. Developmental Psychology of Preschool Children.Fujian Fuzhou: People's Publishing House 2010:92-93

20 Hyvärinen L, Näsänen R, Laurinen P. New visual acuity test for preschool children. *Acta Ophthalmol (Copenh)*1980;58(4):507-511

21 Gräf M, Becker R, Neff A, Kaufmann H. Examations with the Cardiff Acuity Test. *Ophthalmologe* 1996;9(4):333-340

22 Zhao KX, Zheng YZ. Pay a special attention to the influences of age on children amblyopia diagnosis. *Chi J Ophthalmol* 2007;43(11):961-964