VA testing in optometric practice

Part 2: Newer chart designs

In Part 2 of this series on visual acuity testing, Professor David Thomson looks at newer test chart designs and possibilities for the future.

The limitations of the Snellen chart design have been known for many years and attempts to improve it started soon after the chart was proposed, and have continued ever since. Of all the alternative designs that have been proposed, a chart originally developed by two Australian optometrists, Ian Bailey and Jan Lovie-Kitchin, has emerged as the preferred alternative to the Snellen chart.

Bailey-Lovie chart

There are many advantages to the Bailey-Lovie chart (**Figure 1**). The first key feature is that it has five letters on each row. This ensures that the task is equivalent for each row and helps to ensure equal contour interaction. It also provides more letters for patients with poorer visual acuity. The letter spacing on each row is equal to one letter width. Likewise, the row spacing is equal to the height of the letters below. In this way, contour interaction is scaled in relation to letter size. The letter size follows a logarithmic progression, increasing in 0.1 logMAR steps.

LogMAR is an acronym for Log_{10} of the Minimum Angle of Resolution (MAR). The MAR is taken as the stroke width of the letters, which is one fifth of their vertical angular subtense. Thus a 6/6 letter which subtends 5 minutes of arc, equates to a MAR of one minute and a logMAR of 0 ($Log_{10}(1)=0$). **Figure 2** shows the conversion. It can be seen from this that one disadvantage of the logMAR notation is that for letter sizes smaller than 6/6, the logMAR score is negative.

Most logMAR charts cover the range -0.30 (6/3) to +1.00 (6/60), which is sufficient to avoid truncation. For patients with visual acuities of less than +1.00, it is entirely valid to reduce the testing distance and apply a simple correction factor.

The logarithmic progression of letter sizes is justified because it has been shown that 'just noticeable differences' are approximately equal across the range of letter sizes if a logarithmic scale is used. In other words, the difficulty of the task increases in approximately equal steps if a LogMAR scale is used.

Another advantage of a regular progression of letter sizes is that it permits inter-line interpolation. In other words, if a patient reads all the letters on one line and half of the letters on the next, it is reasonable to assign a score half way between these two letter sizes.

As the scale increment on a Bailey-Lovie chart is 0.1 and there are five letters on each line, each letter can be assigned a score of 0.02 (i.e. 0.1/5). Thus, if a patient reads all the letters down to the 0 (6/6) line, their logMAR score would be 0. If they read one letter incorrectly on this line, their score would be 0.02 – two letters incorrect = 0.04, three letters = 0.06, etc. This interpolated scoring method avoids the confusion inherent in Snellen scoring and improves the precision of the measurement.

The disadvantage of LogMAR scoring is that it requires some mental arithmetic to add or subtract the appropriate number of '0.02s'. The fact that negative logMAR scores represent good visual acuity is also rather counterintuitive.

To avoid these problems, Bailey proposed an alternative method of scoring which he called Visual Acuity Rating (VAR). The rather complex formula (VAR = 100 – (50 x logMAR)) belies a very straightforward and intuitive scoring method (**Figure 2**).

If a patient were to read all the letters down to and including the 6/6 line (logMAR = 0), they are awarded a VAR score of 100. If they were to read one letter incorrectly, their score would be 99, two letters = 98, etc. If they read beyond the 6/6 line (logMAR = 0) by one letter, the score becomes 101, two letters more = 102, etc. This notation maintains all the advantages of logMAR scoring but requires less mental arithmetic and avoids negative scores. It also provides a number which patients can easily comprehend.

The Bailey-Lovie chart employs the letter set specified in the British Standard. A variant of this chart, employing the Sloan character set, was developed for the Early Treatment Diabetic Retinopathy Study (ETDRS). The letters for each line were carefully selected to give the same average legibility.

Despite the well-documented advantages of the LogMAR chart design, clinicians have been slow to embrace the new charts. This may be because logMAR charts tend to be larger, and measurements may take slightly longer than with a Snellen chart. The logMAR scoring system may also be off-putting to some, while others simply do not perceive a problem with the Snellen chart within a clinical setting.

Figure 1
A Bailey-Lovie LogMAR chart displayed on Test Chart 2000

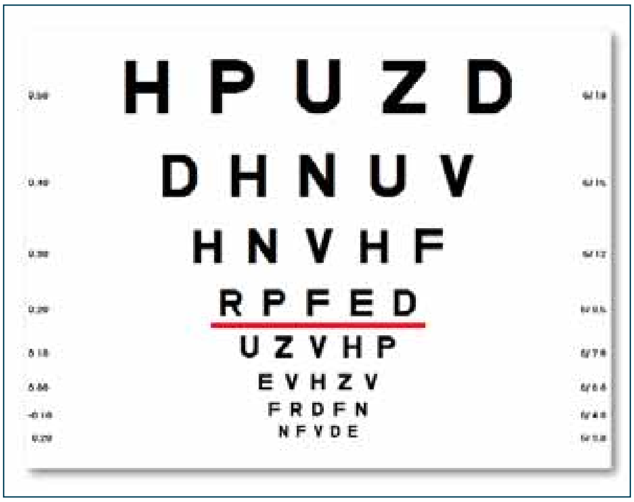
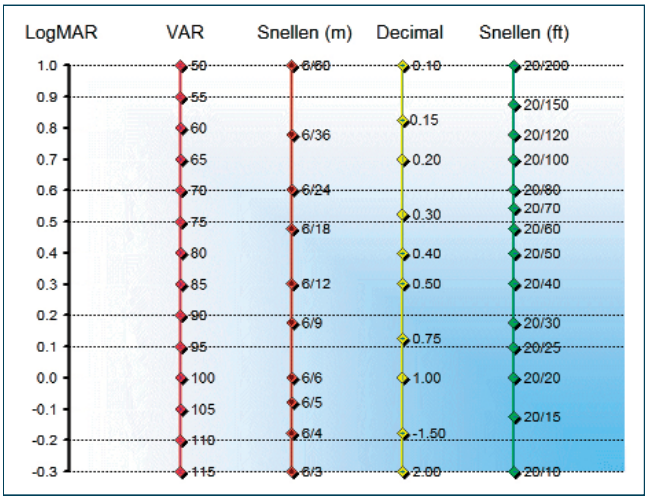


Figure 2
Conversion chart for LogMAR, VAR, Snellen (m), Decimal and Snellen (ft)



When to stop?

Whatever the design of the test chart, the measurement of visual acuity remains a subjective procedure and is subject to both examiner and patient bias. For example, a nervous patient may tend to adopt a conservative criterion, being unprepared to name a letter unless they are certain that they are correct. A more confident patient may be more willing to guess and will, therefore, tend to record a better score. The examiner can also influence the measurement by the instructions and encouragement given during the test.

To avoid these biases, patients should be encouraged to continue reading down the chart even if they are not confident about their responses, until they incorrectly name at least half of the letters on a line.

Viewing distance

Visual acuity is a measure of the minimum angle of resolution (MAR) and, therefore, provided that the letters are suitably scaled, acuity should be independent of viewing distance. However, test charts are often used as part of a refractive assessment, and testing distances of less than three metres may overestimate the vision of uncorrected myopes and some compensation to the final refractive correction may be required.

A recent study (unpublished) by the author also suggests that the endpoint of a refraction is less well-defined for viewing distances of less than four metres, presumably as a result of fluctuations in accommodation.

Conventional test charts are generally calibrated for a viewing distance of six or three metres, requiring the consulting room to be designed accordingly. This constraint has been removed by computerised test charts, where the viewing distance can be specified to the nearest centimetre, and the charts scaled accordingly.

Modes of presentation

Visual acuity is a robust measurement, being reasonably tolerant of variations in luminance, contrast and mode of presentation. Provided that the chart luminance is above $100cdm^{-2}$ and the contrast is greater than 90%, different test units render very similar measurements.

The first generation of test charts were printed on card and externally illuminated. These were then replaced by back-illuminated charts printed on opal panels. The principal drawback of all forms of printed charts is their lack of versatility. The viewing distance is predetermined and there is little scope for varying the chart design or the selection of optotypes.

Projector charts offer a little more flexibility although the selection of charts is still rather limited and their design frequently fails to conform to current standards. The background luminance of projected charts also tends to be rather non-uniform and the contrast of the charts is very sensitive to the ambient illuminance.

Figure 3
Computer-based test charts such as Test Chart 2000 offer the clinician an unprecedented range of visual assessment tools

Computer test charts

The potential of computer displays for presenting visual stimuli was first recognised almost 50 years ago, but the cost and relatively poor performance of these systems limited their use to research laboratories. As the quality of computer displays improved and the cost of the hardware fell, a number of computer-based test charts were developed. However, these early systems employed CRT monitors which were bulky and not ideal for the purpose.

The turning point for computer-based test charts came with the advent of LCD flat panel displays. These displays are compact and easily wall mounted, produce high contrast, high luminance displays which do not flicker, and are remarkably immune to ambient light. In short, they are ideal for the purpose.

In the late 1990s, a team of optometrists at City University set about developing the software to exploit this emerging technology and the result was a Windows-based program called Test Chart 2000 (**Figure 3**). As the price of flat panel displays continued to fall, at last there was a cost-effective and versatile alternative to back-illuminated and projector charts. Optometrists in the UK were quick to appreciate the benefits of computerised test charts and since their launch in 2000, hundreds of consulting rooms and clinics have been equipped with the system. Using a standard PC and flat panel display, clinicians now have access to an unprecedented range of test charts and other visual assessment tools.

Test Chart 2000 includes the following features:

- Viewing distance can be specified to the nearest centimetre. Charts are simply scaled for the viewing distance that is entered thus removing the size constraints for a consulting room

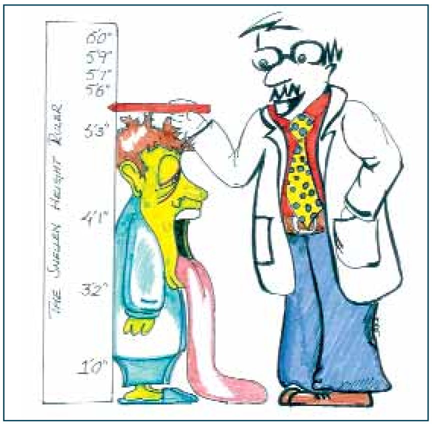


Figure 4
"Your Snellen height is normal so I pronounce you 100% fit!"

- A wide range of chart designs can be implemented including LogMAR, Snellen and single letters
- A wide range of optotypes including British letters, Sloan letters, Sheridan-Gardner letters, Lower case letters, Landolt Cs, Tumbling Es, Kay symbols, Lea symbols and Lea numbers
- Letter/optotypes can be randomised
- Contrast of all charts can be varied between 0% and 100%
- On-screen cursors and lines can be used to guide patients
- Various scoring notations including Snellen, Decimal, LogMAR and VAR are supported

In addition to the acuity charts, Test Chart 2000 provides a wide range of other stimuli and tests, including duochrome, fan and block, cross-cylinder, number plate, fixation disparity, Maddox rod, associated phoria, stereopsis, Worth 4 dot, vernier acuity and a wide range of fixation stimuli. Over the past few months, a number of test chart systems developed in other parts of Europe and based on the same principle have become available in the UK. To date, there is little published information on the characteristics of and efficacy of these systems.

Given the complexity of both the visual environment and the visual system, it is not surprising that a single measure of visual performance (VA) sometimes fails to provide a complete description of patients' visual capability in the real world (**Figure 4**). Indeed, it is surprising that VA matches patients' visual experience as frequently as it seems to. However, it is well known that VA taken in isolation can sometimes be misleading, particularly in patients with media disturbances and various neurological conditions. In these cases, measurements of contrast sensitivity and low contrast acuity can provide valuable information.

The future

Computerised test charts already have much to commend them. As the quality of displays continues to improve, it seems likely that these will become the preferred method of assessing vision in optometric practice. This change will open up the possibility of adopting newer chart designs and finally laying the Snellen chart to rest.

Currently, the ETDRS chart is generally considered to be the gold standard. However, even these charts achieve surprisingly poor test-retest repeatability in the clinical setting. A new computer-based system employing advanced psychometric methods is currently being developed at City University. Preliminary results suggest that the system is capable of measuring VA with significantly better precision than the ETDRS charts.

Given the key role of VA in so many aspects of clinical practice, the end of term report must conclude – "Measuring VA in optometric practice – must do better!"

References

For a full list of references, email w.d.thomson@city.ac.uk.

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