


Creation of Three New Optotypes Chart and Evaluation of the Reliability on Healthy Subjects

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Purpose: To design a new optotype that is not based on any Roman character.

Methods: Fifty healthy adults (12 men and 38 women), aged between 20–35 years, were enrolled. Three new optotypes were designed. The first is an open square, the second is a horned square, and the last is a horned circle. The main outcome is the correlation between Landolt C visual acuity and that measured using the 3 newly designed optotypes.

Results: Mean subject age was 27.2 ± 3.7 years. Corrected visual acuity scores were similar across all five tests. Under fogging, the three new optotypes yielded significantly lower scores than Tumbling E and no significant difference was found between the Landolt C and the new optotypes. Bland-Altman analysis showed minimal bias and the closest agreement with Landolt C for the open square optotype, especially under fogging conditions (Bias: -0.006 ; 95% LoA: -0.172 to 0.160). All five tests were significantly correlated ($P < 0.001$), with the open square showing the strongest correlation with Landolt C. Among subjects, 33% had ≥ 1 diopter of with-the-rule astigmatism, but fogging did not reveal differences between astigmats and non-astigmats. Visual acuity was higher in non-astigmats for all optotypes except the open square.

Conclusion: Three newly developed and conventional optotypes including the Landolt C and Tumbling E tests to be similarly effective in measuring visual acuity. These optotypes can be considered as combinations of the Landolt C test.

Keywords: visual acuity test, vision test, optotypes

Introduction

Visual acuity (VA) measurement is a core component of ophthalmic examination and is traditionally performed using alphabet-based charts such as the Snellen chart. However, reliance on Roman letters poses limitations when assessing individuals who are illiterate, young children, or patients unfamiliar with Western alphabetical symbols. Examples of such alternative visual acuity charts include the Landolt C, Lea symbol, HOTV, and Tumbling E charts. The Landolt C is a well-known optotype developed by Edmund Landolt in 1899 and commonly used for evaluating visual acuity.¹ The Tumbling E eye chart was designed by Taylor in 1978.² Although the Tumbling E chart is derived from a symbol used by the Australian aborigines, the character happens to be similar to a Roman “E”.

The Landolt C and Tumbling E visual acuity tests are used in Korea, where patients are often not familiar with Roman letters. Lea symbols such as a square, circle, house, or heart facilitate visual acuity measurements among preschool children.³ However, use of Lea Chart can overestimate visual acuity in comparison to that measured using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart.⁴ In addition, many optotypes differ in contour interaction, gap configuration, and surrounding luminance, all of which influence threshold resolution and may lead to inconsistent results across charts. These limitations underscore the need for culturally neutral optotypes that maintain the psychophysical principles of the Landolt C but avoid dependence on alphabet familiarity. This pilot study aims to (1) introduce the design principles behind these non-alphabetic optotypes and (2) evaluate their reliability under both corrected and fogged conditions.

Methods

This prospective pilot study was approved by the Institutional Review Board (IRB) at Kim's Eye Hospital. Fifty adults (12 men and 38 women), aged between 20–35 years, were enrolled. The restricted age range minimized accommodation variability and presbyopic confounding. All participants provided informed consent. All procedures conformed to the guidelines of the Declaration of Helsinki. Individuals who were free of ocular disease were enrolled in the study. Subjects who had best-corrected visual acuity (BCVA) of less than 20/20 as measured by visual acuity chart were not included.

Three new optotypes were designed. The first is an open square, the second is a horned square, and the last is a horned circle. The horn element was positioned externally rather than internally to avoid excessive crowding and to replicate a directional discontinuity similar to the opening of a Landolt C. The horn subtended 1 arcminute at 20 feet, matching the standard Landolt C gap size (Figure 1). Stroke width, optotype size progression, and spacing followed ETDRS chart design specifications. All tests were performed in the same examination room with the same level of illumination. Only the right eye was used for statistical analysis to avoid violating independence assumptions. All tests were performed on the same day, and a 15-minute rest period was followed by the next test.

The main outcome is the correlation between Landolt C and Tumbling E visual acuity and that measured using the 3 newly designed optotypes. All visual acuity tests were designed similar to ETDRS chart (Figure 2) and they were performed at 4 meters, first with the patient corrected for BCVA and then fogged by an overlying +1.50 diopter spherical lens. The mean of the 2 visual acuity measurements was used under both conditions. The patients were divided into 2 groups according to the presence of >1 diopter of astigmatism.

The data were analyzed using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA). Comparisons among visual acuity charts were performed using repeated-measures ANOVA. To assess the interchangeability of the test optotypes with the standard "C" optotype, Bland-Altman analysis was performed. These statistical methods were chosen because simple correlation analyses are insufficient to assess interchangeability. Statistical significance was defined as $p < 0.05$.



Figure 1 From left to right, Landolt C, Tumbling E, Opened square, Horned square and Horned circle.

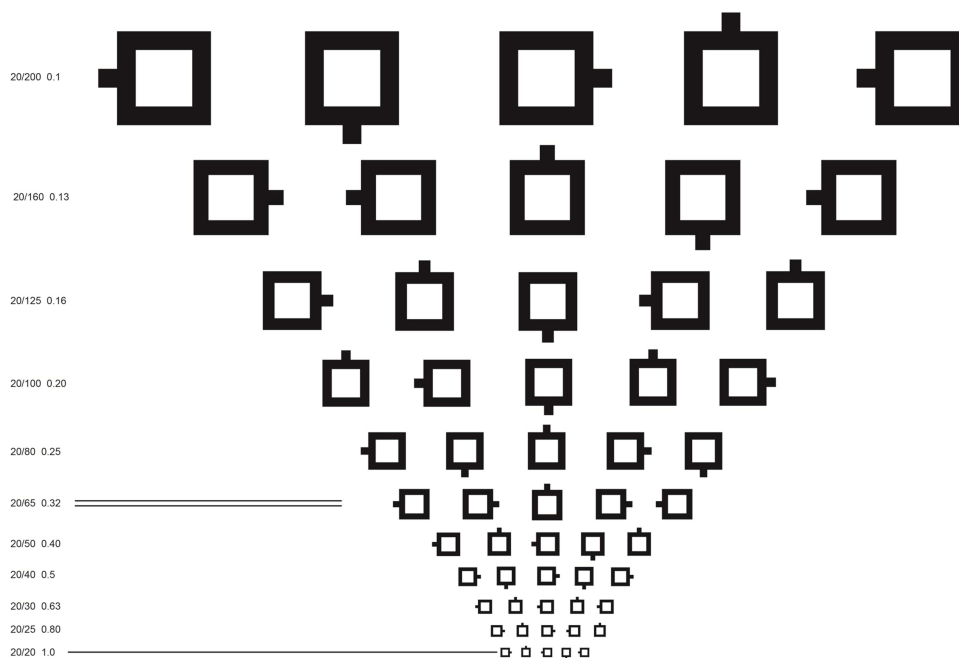


Figure 2 New optotype chart.

Results

Mean age of the subjects was 27.2 ± 3.7 years. Mean BCVA (logMAR) was as follows (mean \pm standard deviation [SD]): Landolt C: 0.06 ± 0.09 , Tumbling E: 0.02 ± 0.05 , horned square: 0.09 ± 0.10 , horned circle: 0.06 ± 0.09 , and open square: 0.06 ± 0.09 . The corrected visual acuity scores were similar for all 5 visual acuity tests. Under fogging conditions, Tumbling E visual acuity was significantly better in comparison to that measured using the Landolt C chart (Tumbling E: 0.37, $P = 0.001$). The 3 new optotypes also yielded significantly lower scores than that obtained using the Tumbling E chart. There was no significant difference between visual acuity measured using the Landolt C chart and the same measured using the 3 new optotypes.

In the BCVA condition, the mean difference (Bias) between the Landolt C optotype and the four test optotypes was generally small, indicating minimal systematic error (Table 1). The smallest mean difference was observed for the door optotype (Bias: 0.024), suggesting the closest average agreement with the Landolt C. However, the 95% Limits of Agreement (LoA) were wide, ranging from a difference of approximately -0.24 to $+0.40$. The narrowest limits were observed for the square optotype (LoA: -0.244 to 0.314), indicating the highest precision in agreement among the test optotypes.

In the Fogging condition, the agreement was notably better. Both the Horned square (Bias: -0.004) and the Opened square (Bias: -0.006) optotypes showed a mean difference close to zero, demonstrating virtually no systematic bias compared to the Fogging C measurement (Table 1). The overall best agreement was found with the Opened square optotype, which had the narrowest 95% LoA (-0.172 to 0.160). This suggests that 95% of the measurements taken with the Opened square optotype were within 0.17 of the Landolt C measurement (Table 1).

Notably, 33 out of 100 patients had ≥ 1 diopter of astigmatism; each of these subjects had with-the-rule astigmatism. The fogging test did not reveal any difference between astigmats and those without astigmatism. Higher visual acuity was noted in the latter group when using any optotype other than the open square (Table 2).

Table 1 Agreement Between Landolt C and Other Optotypes

	Compared Optotype	Mean Difference (Bias)	95% Limits of Agreement (LoA)
BCVA state	E_game	0.134	-0.136, 0.403
	Horned square	0.035	-0.244, 0.314
	Horned circle	0.057	-0.243, 0.357
	Opened square	0.024	-0.279, 0.327
Fogging State	E_game	0.166	-0.148, 0.481
	Horned square	-0.004	-0.174, 0.165
	Horned circle	0.018	-0.180, 0.216
	Opened square	-0.006	-0.172, 0.160

Table 2 Visual Acuity Test According to Astigmatism. (LogMAR)

	Corrected Visual Acuity			Under Fogging Method		
	No Astigmatism (N = 67)	Astigmatism (N = 33)	P-value	No Astigmatism (N = 67)	Astigmatism (N = 33)	P-value
Tumbling E	0.01 ± 0.03	0.04 ± 0.06	0.016	0.40 ± 0.22	0.41 ± 0.18	0.835
Horned square	0.03 ± 0.08	0.11 ± 0.13	0.015	0.41 ± 0.19	0.45 ± 0.20	0.301
Horned Circle	0.03 ± 0.08	0.11 ± 0.13	0.015	0.44 ± 0.22	0.46 ± 0.22	0.810
Landolt C	0.03 ± 0.07	0.08 ± 0.12	0.038	0.42 ± 0.22	0.44 ± 0.21	0.718
Opened square	0.03 ± 0.07	0.08 ± 0.13	0.086	0.46 ± 0.23	0.44 ± 0.19	0.640

Discussion

This study introduced three newly designed, culturally neutral optotypes and evaluated their reliability in comparison with the standard Landolt C and the semi-alphabetic Tumbling E. The results demonstrate that all three novel optotypes—open square, horned square, and horned circle—produce visual acuity values comparable to Landolt C in healthy adults. Among them, the open square showed the strongest agreement, suggesting that gap-based directional resolution can be preserved even in simplified geometric forms.

The use of the Bland-Altman method allowed for a rigorous assessment of the agreement between the novel test optotypes and the Landolt C, addressing the limitations of relying solely on correlation. The wide LoA observed in the BCVA condition (eg, for E_game, LoA: -0.136 to 0.403) suggests that while the correlation might be strong, the test optotypes may not be perfectly interchangeable with the Landolt C in this condition, as a difference of up to 0.40 may be clinically significant.

Conversely, the tighter LoA observed for the Opened square in the Fogging condition provides strong statistical evidence that this optotype can be considered highly interchangeable with the Landolt C under reduced visual acuity conditions. The negligible bias (-0.006) further supports that the Opened square does not systematically over- or underestimate the visual acuity compared to the Landolt C when Fogging is applied.

This suggests that use of the Tumbling E chart may overestimate visual acuity in children and adult,^{5,6} perhaps due to differences in the luminance of the surrounding field.⁶ The crowding phenomenon could also affect the results of visual acuity testing.⁷ When letters are spaced too closely, adjacent contours appear crowded in such a way that diminishes acuity.⁸ These contour interactions vary throughout an ETDRS chart. For instance, lines higher up on the chart have less crowding than lines that are lower down.⁹ When the same phenomenon was examined before and after fogging, there was no significant difference between the Landolt C test and the 3 optotypes introduced here. This suggests minimal crowding effects.

Although we found BCVA measurements obtained using the Landolt C and Tumbling E to be similar, the differences were clear when examined under fogged conditions. Notably, the response to fogging varies greatly among patients.¹⁰ Based on these findings, the Landolt C was chosen for comparison with each of the 3 newly developed optotypes. Visual acuity was lower when measured using any of the new optotypes in comparison to use of the Landolt C, but this trend was not significant. Again, this discrepancy may stem from the luminance of the surrounding field.¹¹

Reich and Ekabutr reported that visual acuity thresholds for the Tumbling E were slightly better than those for Landolt C, particularly in the presence of astigmatism, especially against-the-rule astigmatism.¹² Although the study subjects were corrected, horned type optotypes yielded lower visual acuity scores; use of the Landolt C or Tumbling E tests was associated with higher levels of visual acuity. In contrast to the Tumbling E, with 2 gaps, the Landolt C has 1 gap. In addition, the horned-type optotype includes a projecting edge, rather than a gap. These differences in pattern could affect visual acuity measurements in patients with astigmatism due to the contour interactions induced. The projecting part of the optotype might be affected strongly by the total luminance of the visual acuity chart and modified contour interactions.¹³ Notably, there was no difference among optotypes after fogging. Because the lenses used to treat astigmatism distort letters, the letters on the visual acuity chart became smaller under the corrected state. Thus, the size of the letter could affect visual acuity as measured in patients with astigmatism.

This study has limitations. Because only healthy adults with normal vision were included, generalizability to pediatric populations, those with refractive errors, amblyopia, or low vision remains limited. Additionally, this pilot study did not include a formal power calculation for the sample size. The present results will inform sample size calculations for future multicenter trials. A further limitation is the testing of only one eye per subject to maintain independence; although appropriate methodologically, this reduces the total number of data points. Future work should extend evaluation to broader clinical settings, including binocular testing and assessments of test–retest repeatability.

Despite these limitations, the findings support the feasibility of non-alphabetic geometric optotypes as reliable alternatives to existing charts. Their strong agreement with Landolt C and culturally neutral design suggest meaningful potential for clinical application.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the institutional ethical standards and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. IRB approval number is B-2012-002 by Institutional Review Board of Kim's Eye Hospital.

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Disclosure

The author reports no conflicts of interest in this work.

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