NEAR VISUAL ACUITY TESTS USING CHINESE CHARACTERS AND THE LOGMAR PRINCIPLE

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SYNOPSIS

A new near visual acuity test chart using Chinese characters is described. A typeface of a style commonly used for printing school textbooks or newspapers was selected, and characters are arranged in a geometric progression of print sizes and spacings, such that in each column characters and spacings are 1.26 times larger than those in the previous column.

The geometric progression of character size is based on the LogMAR principle, and its use as a guide to

(1) the determination of near vision needs,
(2) the prescription of spectacles (near magnification or dioptral addition) and
(3) the specification of a near viewing distance necessary for the patient to resolve a given print size is described.

INTRODUCTION

The measurement of distance visual acuity is an essential element of any eye examination, and usually tests for the threshold of recognition of single alpha-numeric symbols (1-3). A patient is presented progressively smaller symbols until her or she can no longer recognize the detail of the symbol, and the 'threshold' acuity is graded according to the Snellen fraction, in which the numerator expresses the test distance in metres or feet and the denominator the size of the smallest symbol correctly identified. The denominator is scaled according to the standard distance at which the detail or stroke width of that particular size of symbol subtends an angle of one one minute of arc 1'.

Convention holds that a visual acuity of 6/6 (20/20) is normal although young adult patients frequently manage to resolve detail smaller than 1'. Vision worse than 6/60 (20/200) often represents 'blindness' from a medico-legal or social welfare point of view, even though many activities of daily living can still be performed visually. Decimal equivalents of Snellen acuity (1.0 = 6/6, 0.1 = 6/60) are used in Europe and China (4) but have the disadvantage of being converted to percentages and as such can be misleading if used to represent the percentage of vision remaining after an eye disorder: e.g. 6/12 or 0.5 acuity does not represent a remaining visual function of 50% (5).

Many variations in symbol design have been advocated over the years: from the original Snellen letters Landolt C's have been considered for research purposes (6), and illiterate or tumbling E's have been used for children and patients unfamiliar with a particular language (4). In many English-speaking countries British standard letters (7,8) or Sloan numerals and letters (6,9) are preferred. However, the principles behind these different symbol designs are basically the same. The use of checkerboard targets was advocated (10) in the 1940's but they have not been widely adopted because of the difficulties in explaining the acuity task to naive observers, the different nature of the task (pattern resolution rather then recognition of detail) (1), and the possibility of error from spurious resolution at some intermediate levels of defocus. More recently 'acuity' functions have been addressed by the use of grating targets of varying contrast and spatial frequency and the plotting of the contrast sensitivity function (CSF) (11,12). This is the visual modulation transfer function in which the high spatial frequency cutoff represents the CSF equivalent of Snellen acuity.

An important advance in the technique of measuring visual acuity was the use of minimum angle of resolution (MAR) as a unit of quantification and the expression of this unit in a geometric progression of letter size (3,6,13,14). Bailey & Lovie (15) developed this idea and published a distance acuity chart in which their British standard letters are arranged in a geometric or logarithmic progression. The Bailey-Lovie logMAR chart is now widely accepted in eye clinics where careful specification of visual acuity is necessary. The Bailey-Lovie design has been adapted to a second chart using Sloan letters, (16) and recommended for use as conforming to standards set by the committee on vision of the American National Academy of Science — National Research Council (17).

In an important contribution published in this journal, the logMAR method of scaling visual acuity has been used in a chart designed by Woo & Lo (18) using Chinese characters. This chart makes use of characters modified from their original Chinese format to have a 5 x 5 matrix, a standard stroke width of 1/5 character height, and a progression in the number of strokes contained in each character from one edge of the chart to the other. Woo & Lo's (18) charts make use of the logMAR progression of character size and spacing, and include additional contours to maintain 'contour interaction' (19) effects on terminal characters in each column or row as well as on centrally-placed characters.

WHAT IS THE ADVANTAGE OF THE LOGMAR PRINCIPLE?

A geometric progression of letter size recommended for use on visual acuity charts (15,16) is given in Table 1. The logarithmic equivalents of the angular subtends of these letters are given in column 5 of that table. For visual acuities worse than 6/60, some ophthalmic practitioners have resorted to finger counting or hand movement criteria for rough quantification, in part because of the large and unmanageable letter sizes required for these patients. Columns 7 through 15 demonstrate how the test distances can be altered systematically to enable the accurate scaling of visual acuity down to levels of vision much worse than 6/60. The great benefit of the logMAR system is appreciated especially by ophthalmic practitioners who are consulted by low vision patients, where the need to quantify vision in precise terms cannot be met by the use of standard (6m or 3m) viewing distances. Westheimer (3) in a separate review of the data of other researchers has determined the appropriateness of the logMAR scale, and his work supports our use of logMAR as a basis of optical prescription. I suggest that if vision can be improved optically by at least 2 logMAR 'steps' or 0.2 log units of MAR at any level (say from 6/30 to 6/21, or from 6/300 to 6/210), then that optical correction is likely to be of practical benefit to a patient. Thus for the first time, some precision in the specification of visual status and the prescription of optical aids for distance is available to the clinician. A more detailed explanation of the logMAR system is given by Bailey & Lovie (15) and a sliding scale calculator to convert an acuity for any standard viewing distance into conventional (6m) Snellen acuity has been published by Johnston (20).

MEASUREMENT OF VISUAL ACUITY AT NEAR

Although not demonstrated in their paper, Woo & Lo (18) described a set of their visual acuity charts reduced in size and designed for use at the reading distance. Because of the nature of the reading task in Chinese — the use of complete, single ideosyllabic characters — it is likely that both their distance and near charts should give comparable results for MAR provided that a proper adjustment is made for changes in viewing distance, near refractive error, character size and angular subtense.

A similarity between distance and near visual acuities is not always apparent for alphabetic languages. Typically, distance visual acuity is determined using single upper-case capital letters while extended text of short, medium or long words in more closely spaced lower-case letters is used to determine near visual acuity (21-23). For some eye disorders this presents a discrepancy, for example, where retinitis pigmentosa or hemianopsia patients may have a relatively small distance acuity impairment (single letter tests) but a larger impairment when near acuity is measured with extended text (words).

Both Sloan & Brown (21) and Sloan & Habel (22) emphasised the need to test the facility of a patient's near vision on fluent text or meaningful prose, as well as on the disconnected words of most near acuity charts. Bailey & Lovie (23) stressed that a patient's reading skills should be tested on the material likely to be encountered in the course of business, recreational or social activities. If a patient has been denied reading for any time, as a result of impairment of vision or inadequate optical correction, some practice may be necessary to re-establish reading skills. At consultations where optical aids on loan to low vision patients are reviewed, improvement in reading can be revealed that is not predicted by reading performance measured at initial consultation.

Cards for the measurement of near visual acuity using continuous alphabetic test have been described by Sloan & Habel (22) and Sloan (24). These reading cards are graded in M units, where the x or loop height of a 1 M lower case letter subtends an angle of 5 minutes of arc (5') at a 1 metre viewing distance, or equal to the anle subtended by a 6 m standard letter at a viewing distance at 6 m. Nine cards make up the adult series, having print of 1, 1.5, 2, 2.5, 3, 4, 5, 7 and 10M, and another series is available for children or unskilled adult readers. 1 M print corresponds closely to 8 point Times Roman print or N8, and is of a size commonly found in newsprint. If a patient can read 1 M print (N8 print) at a normal viewing distance of 40 cm, no special reading addition other than that required to correct for presbyopia may be necessary. If a patient can read only 4 M print at 40 cm, then at least 4x magnification will be required to enable 1M print to be read. This magnification can be obtained either by the prescription of a near telescope, or a change in viewing distance to 10cm and an appropriate increase in near dioptral addition.

Bailey & Lovie (23) have published a set of logMAR reading cards each containing seventeen print sizes (from N2 to N80) graded according to the geometric progression recommended by Green (13). Their charts make use of unrelated 10, 7 and 4-letter words having no contextual meaning to influence the guessing of adjacent words found difficult to recognize (Figure 1). In particular they have

Column 1 - Standard viewing distance	Column 2 - Height of a letter 5x(mm) required to subtend 5' (min arc) at the viewing distance	Column 3 - Stroke width of a letter x(mm) required to subtend 1' (min arc) at the standard viewing distance	Column 4 - Angle subtended at 6m by a stroke width of a standard letter (min arc) MAR	Column 5 - Log angle (in min arc) logMAR	Column 6 - Equivalent visual acuity in Snellen notation	Column 7 - Actual visual acuity	Column 8 - LogMAR acuity	Column 9 - Equivalent Snellen acuity corrected for a 6m viewing distance	Non standard viewing distance of 2.4 m: Column 10 - Actual visual acuity	Column 11 - LogMAR acuity	Column 12 - Equivalent Snellen acuity corrected for a 6m viewing distance	Non standard viewing distance of 0.95m (95cm): Column 13 - Actual visual acuity	Column 14 - LogMAR acuity	Column 15 - Equivalent Snellen acuity corrected for a 6m viewing distance	Non standard viewing distance of 0.25m (25cm)
3.8	5.53	1.11	0.63	-0.2	6/3.8	2.4/3.8	0.2	6/9.5	0.95/3.8	0.6	6/24	0.25/3.8	1.2	6/95	
4.8	7.0	1.40	0.8	-0.1	6/4.8	2.4/4.8	0.3	6/12	0.95/4.8	0.7	6/30	0.25/4.8	1.3	6/120	
6.0	8.73	1.75	1.0	0.0	6/6	2.4/6.0	0.4	6/15	0.95/6.0	0.8	6/38	0.25/6.0	1.4	6/150	
7.5	10.91	2.18	1.25	0.1	6/7.5	2.4/7.5	0.5	6/19	0.95/7.5	0.9	6/48	0.25/7.5	1.5	6/190	
9.5	13.80	2.76	1.58	0.2	6/9.5	2.4/9.5	0.6	6/24	0.95/9.5	1.0	6/60	0.25/9.5	1.6	6/240	
12.0	17.46	3.49	2.0	0.3	6/12	2.4/12	0.7	6/30	0.95/12	1.1	6/75	0.25/12	1.7	6/300	
15.0	21.82	4.36	2.5	0.4	6/15	2.4/15	0.8	6/38	0.95/15	1.2	6/95	0.25/15	1.8	6/380	
19.0	27.64	5.53	3.2	0.5	6/19	2.4/19	0.9	6/48	0.95/19	1.3	6/120	0.25/19	1.9	6/480	
24	34.90	6.98	4.0	0.6	6/24	2.4/24	1.0	6/60	0.95/24	1.4	6/150	0.25/24	2.0	6/600	
30	43.64	8.73	5.0	0.7	6/30	2.4/30	1.1	6/75	0.95/30	1.5	6/190	0.25/30	2.1	6/750	
38	55.25	11.05	6.3	0.8	6/38	2.4/38	1.2	6/95	0.95/38	1.6	6/240	0.25/38	2.2	6/950	
48	69.80	13.96	8.0	0.9	6/48	2.4/48	1.3	6/120	0.95/48	1.7	6/300	0.25/48	2.3	6/1200	
60	87.25	17.45	10.0	1.0	6/60	2.4/60	1.4	6/150	0.95/60	1.8	6/380	0.25/60	2.4	6/1500	
75	109.1	21.82	12.5	1.1	6/75										
95	138.2	27.63	15.8	1.2	6/95										
120	174.6	34.91	20.0	1.3	6/120										
150	218.2	43.63	25.0	1.4	6/150										
190	276.4	55.27	32.0	1.5	6/190										
240	349.0	69.81	40.0	1.6	6/240										
300	436.4	87.27	50.0	1.7	6/300										
380	552.5	110.5	63.0	1.8	6/380										
480	698.0	139.6	80.0	1.9	6/480										
600	872.5	174.5	100.0	2.0	6/600										

Table 1 Relationship between letter size, stroke width, angular subtense (minimum angle of resolution MAR) and logMAR for standard (6m) and nonstandard visual acuity test distances.

*Columns 1 through 6 give equivalent scaling dimensions for a 6 m standard viewing distance, letter size, angular subtense, logMAR and conventional Snellen acuity. Columns 7 through 9 show how the use of a non standard (2.4m) viewing distance alters the logMAR visual acuity by 4 'steps' upwards: i.e. logMAR 1.0 is represented by 2.4/24 (6/60), logMAR 1.4 by 2.4/60 (6/150) etc. Columns 10 through 12 represent similar adjustments for a non standard viewing distance of 0.95m (95cm) and Columns 13 through 15 represent figures for a non standard viewing distance of 0.24m (or 25 cm). In this way the low levels of visual acuity represented by large angular subtends can be measured by letters of more manageable size at a closer viewing distance, without changing the geometric progression of letter size or the nature of the task.

Geometric progression of parameters

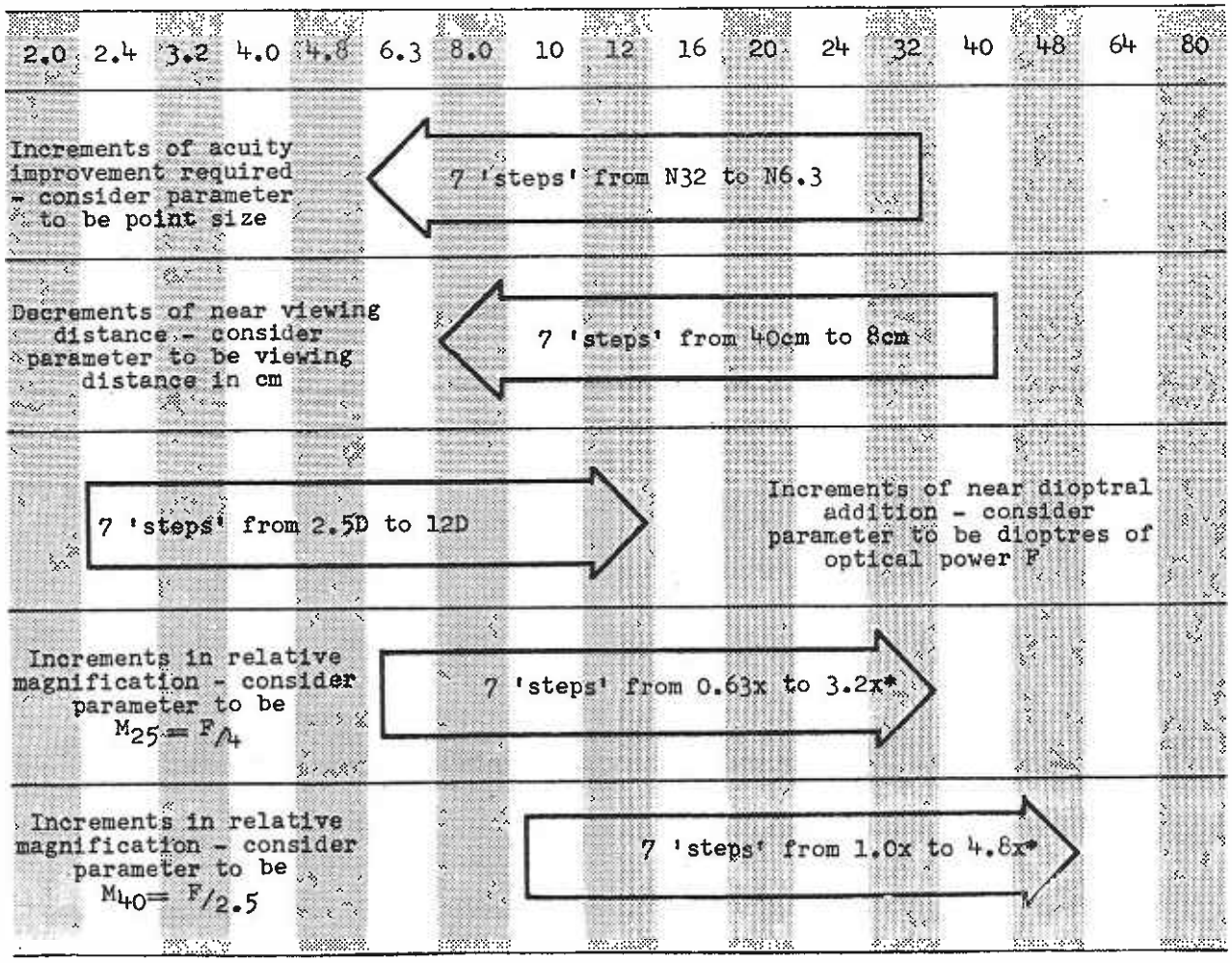

Figure 1

This figure demonstrates the schematic method by which the inter-relationships between near vision parameters can be altered systematically. Consider a low vision patient whose near visual acuity is measured to be n 32 at 40 cm. From Table 2 this represents LogMAR near acuity of 1.0, equivalent to a logMAR distance acuity of 1.0 or 6/60 (20/200). If the patient requires a near acuity of N6 (a change of 0.7 log units or 7 'steps' of geometric progression) then systematic changes in near viewing distance, near dioptral addition, and relative magnification are required as illustrated.

Because the increment 6.3 32 is the same in logarithmic terms as 0.63 3.2, extrapolation by a factor of 10 may be necessary when the sequence of numbers runs out at the high or low ends of the progression in Column 1.

Table 2 Comparison of print size in N notation, points, M units and logMAR acuity for Bailey Lovie or Sloan near vision charts and viewing distances of 25 and 40 cm.

Print size N units, points	Sloan M units	Near acuity logMAR at 25 cm	Near acuity logMAR at 40 cm
80	10	1.6	1.4
64	8	1.5	1.3
48	6	1.4	1.2
40	5	1.3	1.1
32	4	1.2	1.0
24	3	1.1	0.9
20	2.5	1.0	0.8
16	2	0.9	0.7
12	1.5	0.8	0.6
10	1.25	0.7	0.5
8	1.0	0.6	0.4
6	0.75	0.5	0.3
5	0.63	0.4	0.2
4	0.5	0.3	0.1
3.2	0.4	0.2	0.0
2.5	0.32	0.1	
2	0.25	0.0	

Note that a change in viewing distance of 2 'steps' of geometric progression (from 25 to 40 cm) alters the logMAR equivalent of near acuity by 0.2 units: see Figure 1

maintained a standardization of the reading task by keeping the between-word and between-row spacings proportional to print size, using a 1.26 times increment in size (0.1 log increment) between print rows, and having the same number of words of about equal difficulty on each row. The Bailey-Lovie logMAR reading cards use two notations for print size; one in printers' points or N units, and the other in logMAR for a viewing distance of 25 cm (Table 2). A particular advantage of their logarithmic progression of print size is the predictive information it affords the clinician. Although clinicians appreciate that the parameters of near vision are inter-dependent (visual acuity or print size, near viewing distance, dioptral near addition and magnification), these charts simplify the relativities between a change in one parameter and the consequential changes in the other (Figure 2). Bailey & Lovie (15) give further examples of the predictive use of the logarithmic progression.

NEW NEAR VISUAL ACUITY CHART

The need for a new near visual acuity chart using Chinese characters was established during optometric consultations at the General Eye and Low Vision Clinic of the Hong Kong Society for the Blind. It was observed that some children with low vision who attended the Ebenezer School and Home for the Blind in Hong Kong had been taught to read English letters and words either printed in large type or magnified using optical aids. However, their teachers had experienced difficulty in teaching them to read Chinese print because of the greater complexity and smaller detail of these characters relative to English letters. At that time no systematic method for assessing near visual acuity was readily available in Hong Kong. The near chart designed by Woo & Lo was not available commercially, and in any case its stylized print and similarity to the distance chart made it unsuitable as a test of reading skills when conventional news print or book print was used.

A further need was recognized. A reading fluency test was necessary to monitor any improvement in reading capability that might occur after the prescription of optical aids. This test had to take into account the different academic levels of students likely to require assessment, and be available in several print sizes, at least to an extent where the field restriction of optical magnifiers could be discounted as an obstacle to good reading performance.*

The first stage of this project is reported in this paper. A type style was chosen to match closely the character font commonly used in school tests, magazines or newspapers in Hong Kong. This style, designated MNL or 楷書 was reproduced in 15 columns of 6 characters from 5P (7G) to

*A set of twenty oral reading cards of 5 print sizes and at 4 educational levels has been prepared and is presently under test in selected Hong Kong Schools. The results of this test will be reported in a later communication.

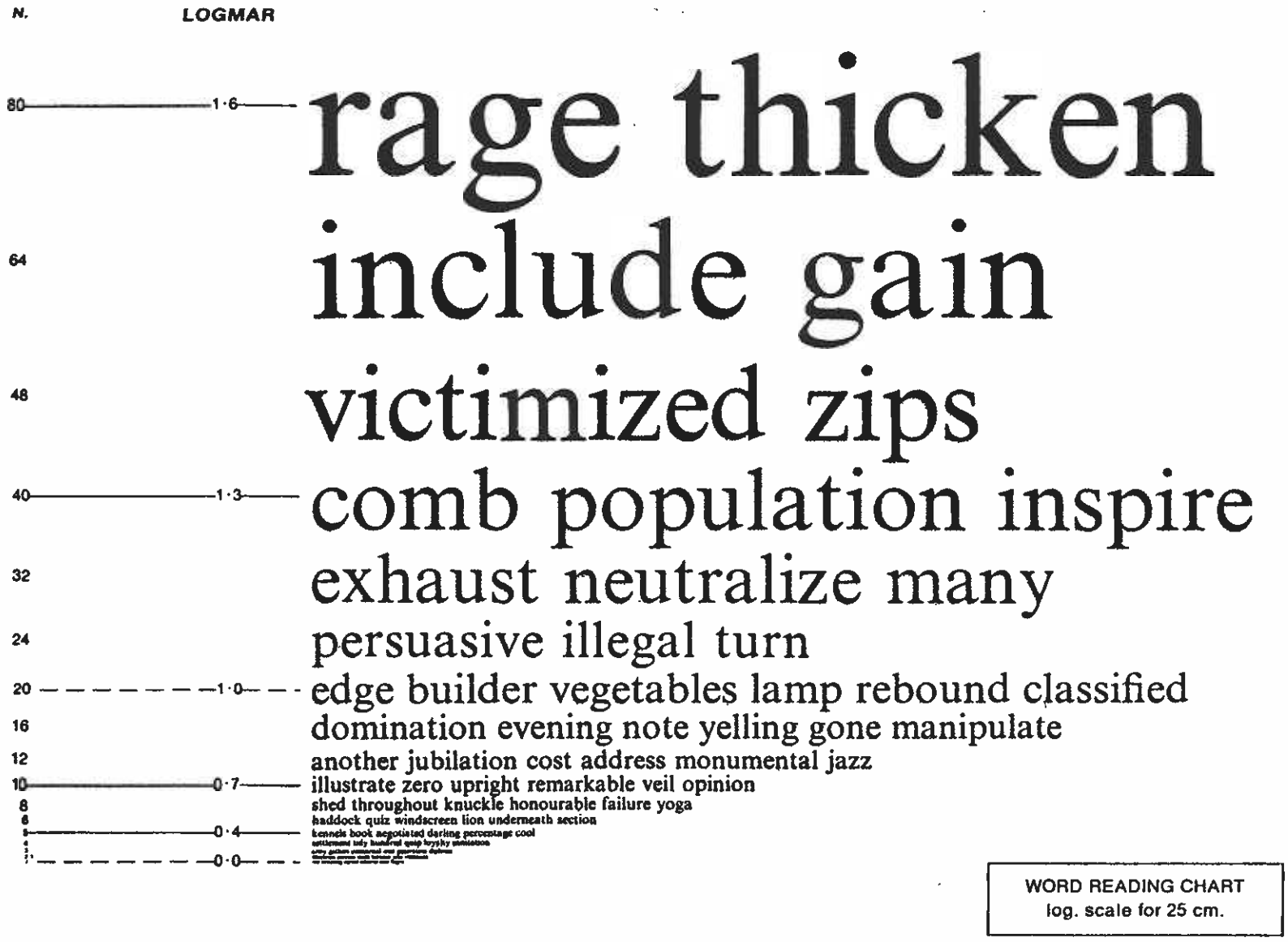

Figure 2 One example of the Bailey-Lovie word reading card using a geometric progression of word sizes and spacings, reduced to 70% of original size.

64P (90G). Because of size limitations only 5 characters appear in the 80P (120 G) column, and 4 characters in the 100P (140 G) column. A nearly-logarithmic progression of character size, intercharacter spacing, and between-column spacing as suggested by Bailey & Lovie (25) has been maintained. Because of a loss of printing fidelity, characters in a size smaller than 5P (7G) could not be used. Print sizes have been identified at the top of each column, and print columns have been assigned a logMAR equivalent value using 24P (36G) as logMAR 1.0 of Chinese characters at a viewing distance of 25cm. Note that this is one logMAR 'step' (0.1 log unit of MAR) of print size larger than that for alphabetic characters, because of the greater detail and more difficult resolution demands of Chinese print. Four separate cards (—) to (楷 書) have been prepared to prevent acuity scores being influenced by practice and learning effects.

The charts are designed with the largest characters on the right, and patients are instructed to read the top row of characters from right to left until first difficulty is experienced. At this size the patient is requested to read down the column of print so that reading speed and recognition accuracy can be determined. Normally a patient goes from 'seeing' to 'non seeing' over about 0.2 logMAR levels. However, because normal (nonstylized) characters have been used and no attempt was made to use characters of precisely equivalent recognition difficulty, the range of print sizes over which a patient must read to determine a near acuity threshold may be larger than this. In any case the recognition errors or failures on the more complex characters can be taken as indicating a functional acuity threshold, and this choice of threshold will be supported by a slower reading speed at these character sizes.

The Chinese character logMAR reading charts is illustrated in Figure 3.

As explained in a previous section and in Figure 1 the charts are designated in logMAR for a 25 cm viewing distance, and at this distance a +4.0 DS near addition should be worn over the distance spectacle correction if the patient is presbyopic. If a near visual acuity threshold of 20P (28G) is demonstrated by a patient at a viewing distance of 25 cm, a logMAR acuity of 0.9 is established. To improve this level of function to 12P (18G), at least 2 'steps' of improvement in function are required. This can be obtained by increasing the near addition by 2 'steps' (from +4.0 to +6.5 DS) and decreasing the viewing distance by 2 'steps' (from 25 cm to 16 cm). In practice it is wise to provide some spare capacity over and above the threshold of near acuity, so an additional 'step' or two of improvement should be demonstrated, e.g. to 10P (14G) at 12 cm with a +8.0 DS add, or 8P (12G) at 10 cm with a +10 DS near addition (see Figure 3). Reading speed as well as accuracy of recognition is a useful guide to the practitioner in assessing functional vision, and providing sufficient encouragement is given to motivate patients to use a close viewing distance, success in rehabilitating reading skills will be obtained.

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The Bailey Lovie word reading charts are available from the National Vision Research Institute, 386 Cardigan Street Carlton Vic 3053 Australia. The Chinese character near acuity charts are available from the Hong Kong Society for the Blind, 33 Granville Road 8/F, Kowloon, Hong Kong

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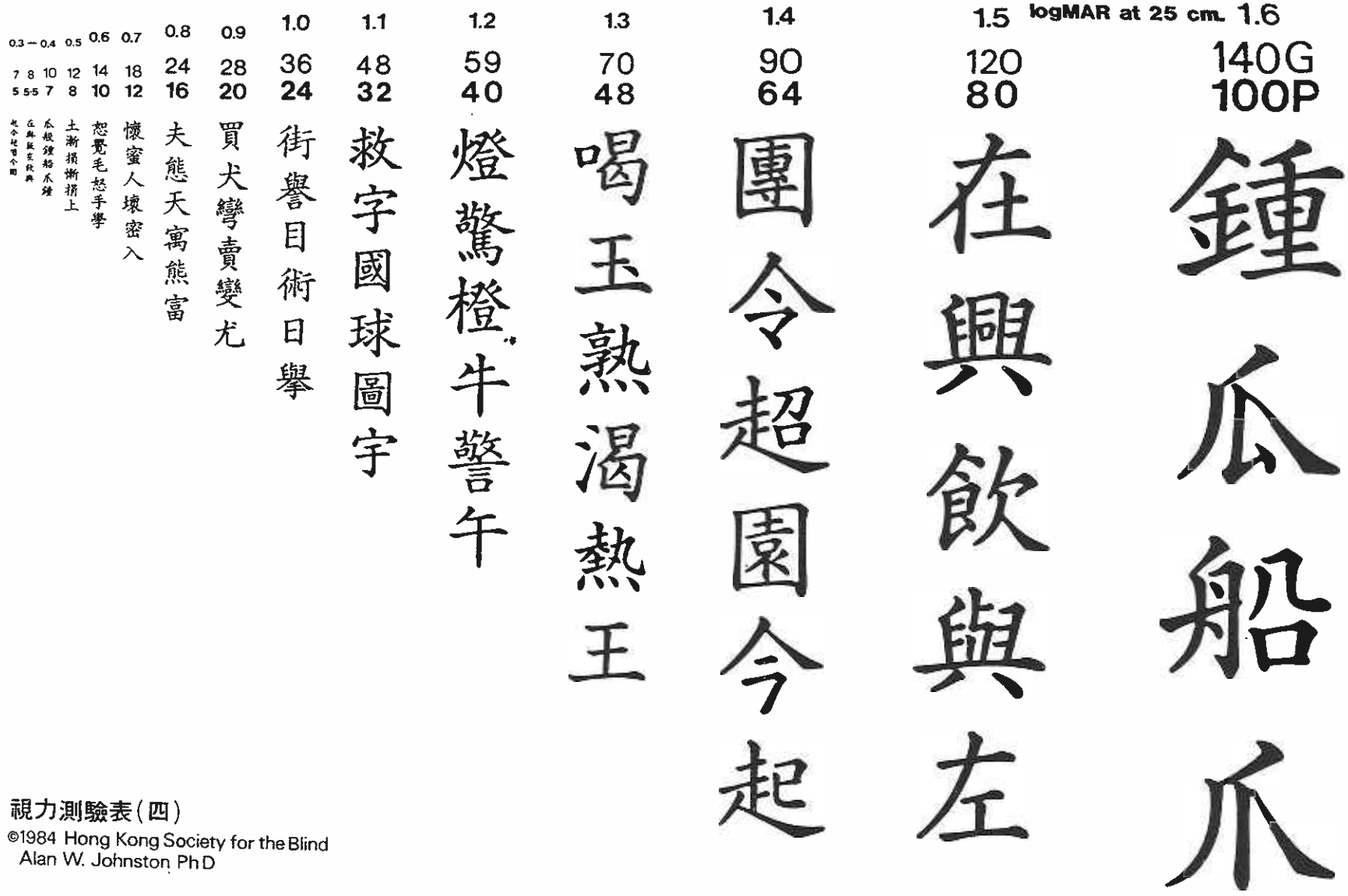

視力測驗表(四)

Figure 3 The Hong Kong Society for the Blind word reading chart, reduced to 70% of original size.