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ORIGINAL ARTICLE

# VISUAL ACUITY: AREA OF RETINAL STIMULATION

**REBECCA DUYSHART** BOrth

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## Abstract

*This paper presents a new concept in design specifications of optotypes used and questions whether the difference in area between optotypes at the same level of threshold acuity influences legibility. Forty subjects were examined with two series of test cards - Equal Area (EA) and Equal Dimensions (ED) - that consisted of single, solid, geometric shapes. The results suggest that on first examination the area of an optotype is significant in the perception process of identifying the optotype perceived.*

**Keywords:** *design specifications, legibility, optotype, resolution, vision.*

## INTRODUCTION

The evolution of optotype design used to assess visual acuity has in principle remained unchanged since 1862 when the Dutch ophthalmologist Snellen devised an eye test chart and Donders in 1866 advocated its use[1,2,3]. Letters were used as optotypes and its specifications were based on the mathematical principle that optical infinity occurs at 6m and the minimum angle of resolution is at one minute of arc[4]. Every Snellen letter subtends five minutes of arc and the line width corresponds to 1 minute of arc for each visual acuity level[2,4-11] (Figure 1).

The two fundamental shortcomings of Snellen Letter optotypes are that they do not provide equal legibility and that they represent a measurement of form perception about which very little is known[4,11,12]. These design anomalies emphasise that the assessment of vision with Snellen optotypes incorporates not only the processes of resolution but perception an recognition[13-16].

Ffooks[13] suggests that visual acuity tests depend on the quantity of information presented per unit area. All optotypes are designed within two dimensions; length times width within the five by five minutes of arc grid. Yet, optotype calculations are founded on a linear measurement, that is the diameter of a retinal cell at the fovea. Thus, despite all current optotypes complying with the Snellen principle, each

*Address for correspondence:* R. Duyshart, School of Orthoptics, Faculty of Health Sciences, La Trobe University, Bundoora, Victoria, 3083. Submitted: November 1994 Accepted for publication: April 1995. This paper was presented in part at the 51st Annual Scientific Conference, Orthoptic Association of Australia, NSW 1994.

provide a different area of retinal stimulation than that of another.

Vitz and Todd[17] suggested that perception of geometric shapes is dependent on progressive analytical levels of line, angle and area; that is, the longer the line, the wider the angle and the larger the area, the greater the chance of a geometric shape being perceived. Could the difference in area between optotypes per level of visual acuity possibly be one of the factors that contribute to the differences associated with legibility?

*Apparatus*

Two series of **test cards** were produced; Equal Area (EA) and Equal Dimension (ED). In both series the solid single optotypes which the subjects had to discriminate were the circle, triangle, square and diamond (a square rotated forty five degrees). The diamond was included as an internal control within the two series; being of the same dimension and area as the square, per level of visual acuity. The basis of calculation at each level of visual acuity in both series, was on the circle - which subtended five minutes of are. Calculations were based on the circle in order to comply with the retinal organisation of the receptive fields, which are essentially circular in shape[13]. Thus, the circle in either series was of the same dimension and area at each level of visual acuity. In the ED series, at each level of Visual Acuity (VA), the geometric shapes have the same dimensions as the circle. That is for example, at the theoretical distance of 6000mm, the circle has a diameter of 8.73mm, the square and diamond

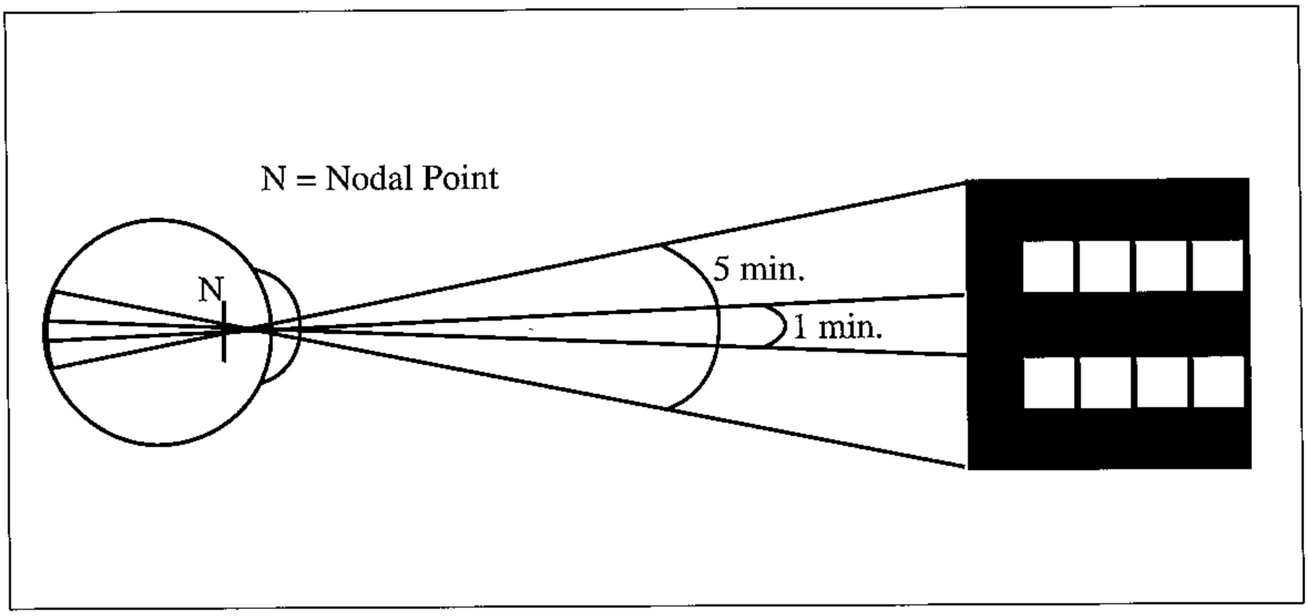


*Figure 1.* Angles subtended by Snellen optotype in minutes of arc.

METHOD

*Subjects*

Forty subjects, 13 males and 27 females, aged between four and six years of age were recruited from Theodore Preschool in Canberra. Selection was dependent on parental consent, the child's willingness to participate, the ability to concentrate throughout the tests and availability for retesting. Subjects were randomly allocated into groups A and B by order of presentation irrespective of age and gender.

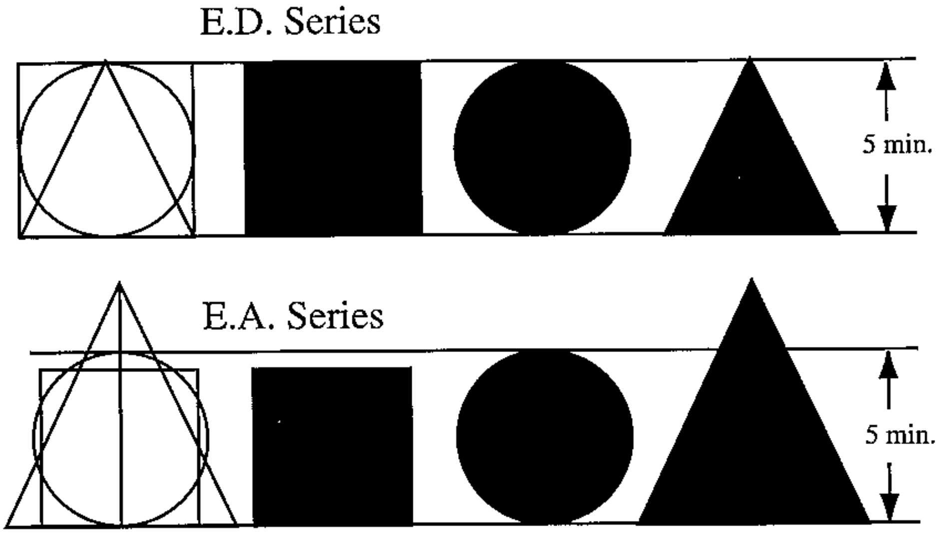


*Figure 2.* Comparative size difference of shapes in each series of test cards

have 8.73 x 8.73mm dimensions and the triangle's base and height is also equal to 8.73mm. The geometric shapes in the EA series, at each level of visual acuity, covered the same area as the circle. From the area of the circle, per level of visual acuity, the dimensions of each shape were calculated. For example, at the theoretical distance of 6000mm, the circle had a diameter of 8.73mm and it's area equal to 59.82mm squared. The dimensions of the square and diamond, were then calculated to be 7.74 x 7.74mm and, the triangle's base and height measuring 11.75mm (Figure 2).

The EA and ED series of test cards had the geometric shapes displayed as single black optotypes that were laser printed (nine hundred dots per square inch), centrally on a white sheet of A4 paper; width and length 21 and 29 centimetres respectively. The sequence of shapes at each level of visual acuity varied from the preceding and proceeding sequence and where possible, avoided the diamond/square and square/diamond succession. The sequence of optotypes was identical in each series of test cards.

The answer card consisted of a laminated sheet of white A4 paper, which displayed a laser printed black circle, triangle, square and diamond. Cut outs of the geometric shapes were of the same dimensions as those printed on the answer card and were constructed from green cardboard. These separate cut outs were termed teaching shapes (Figure 3).

*Procedure*

An initial pre-examination training session was performed with the examiner sitting beside the subject for a maximum of five minutes. Each shape was isolated by a single green teaching shape, placed over the same black shape on the answer card, while a verbal description of that shape - from a point form dissertation - was given.

After each shape was identified and described the subject's comprehension of the shapes was tested. The examiner sat beside the subject while a single optotype was displayed from either the EA or ED series. The subject was asked to indicate, by pointing to a shape on the answer card, which was (thought to be) the same as the shape that had just been presented. The procedure was repeated until all four geometric shapes were correctly identified. The training session was repeated if any of the shapes were mismatched. If the subject failed the second comprehension test, that subject was not included into the sample.

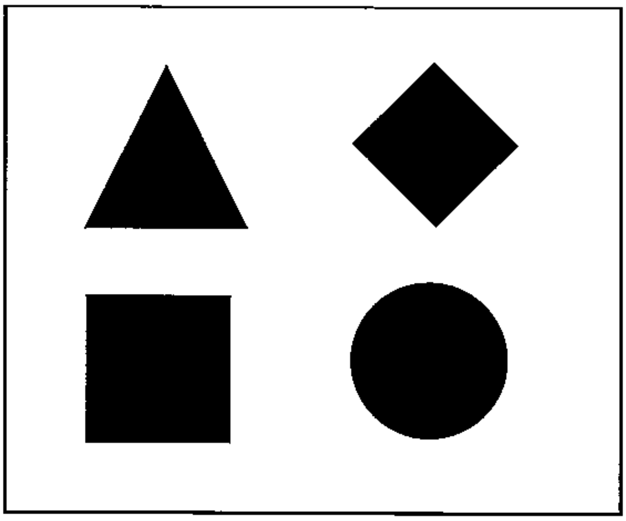

*Figure 3.* Answer Card

Group A subjects were examined initially with the EA series first, followed by the ED series. Group A subjects were then re-examined two days later with the ED series first, followed by the EA series of single optotypes. Group B subjects were first tested with the ED series, followed by the EA series. Group B were re-examined two weeks later with the EA optotypes first, followed by ED optotypes. The allocation of subjects into Groups A and B was to control for the possibility of a learning effect, which may have influenced the re-examination results. It was hypothesised that Group A would have a greater chance of remembering how the test was performed and thus, fewer errors than Group B. The right and left eyes were examined alternately with each series.

The test was conducted at six meters. This distance was initially measured and marked on the floor. If the subject was unable to identify the majority of shapes within the first three visual acuity levels with either eye at the six meter distance then that subject was not included in the sample.

The single geometric shapes were all displayed at each level of visual acuity; the display started at 6/60, progressing towards 6/5. The criterion for establishing the visual acuity level per shape was that the subject must be able to see the shape at the previous level to that level where the shape could not be seen. Thus, when an incorrect response was given for a shape, that shape was not displayed again. The criteria for an incomplete test was determined by the child's poor concentration/co-operation, illhealth, and/or an indication by the child of not wanting to proceed with the examination.

Re-testing occurred at the same time of day. All tests were conducted in the same room in order to keep the examination environment constant. The examination room was separate from the main pre-school room, all external lighting extinguished. The artificial light was recorded 1.2 meters off the ground (where the vision test was held by the examiner) to be that of 350 Lux. The light intensity was measured by a cosin and colour corrected Topcon IM-2D light meter (serial no. 81572374). It was internally calibrated and had a Lux range from 0.9 to 19,000 units.

## RESULTS

The following data was evaluated in terms of percentage error; calculated by counting the number of eyes which did not have the same visual acuity level in the alternate series, divided by the total number of eyes in the sample. The results were evaluated with Groups A and B combined as no learning effect was indicated.

TABLE 1
Percentage errors for the EA series

| | Optotype | | | |
|---|---|---|---|---|
| | Circle | Triangle | Square | Diamond |
| 1st | 17.5 | 17.5 | 35.0 | 32.5 |
| 2nd | 21.3 | 6.3 | 18.8 | 17.5 |
| Total | 38.8 | 23.8 | 53.8 | 50.0 |

In either series the circle had approximately the same percentage error (Tables 1 & 2). For all geometric optotypes apart from the circle, the percentage error on second examination decreased (Tables 1 & 2). The triangle had the least percentage error on second examination and the greatest difference in percentage error between first and second examination (Tables 1 & 2).

TABLE 2
Percentage errors for the ED series

| | Optotype | | | |
|---|---|---|---|---|
| | Circle | Triangle | Square | Diamond |
| 1st | 18.8 | 26.3 | 27.5 | 22.5 |
| 2nd | 21.2 | 8.8 | 13.7 | 13.8 |
| Total | 39.4 | 35.1 | 41.3 | 36.6 |

In the EA series, on first examination the triangle has the same percentage error as that of the circle which was also the lowest (Table 1). However, in the ED series on first examination the triangle's percentage error differed marginally from that of the square, which had the highest percentage error in the ED series (Table 2).

## DISCUSSION

The circle was of the same area and dimension in each series and thus, it would be expected that the percentage error would be the same in either series. However, it is interesting to note that the circle was the only geometric shape which had an increase in percentage error on second examination in either series. On first examination, the percentage error for the EA square and diamond was approximately twice that of the EA circle and, less than the circle on second examination in either series. The EA square and diamond have dimensions that are less than that of the circle and triangle in the EA series and thus appear smaller in size (Figure 2). However, the small difference in size would not account for the elevated percentage errors. It may be postulated that the high percentage errors associated with the EA square and diamond were due to the difficulty in determining whether the shape seen was either a square or a diamond - possibly associated with the anomaly of spatial orientation, which is inherent within the pre-school population[18]. Furthermore, once the subject had learnt to differentiate between a square and a diamond there may have been confusion between these shapes and that of the circle, which would account for the circle's increase in percentage error on second examination in either series. Eskridge[2] suggests that letters which have a similar appearance are often more complex to distinguish than those with distinctive features. Area may be a key component to Eskridge's[2] hypothesis and the reason why the LH test is a successful pictorial visual acuity test as each contoured optotype has a similar overall shape and thus, legibility[19].

The greatest difference in area of the same shape in each series and in comparison with other geometric shapes was the triangle. The difference in area between the EA and ED triangle is approximately fifty percent - the ED triangle being the smaller of the two (Figure2). The percentage error was greater for the ED than the EA triangle (Table 1 & 2) and thus, it may be inferred that because the ED triangle was the smaller of the two it was more difficult to identify. To suggest a relationship between decreased optotype area and increased difficulty in optotype identification would imply that the ED triangle should have had the greatest percentage error than any other optotype. However on first examination in the ED series the triangle was almost as difficult to identify as the square. Yet, on second examination, the ED triangle had a significantly lower percentage error associated with the EA triangle on second examination. It therefore may be inferred that area was initially an influential factor in shape perception and once the distinctive features of the triangle were identified, the triangle was then recognised.

Visual acuity incorporates the processes of resolution, recognition and perception[13-16]. The traditional interpretation of visual acuity measurements has been on the basis of resolution as only the line width of the optotype is considered to be of clinical importance due to its correlation with the functional integrity of the retina. while perception and recognition are thought to be of psychological origin their role in visual assessment has not been fully explored and in particular correlated to stimulus specifications within the preschool population. Where vision plays a key component in the assessment and management of orthoptic and ophthalmic cases it is important to remember that normal acuity of vision does not ultimately lead to correct shape discrimination[20]. It has been suggested that pictures and letters may be distinguished by overall shape, rather than resolving the line width[19,21,22].

Although the single solid geometric optotypes used in this study were not a resolution task, the results imply that within the pre-school population perception and recognition are influential factors in visual functions and should be considered when a child's vision is assessed for the first time in a clinical setting or screening programme. Further research needs to be conducted with a larger sample size of normal and amblyopic pre-school children on the subject of visual acuity and area of retinal stimulation.

## CONCLUSION

The importance of discovering in detail what factors, apart from resolution, influence the assessment of visual acuity has been highlighted as the results imply (for a normal pre-school population) that optotype area on first examination was an influential factor in shape perception until the distinctive features were identified then recognised.


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