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ORIGINAL ARTICLE

COMPARISON OF CROWDED SINGLE OPTOTYPES WITH LINEAR ACUITIES IN AMBLYOPES

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Abstract

In order to evaluate the effectiveness of the letter matching test (LM test) in the detection of the crowding phenomena, the authors compared it to two conventional tests, the linear Snellens/Sheridan Gardiner test and the Sheridan Gardiner Singles test. The LM test differs from conventional tests in that the less complex singles test has been enhanced by the addition of four 'crowding bars' to increase sensitivity to the crowding phenomena. To find out if the LM test provides an accurate equivalent to the linear charts, visual acuities were compared in amblyopic patients (n = 15) and a control group of normals with no history of amblyopia (n = 30). The amblyopic group was found to have significantly different acuities when comparing results in the singles tests with the results in both the linear and LM test. In addition there was no significant difference found between the linear and LM test acuities. These findings are consistent with the hypothesis that the crowding bars contained in the LM test provide contour interactions which are similar to the linear chart, therefore providing a reliable alternative method to single optotypes in the measurement of vision in the young.
Key Words: *crowding phenomena, contour interactions, singles acuity, crowding acuity, pre-school children.*

INTRODUCTION

It is widely recognised that amblyopia is a major problem in the development of normal (equal) vision in children. The earlier it is detected, and treatment initiated, the greater the chance for the best possible outcome for vision. Early detection of amblyopia therefore is of major clinical importance.

Previous research by Stager[1], states "most amblyopia develops before age four when children are less verbal and less cooperative with complex visual tasks". A test therefore, is required, that is accurate in detecting amblyopia and is not too complicated for a child to comprehend.

Conventionally tests involving single optotypes have been used, such as the Sheridan Gardiner singles test. However, these tests have been found to be less effective

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in detecting amblyopia than lines of letters "because single symbols do not present contour interactions that exploit the crowding phenomena"[2]. This phenomena has been described as when "neighbouring contours impair the resolution of a centrally fixed letter"[3].

Therefore to increase testing simplicity but still maintain sensitivity to amblyopia several 'crowded' acuity tests have been developed. These tests include optotypes flanked by bars on each side to introduce contour interactions without introducing a second test type. Rodier[4] studied crowding by using modified Allen pictures, and Stager[1] used letters with confusion bars on the BVAT. Stager[1] showed that the visual acuity recorded for normal and amblyopic eyes was lower when crowded optotypes were used than with isolated optotypes. Problems with these tests have been that Allen pictures are generally unknown and do not adhere to the Snellen's principle of its components subtending 1 minute of arc. The BVAT is currently scarcely used due to its expense and because it is not portable enough for vision screening in schools.

A test developed in the University of Otago in New Zealand[5] called the letter matching test (LM Test) has been devised that claims to be sensitive to the crowding phenomena yet is simple to comprehend. The aim of this study is to determine whether the LM Test is as sensitive to the crowding phenomena as the Snellens/Sheridan Gardiner linear test. If this is so it may then be useful in detecting amblyopia in young children.

METHOD

This study compares the LM Test it to the conventional Snellens/Sheridan Gardiner linear test and the Sheridan Gardiner singles test in amblyopic and normal subjects.

Acuity Tests

a) LM test: The LM Test uses 'crowded' optotypes to assess vision and is held at four metres (or two if necessary). It is a high contrast test that consists of black letters on white card (see Figure 1). The test is much the same as the Sheridan Gardiner test, as single letters, a matching card and the same letters , that is, A, H, O, U, T and V are used. The crucial difference of the LM test is the four black bars that surround the letters called 'crowding' bars. The crowding bars are positioned $1/2$ width of the letter separation from the letters being viewed. Researchers found in 1990 that this separation is the best approximation of amblyopic linear vision in the BVAT testing context[1]. This test assesses vision from 6/60 to 6/6. All children were first introduced to the test at near and the 'matching' procedure explained.

b) Linear acuity: Linear acuity was

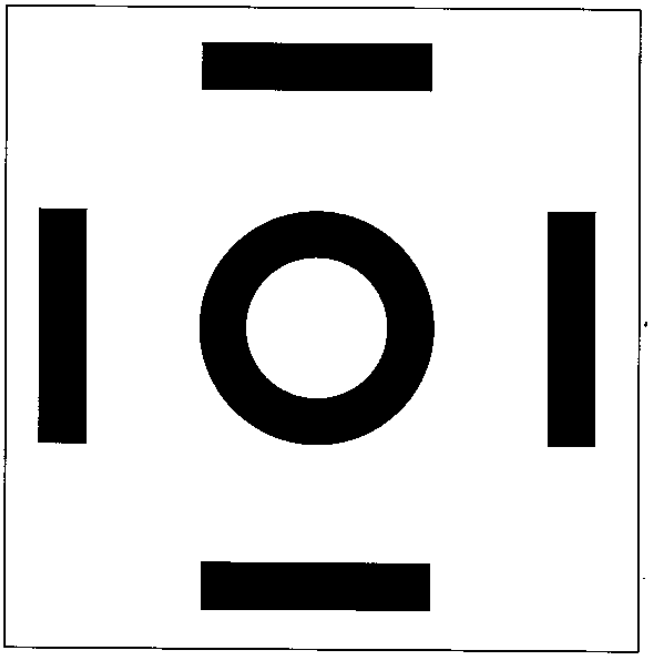

Figure 1: LM test optotype showing crowding bars surrounding the single letter.

assessed using the either the Snellens chart or the Sheridan Gardiner linear chart measuring the acuity from 6/60 to 6/5 at 6m. Amblyopes with acuity of less than 6/24 could not be included in the study as a line of less than three letters does not provide contour interactions which exploit the crowding phenomena[3].

c) Singles acuity: Isolated optotype visual acuity was tested with the Sheridan Gardiner singles test at 6m measuring acuity from 6/60 to 6/3.

Subjects

Subjects had to be old enough and of sufficient concentration to perform all three tests without a great loss of concentration. All subjects were examined by one of the three examiners using all three tests, except five amblyopes who were only tested with the linear and LM tests. Those with organic or neurological causes of decreased vision such as nystagmus or cataracts were not included in this study. Specially designed recording forms were used to ensure a random ordering of tests for each patient. For each separate test the eye assessed first was also randomly selected. These measures were undertaken to avoid the confounding effects of fatigue, loss of concentration and the learning curve. Responses were recorded when gained on the first and second attempt with no prompting. Testing was performed at primary schools and a public hospital.

a) Amblyopic subjects: Subjects were included as amblyopes if their linear acuity differed by one line or more between the two eyes. There were 15 subjects consisting of 13 children and 2 adults, whose ages ranged from 4 to 33 years (mean = 9.6 yrs). They were classified into anisometropic (40%), strabismic (20%) and a combination (40%) of them both.

b) Normal subjects: There were 30 normal subjects, 2 adults and 28 children who had less than a lines difference in linear visual acuity between the two eyes and a visual standard of greater than or equal to 6/6. Their ages ranged from 4 to 30 years with a mean of 7.4 years.

Scoring Procedure

In order to compare the three visual acuity tests a system of scoring had to be developed. This was because the linear chart contains different numbers of letters on each line, while the singles and LM test have only three letters per level of acuity. For the linear test a maximum score of three was attainable for each line with the overall minimum score for a complete line being 3 (6/60) and the maximum score being 21 (6/6). For incomplete lines each letter within that line was ascribed a fraction of three. This was calculated by dividing the number of letter gained by the number of letters in the line and multiplying this fraction by three. The converted scores were termed 'acuity units'.

As the LM test only measures visual acuity to 6/6, the linear test measures to a maximum of 6/5 and the singles measure to a maximum of 6/3, all results were truncated at 6/6 so comparisons could be made.

Statistical Analysis

Comparisons between tests within a subject type (amblyopic, preferred and normal eyes) were analysed using Friedman two way ANOVA. The comparison of each test between subject types was achieved through the use of a one way ANOVA.

To reduce the probability of a type one error, (a difference in performance between isolated/linear and surrounded optotypes

when there is actually no difference), the p for each individual test was set at 0.0056.

RESULTS

Mean visual acuity results (expressed in acuity units and the standard VA level) for normal and amblyopic subjects (amblyopic and preferred eyes) are summarised in Table 1 and Figures 2 & 3.

Amblyopic Subjects

The mean acuity of the amblyopic eyes when tested with the linear method was approximately a line and a half difference than when tested with the singles test ($p = 0.0019$). When tested with the LM test there was also found to be approximately one line and a half difference than when tested with the singles test (Figures 2 & 3). As expected both these differences were statistically significant ($p = 0.0019$). There was no significant difference in mean acuity of the amblyopic eye when tested with the linear chart and with the LM test.

When comparing mean acuities of the preferred eyes of the amblyopes between the three tests, there was no statistically significant difference between the linear and singles test, the singles and LM Test, or the linear and LM test (Figures 2 & 3).

Normal Subjects

When comparing mean acuities of normal subjects there was no statistically signif-

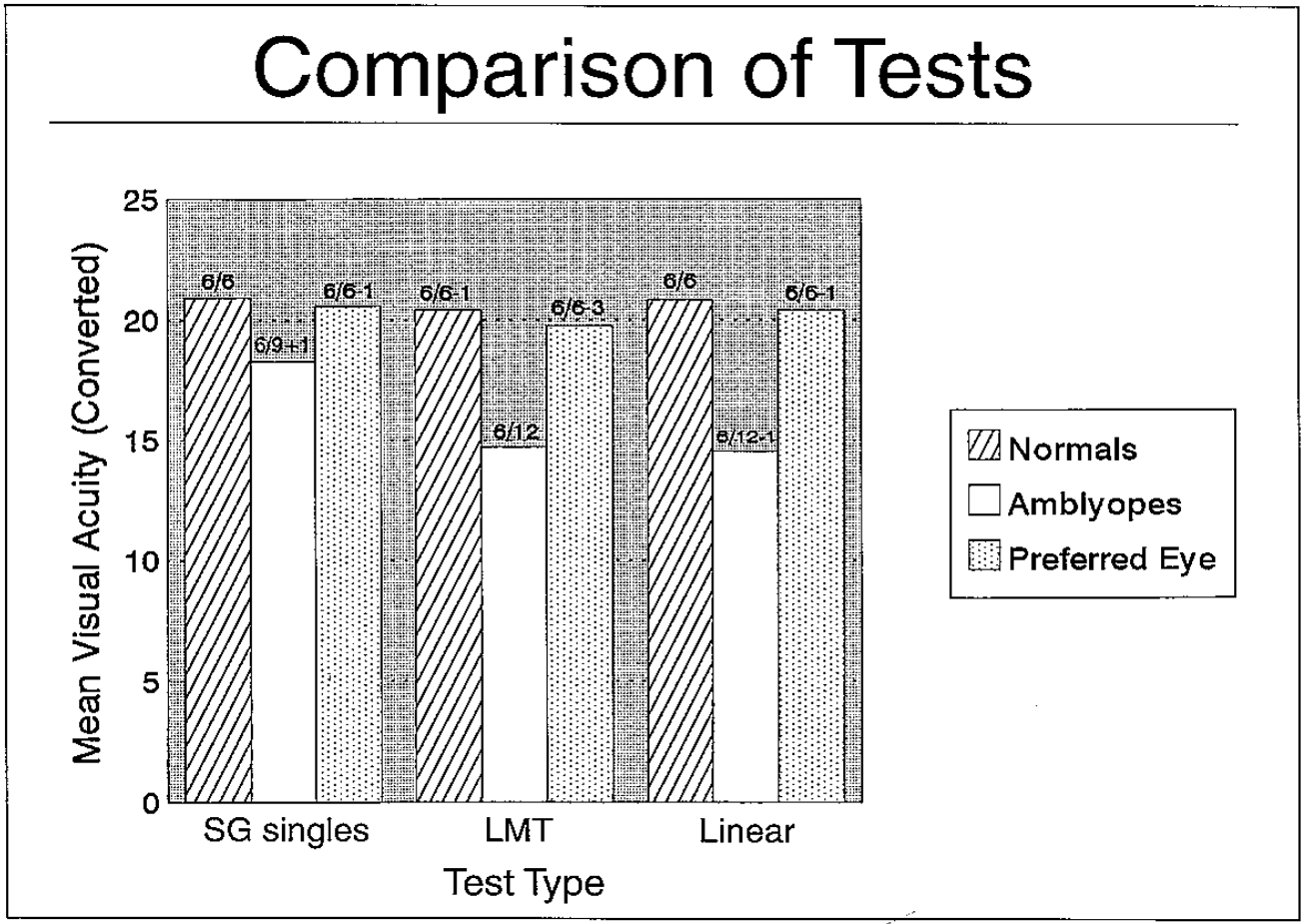

Figure 2: Comparison of mean visual acuity between the three vision tests for normal subjects and amblyopic subjects with amblyopic and preferred eyes.

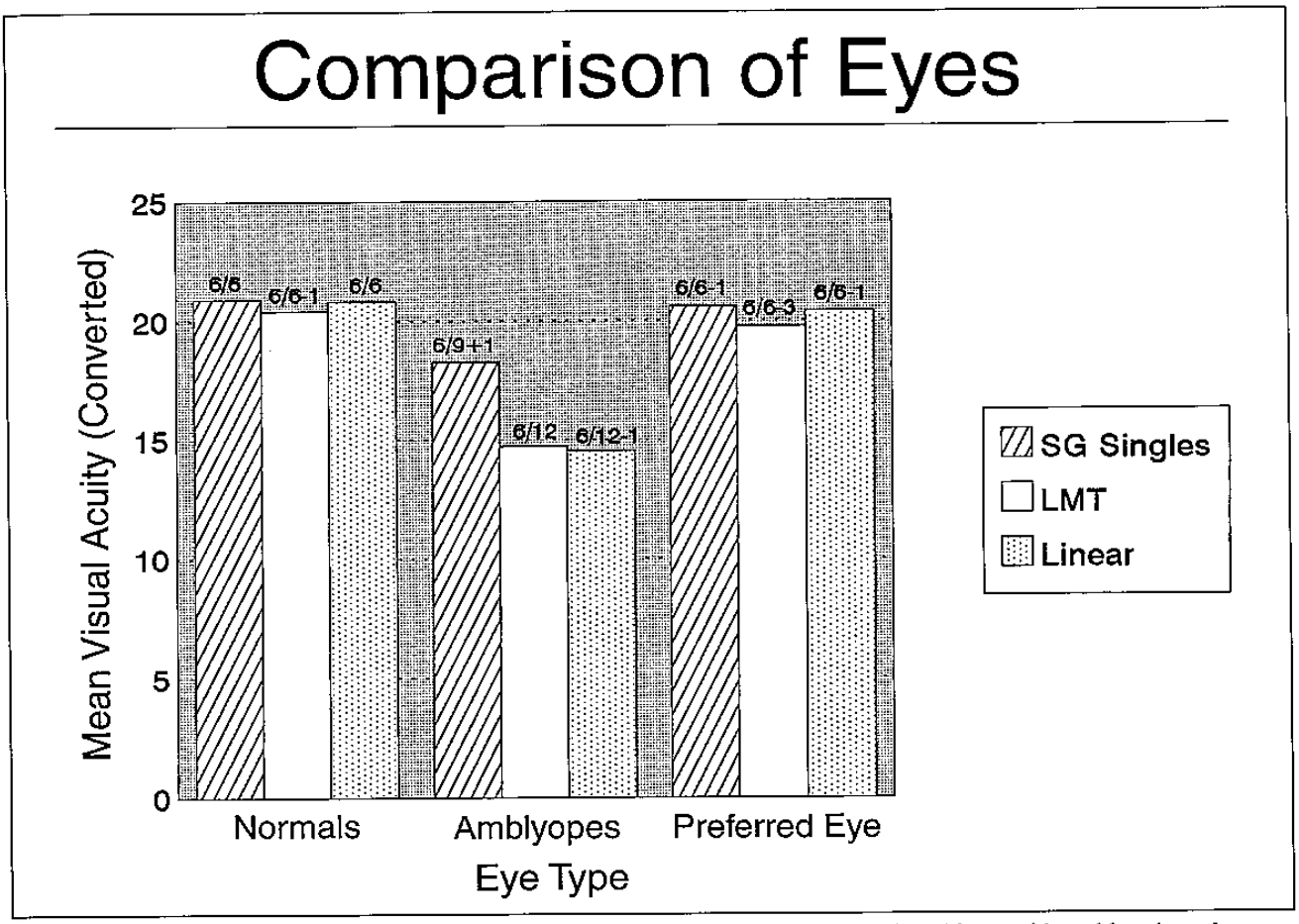

Figure 3: Comparison of mean visual acuity between normal subjects and amblyopic subjects with amblyopic and preferred eyes for each of the three vision tests.

icant difference found between the linear and singles test, the singles and LM test, or the linear and LM test (Figure 2).

Normal and Amblyopic Eyes

When comparing the mean visual acuity of the normal eyes and amblyopic eyes a significant difference was found on all three tests. The linear test showed a difference of over two lines (6.31 acuity units) between the amblyopic and normal eyes ($p<0.0001$); the Sheridan Gardiner singles test showed a difference of less than a line (2.64 acuity units $p<0.050$); the LM test showed a difference of approximately two lines (5.71 acuity units $p<0.0001$) (Figure 3).

When the mean visual acuity of normal eyes is compared with that of preferred eyes, there was no significant difference between them in all three tests.

DISCUSSION

In this study the amblyopic eyes showed a significant difference in mean acuities between the linear and singles, and LM test and singles tests, while the preferred eyes of the amblyopes and the normal eyes showed no significant difference between tests. The LM test and linear test show approximately equal acuities for amblyopic eyes and both are more sensitive to a reduction in vision than the singles test. Previous research has shown that single letters do not contain the means for detecting the crowding effect due to their lack of contour interactions[6]. The present study has shown that the addition

TABLE 1
Mean Visual Acuity for normal and amblyopic subjects.

	NORMAL SUBJECTS		AMBLYOPIC SUBJECTS			
	NORMAL EYES		AMBLYOPIC EYES		PREFERRED EYES	
	VA: Acuity Units	VA: Standard Format	VA: Acuity Units	VA: Standard Format	VA: Acuity Units	VA: Standard Format
Linear Chart	20.85	~6/6	14.54	~6/12-1	20.4	~6/6-1
LM Test	20.42	~6/6-1	14.71	~6/12	19.74	~6/6-3
Single Letters	20.92	~6/6	18.38	~6/9-1	20.6	~6/6-3

of contour interaction bars to single letters (the LM test) provides a test which is sensitive to the crowding phenomena and obtains results which are similar to the conventional linear test.

The results gained from comparing the mean acuities of the normal and amblyopic subjects in each of the three tests, were shown to be significantly different in all cases. Both the linear and LM test showed a difference of approximately two lines while the singles test showed a difference of less than a line. Although a significant difference was found between normal and amblyopic subjects in the singles test, it fails to demonstrate an obvious clinical difference between the two groups, as a discrepancy of a few letters may be attributed to other factors such as concentration. The LM test and the linear chart, however shows a recognisable clinical difference.

Research has noted that preferred eyes of amblyopes[7] and to a lesser extent normal eyes[3] are also sensitive to the crowding phenomena. One may then have expected to find a difference in mean acuities of normal eyes and preferred eyes between the tests with crowding (SG linear and LM test) and the single letter test in this study. Although the preferred eye acuities were less than the acuities of normal eyes in our study, they were not found to be significantly different. This may well be due to the truncation of the linear and singles results to the level of 6/6 where subtle differences were negated.

There are two main problems with this study that would need to be overcome in future research. Firstly is the method of scoring each of the three tests. If one letter in a line on the linear chart is missed the total score decreases only by a small fraction of three. Moving down the linear chart the numbers of letters per line increases, and the fraction becomes smaller. When using the LM test or singles test there is a maximum of three letters per level of acuity. If one letter is missed the total score is decreased by a whole unit. This may have increased the probability of gaining a type one error in this research (finding a significant difference when there is not one actually present).

Secondly the truncation of the results to

6/6 to aid comparison between tests, reduced the variability contained in our results on the higher acuity levels. Since statistical tests analyse variability, the presence of many similar scores (that is, 21 acuity units) may have hidden any interesting subtle findings.

When analysing the normal subjects' individual acuity levels the majority of subjects gained a visual acuity of 6/4 or 6/3 on the singles test if they were able to gain a visual acuity of 6/6 to 6/5 on the linear chart. This tends to agree with previous observations[8] that the singles acuity of normal eyes is approximately 6/4 to 6/3. It is suggested that in order for any decrease in vision to be detected when testing with Sheridan Gardiner singles, testing must be carried out to the level of 6/3.

It was also observed that a score of 6/5(-) or 6/5 on the linear chart approximated a score on the LM test of 4/4 (6/6). Further a score 6/6 (-) or 6/6 on the linear chart approximated a score on the LM test of 4/6 (+) or 4/4 (-) that is, 6/9 (+) or 6/6 (-). When testing linear acuity it was noticed that responses were slow for the 6/6 line subjects tended to gain a score of less than 4.4 (6/6) on the LM test. This tends to further suggest that the LM test is indeed able to detect crowding, though further investigation is warranted. Modification of the LM test to include letter sizes smaller than 4/4 is suggested.

CONCLUSION

This study showed that the LM test provides a good approximation of visual acuity to that obtained with a Sheridan Gardiner/Snellen's linear chart. It does indeed appear to be sensitive to the crowding phenomena occurring in amblyopes. What remains to be established is whether the LM test as simple as the Sheridan Gardiner singles test to comprehend in the population where it is most needed-: screening a large number of preverbal children who cannot perform linear tests.

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