A new Gujarati language logMAR visual acuity chart: Development and validation

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Aims: Gujarati is the main spoken language of a large proportion of the population of India. The aim of this study was to develop and validate a new Minimum Angle of Resolution (logMAR) visual acuity chart in the Gujarati language. Materials and Methods: A new Gujarati visual acuity chart was designed to logMAR specifications using Gujarati optotypes experimentally selected to have similar relative letter legibility under spherical and cylindrical defocus. The chart validation study was carried out using 153 adult subjects in a large clinical setting in India. Subjects who were literate in English and Gujarati participated in the study. Visual acuity was measured with the new Gujarati logMAR chart and a modified Early Treatment of Diabetic Retinopathy Study-(m-ETDRS) logMAR chart. The method of presentation was randomized between the charts. Repeat visual acuity was measured on a subsequent day with a second version of the Gujarati logMAR chart. Results: The Gujarati chart correlated highly with the m-ETDRS logMAR chart ($r^2 = 0.974$). The mean visual acuity difference (Gujarati – m-ETDRS logMAR) was equal to three letters (~0.06 logMAR). The Gujarati logMAR chart also proved to be highly repeatable ($r^2 = 0.994$, test-retest) with 95% CI of ± 0.04 logMAR. Conclusions: The new Gujarati logMAR visual acuity chart provides a valid and repeatable tool for the measurement of visual acuity in native Gujarati language speakers.

Key words: Gujarati, logMAR, repeatability, validity, visual acuity

The Snellen letter chart employed in the measurement of visual acuity enjoys wide-spread use in clinical practice, despite the well-established limitations in Snellen acuity charts.[1-3] LogMAR based vision charts comprising the same number of near equally legible letters per row, logarithmic progression of letter size, and fixed inter-letter separation are now accepted as the norm when accurate assessment of vision is required for both adults[4] and children.[5,6]

One of the highest recorded rates of visual impairment in the world occurs in India.[7] Given such obvious eye care needs in India, visual assessment using logMAR vision charts are important for both clinical and research needs. Whilst the use of the ETDRS chart[8] would meet such requirements, logMAR-based vision charts in native Indian languages would be preferred. Khamar et al.[9] developed a logMAR-based chart in Hindi and Gujarati, but their charts have not gained wide-spread use, possibly due to limitations in their choice of letter optotypes and the lack of validation with the standard ETDRS logMAR chart. The Gujarati language is one of the common Indian languages spoken widely in Northern India and by expatriate Indians across the world and is one of the world’s most popularly spoken languages.[9] Given the number of native speakers of Gujarati in India, the aim of the present study was to develop and validate a new visual acuity chart in Gujarati using the established logMAR principles.[1]

Materials and Methods

In the first part of the study, we determined the relative letter legibility of Gujarati letters. Twenty four Gujarati letters (Krishna font type) were initially selected for determination of their legibility, based on their relative similarity and ease of modification into a 5 × 5 grid using standard photo-editing software (Adobe PhotoShop™, Edition 6) and scaled to subtend five arc minutes at 6 m (equivalent Snellen 20/20). In order to maintain the appearance and hence the meaning of individual Gujarati letters, stroke widths were not modified from their original font and hence varied slightly depending on the letter [Fig. 1].

Relative letter legibility for the Gujarati letters was determined following a procedure described in detail elsewhere.[10] Single, high contrast (85%) black letters were presented on a white background at the center of a color monitor. Ten adult subjects with normal or corrected to normal visual acuity (at least 20/20 in each eye), who were fluent in Gujarati and English were recruited to the study. The research followed the tenets of the declaration of Helsinki and approval of the experimental protocol was obtained from the Institutional Human Research Ethics Committee. Informed consent was obtained from all subjects after the nature and consequences of the study were explained to them.

Subjects were optically defocused using different blurring lenses mounted in a trial frame (+1.00 dioptre sphere, +2.00 dioptre cylinders [DC], axis 180 and 90). Astigmatic blur was included to assess sensitivity to defocus for horizontal and vertical meridians independently.[11] Using a method of limits, subjects moved slowly from a position beyond their threshold letter identification toward the monitor until they could just correctly identify the letter displayed. The distance from the monitor to the subject’s eyes was recorded. These
distances were converted to relative legibility scores by dividing the distance of correct recognition for an individual letter by the average distance for all of the letters tested. The procedure was randomized across the different defocus conditions and repeated twice for each condition. The average for each condition was used for further analysis. Subjects were acquainted with the experimental procedure prior to data collection. One eye, chosen at random, was used for the experiment, the other eye was occluded. Normal room illumination was employed throughout the experimental process.

Based on the results of the first part of the study, a set of 20 Gujarati optotypes was selected to construct the Gujarati logMAR chart. Two versions of the chart were produced to investigate validation and repeatability. The two versions were identical except that the order of letter presentation was different in each. Charts were constructed for a 6 m test distance (using a mirror) based on principles described elsewhere and comprised 14 rows of five letters beginning with logMAR 1.0 and decreasing in 0.1 log steps to logMAR −0.3. Inter-letter separation was fixed at one optotype width. The legibility of the letters in each row was controlled to ensure consistency across the chart and varied by no more than 10% between rows. Rows were labeled with the Snellen fraction and logMAR equivalent. The charts were printed onto high quality matt white vinyl plastic sheets that could be rolled up for ease of transport and measured approximately 105 cm × 85 cm. The Weber contrast between letter and background was 90% for all charts. For the purposes of comparison and validation, a modified-ETDRS (m-ETDRS) chart was constructed using the Sloan letter set.

For consistency, all measurements were obtained by a single experienced optometrist at a 6 m test distance using a polished ophthalmic mirror. For each subject, measurement of monocular (either right- or left-eye selected at random) uncorrected visual acuity was obtained using the m-ETDRS and version 1 of the Gujarati chart. The fellow eye was occluded. Subjects were asked to read the letters beginning from the top left side of the chart and continue to their limit of recognition. The end point was reached when the subject read three or more letters incorrectly on any given line (>50%). The end-point visual acuity was taken as the visual acuity of the previous line read (i.e. at least three letters read correctly) and each correctly read letter was scored as 0.02 logMAR. The order of chart presentation was randomized between subjects. For each individual subject, measurements were repeated on another day on the same eye, but using the second version of the Gujarati logMAR chart. Data were recorded on separate record sheet and the results of the first measurements were not available during the repeatability phase of the study. All experimental work was carried out on location in a clinic setting in India and completed within a period of about 2 weeks.

Data were analyzed using parametric statistics (Students t-test, Pearson correlation), using a standard statistical package (STATISTICA®, Statsoft, Tulsa, OK). Repeatability of measurements was assessed by obtaining the difference between test and retest measurements of visual acuity and determining the 95% limits of agreement.

One hundred and fifty-three adult subjects aged between 21 years and 77 years who were literate in English and Gujarati with unaided vision of 20/200 or better and with no history of trauma or surgery were recruited to the second part of the study. Subjects were not pre-selected in any other way and those that met the selection criteria and consented to the study protocol were recruited. The sample size was sufficient to determine a difference in visual acuity measurements between the charts of 0.1 logMAR (power 80% with P < 0.05). The study was approved by the Institutional Human Research Ethics Committee and the appropriate local ethics review process in India. All procedures involving human subjects complied with the declaration of Helsinki. Written informed consent was obtained from all subjects after the nature and consequences of the study were explained to them.

## Results

Relative legibility of the Gujarati letters obtained under each defocus condition is shown in Table 1. In order to select letters of close to equal legibility under all defocus conditions we compared relative legibility obtained under astigmatic defocus to that obtained with spherical defocus. The lower panel in Fig. 4 plots the difference between the two Gujarati charts (logMAR 0.0) against their average. There is a strong positive correlation between the two sets of results (r² = 0.974). The lower panel in Fig. 4 plots the difference between the m-ETDRS and Gujarati logMAR results against their average. The mean difference between the charts is −0.06 logMAR (95% CI ± 0.10 logMAR) which is statistically significant (paired t-test, P < 0.0001) and is equivalent to three letters on a logMAR scale.

The top panel in Fig. 3 compares the Gujarati version 1 logMAR and m-ETDRS logMAR results. The straight line through the data represents the best fitting linear regression. There is a strong positive correlation between the two sets of results (r² = 0.974). The lower panel in Fig. 3 plots the difference between the m-ETDRS and Gujarati logMAR results against their average. The mean difference between the charts is −0.06 logMAR (95% CI ± 0.10 logMAR) which is statistically significant (paired t-test, P < 0.0001) and is equivalent to three letters on a logMAR scale.

The top panel in Fig. 4 compares the results for versions 1 and 2 of the Gujarati logMAR chart. The best fitting linear regression is shown and reveals a strong positive correlation (r² = 0.994). The lower panel in Fig. 4 plots the difference between the two Gujarati logMAR results against their average. The mean difference between the two Gujarati charts (logMAR 0.0) was not significant (95% CI ± 0.04 logMAR) (paired t-test, P = 0.8951).

## Discussion

The main result of this study showed that unaided visual acuity measured with the newly designed Gujarati logMAR chart was highly correlated with the visual acuity measured with a m-ETDRS logMAR chart. The new Gujarati logMAR visual acuity chart was well accepted by the participants and all were able to successfully complete the measurements.

Although there was a strong correlation, subjects performed slightly better, on average, with the m-ETDRS chart compared to the Gujarati logMAR chart by 0.06 logMAR, equivalent to...
three letters. Such a small difference is well within the normal variability encountered with logMAR acuity measurements and as such may be considered clinically insignificant. Nevertheless, it is of interest to explore reasons why such a difference may have occurred. The new Gujarati chart was constructed using principles accepted for accurate measurement of visual acuity[1,4] and letter selection was based on rigorous legibility criteria resulting in legibility differences between rows of no more than 10%. Therefore, the difference between the Gujarati and m-ETDRS chart is unlikely to be due to deficiencies in the Gujarati logMAR chart construction. Subjects were recruited based on their ability to read both English and Gujarati, and given that Gujarati was the native language of the participants a small advantage could have existed due to better familiarity for the Gujarati letters. However, such an advantage should have led to better visual acuity with the Gujarati chart and not the other way around. Recent research investigating legibility of Chinese characters describes the intra-opto type complexity, referred to as “within character crowding.”[16] where the complexity in Chinese characters contributes to their legibility. The more complex the character (i.e. more internal features) the more difficult it was to recognize.[16] An alternative explanation is that the structure of different Gujarati letters (predominance of vertical strokes) was differentially affected by the cylinder blur. Comparing the mean relative legibility across defocus conditions [Table 1] shows that cylinder defocus of +2.00DC axis 90 resulted in lower relative legibility than either the spherical or cylinder blur axis 180. Such a result can be explained by the preponderance of vertical strokes in the Gujarati letters which would have been more susceptible to the defocus condition +2.00DC axis 90, thereby resulting in more difficulty in their recognition. This is despite the attempt we made to...
The newly designed Gujarati logMAR visual acuity chart provides an accurate and reliable tool for the measurement of visual acuity in Gujarati language speakers comparing favorably with an m-ETDRS chart and showing high test-retest repeatability. This study reports a standardized visual acuity chart developed in the Gujarati language taking into account the important parameters of equal letter legibility, equal inter-row legibility and chart design. The charts are an added advantage in research studies and in conventional clinical practice for standard measurement of visual acuity.

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Table 1: Relative letter legibility of Gujarati letters under spherical and cylinder blur axis 180 and 90 with mean for each blur condition

| Letters | +1.00DS | +2.00DC X 180 | +2.00DC X 90 |
|---------|---------|---------------|---------------|
| ઐ      | 1.04    | 0.98          | 1.06          |
| ઓ      | 1.01    | 0.96          | 1.01          |
| ઔ      | 0.92    | 0.93          | 0.91          |
| ક      | 1.06    | 0.98          | 1.16          |
| ખ      | 0.99    | 0.92          | 0.95          |
| ચ      | 1.06    | 0.91          | 0.96          |
| છ      | 0.97    | 0.99          | 1.05          |
| જ      | 0.96    | 0.95          | 0.93          |
| ઝ      | 0.99    | 0.83          | 0.94          |
| ઞ      | 1.04    | 1.09          | 0.95          |
| ટ      | 1.07    | 1.00          | 1.04          |
| ઠ      | 1.00    | 1.02          | 0.96          |
| ડ      | 1.03    | 1.10          | 0.98          |
| ઢ      | 1.01    | 1.02          | 0.92          |
| ણ      | 0.96    | 1.03          | 0.95          |
| ત      | 0.97    | 0.97          | 0.92          |
| થ      | 0.97    | 1.00          | 0.92          |
| દ      | 0.97    | 1.00          | 0.95          |
| ધ      | 0.98    | 0.98          | 0.91          |
| Mean    | 0.99    | 0.99          | 0.97          |
| SD      | 0.04    | 0.06          | 0.06          |

minimize the effect of legibility. At present, this explanation is speculative and more research is required in order to determine the precise reason for the differences observed.

The results of the present study are consistent and comparable to other chart validation studies that have utilized the ETDRS logMAR chart (or similar) as a standard for comparison. The high correlation between the results from the newly designed Gujarati logMAR chart and the m-ETDRS logMAR chart and the low limit of agreement indicate that the new Gujarati logMAR chart yields a valid measure of visual acuity. A previous study has proposed a Gujarati language chart based on logMAR principles; however, the results reported showed a wide variation in letter legibility and there was no validation of the new charts against the standard ETDRS chart, which may explain the lack of acceptance of the proposed charts.

Previous work has shown that the repeatability of visual acuity measures is of the order of about ± 1 to 1.5 lines of acuity on a logMAR scale. There was no significant difference found between measurements of visual acuity obtained using the two versions of the Gujarati logMAR charts. The limits of agreement for test-retest measures of visual acuity were less than one line, consistent with previous work.
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