Factors Influencing Recognition of the Optotypes of a VA Chart: Design of Optotypes to Reduce Secondary Cues and Contour Interaction

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Abstract

Apart from the size of the optotypes used, contour interaction, secondary cues, the psycho-dynamic behaviour of the patient, their past experience, and cultural differences may all influence the results of a visual acuity (VA) exam.

This trial compared the rate of recognition for a standard letter chart to that for proposed optotypes based on numbers. The standard C chart was used as the baseline of comparison. A Wave chart that improves on secondary cues in the C and E charts is also described. This chart examines meridional visual acuity and can be used with non-verbal patients.

KEY WORDS:
Visual acuity, Optotypes, Contour interaction, Wave Chart, Meridional visual acuity.

INTRODUCTION

A person's recorded visual acuity (VA) may influence their legal status; for example, it is required to obtain or renew a driver's licence, and can affect decisions regarding the effectiveness of any medical intervention and the need for further treatment.

The history and development of the test chart, the shape and sizing of the optotypes and the layout of the chart have been well documented.[1-18]

The visual angle subtended at the eye by the target defines the nomenclature. The response of the patient, however, is affected by other factors, apart from the size of the target. These secondary factors may influence the recorded result. The main secondary factors arise due to the structure of the single optotypes. The contour interaction/crowding phenomenon and secondary cues influence the ability of the patient to recognize and identify the target. This report will discuss these issues and other factors, and will compare different shapes of optotypes. In addition, new optotypes with a different design are proposed. A limited independent study is presented to support this proposal.

The response of the patient may also be affected by other factors, such as education, cultural background and previous experience. For example, a patient who works in an office or bank will interpret the visual information on seeing letters or numbers more readily than a patient whose daily life, or culture, does not relate to these images.

The patient's psychological make-up, e.g., shyness or exuberance, possible peer pressure from others in the consulting room, hysterical behaviour, etc. may also affect the spoken response. How the examiner requests a response and the order in which the targets are presented may also affect the result.

CROWDING PHENOMENON, CONTOUR INTERACTION AND SECONDARY CUES

The crowding phenomenon affects the ability of the patient to recognise an optotype when the target is in close proximity to other objects, compared to the same optotype in isolation.[19,20] This phenomenon is not discussed here.

On the other hand, contour interaction is the phenomenon whereby the recognition of a single optotype is reduced by nearby flanking stimuli closely adjacent to or within that optotype.[21-34] This differential definition is contentious; in the literature, the terms crowding and contour interaction are often synonymous and interchangeable.[19,20] Leat et al.[24] noted that the crowding phenomenon may be caused by a combination of contour interaction, attentional factors, and eye movements. Contour interaction is a type of neural interaction, or lateral spatial masking, caused by the proximity of the contours near the target. It has been suggested that this occurs at a level higher than the retina, probably in the occipital cortex, and is the result of lateral inhibition in the cortex.[22,23,25]

The effect of the contour interaction within an optotype compromises a subject's ability to recognize and report the object correctly. For example, a number such as 0 has a wide space between the borders, and a 2 has open spaces around the lines. The spacing within the 6, 9 and 8 reflects increasing contour interaction interference. The letters C, D and O are open, whereas W, M and N have increased interference. If we compare the differential spacing within the structure of the letters A and H, H is almost free of contour interaction, whereas A shows increasing contour interaction on moving from the bottom to the top of the letter. However, due to secondary cues, the pyramidal shape of a blurred A will be recognized by a patient who is accustomed to reading Latin letters, and the patient's response will be recorded as being correct. Oblique angular lines, as found in 2, 4, 7, W, N, V, A, Z and K, provide secondary cues to recognition.

To equalize the visual task, and avoid the crowding phenomenon, charts have been designed to have the same number of targets, separated by spacing equal to the size of the target on each line.[14,16] However, the contour interaction and secondary cues have not been considered. The influence of ambient luminance in the investigation of visual acuity is not considered here, since it is expected that, in the consulting room, this is maintained at acceptable and uniform levels.[28]

To improve the standardisation of recording the VA measurement, Raasch et al.[33] noted that the visual task should be essentially equal at each size level, with each target demanding equal resolution and recognition. It is unlikely that perfectly equal legibility can be achieved even with targets such as Landolt C or E charts, as the difference in visual ability in different meridians may favour certain orientations.[35] The designs of the Landolt C and E charts were introduced to counter some of these sources of error, as there is a single design of the contour interaction. Even though the target is equal in shape and size, a blurred image (Figure 1) shows that there is a difference in luminance in certain areas within the optotype, which may give secondary cues as to its orientation.

Figure 1: *Blurred E and C optotypes, showing how the direction can be determined from the luminance.*

As noted by Raasch et al.[33] the C and E charts may also show a preference in correctly recognizing the target in certain directions, due to the effect of saccades and/or meridional amblyopia. Although saccades are omni-directional, the main action, especially when tracking as in reading, is horizontal. These horizontal saccades may influence the ability to recognize targets when placed vertically or horizontally.

In the Wave target (Figure 2) suggested here, Waves and straight lines are compared. The patient is asked to determine which of the four optotypes is the Wave. Since the difference in saccades and luminance within the target are equal, the response is free of secondary cues.

This is determined in two meridians. A definite difference in the level of recognition between vertical and horizontal targets will indicate a meridional effect.

Meridional differences in resolution may occur during the early stages of visual development. In extreme cases, this may affect the ability to resolve targets at certain meridians later in life.[35] Leat[36] reported that about 69% of babies have astigmatism of +1.00 or more at birth. This may be linked to hypermetropia of between +2.00 to +4.00. The prescription reduces rapidly to about 17% at age 6-7 years. It could be postulated that, in certain cases of higher hypermetropia, linked to higher astigmatism, certain meridians may remain blurred during the critical stage of development, and the visual resolution may not develop equally. (NB: On examining an older patient, the practitioner may not be aware of the status of the patient's early visual and neurological development. There may be a marginally reduced visual acuity that is not explained by the presenting minimal prescription.) If meridional amblyopia is noted on the Wave chart, improvement of the VA in a certain meridian could be achieved by the addition of a +2.00 DC cylinder placed over the normal refraction, for use in distance viewing (not for near), for a few hours per day. This is a form of meridional patching by the Humphriss method.

Patients who are non-verbal, whether due to pathology, shyness or cultural norms, may find it difficult to answer questions regarding visual acuity. With the Wave chart, the patient may simply signal the difference between the straight lines and the wave by a hand movement.

Figure 2: *A Wave chart intended to equalize the effect of saccades and differential luminance. Designed to determine if a meridional difference is experienced.*

NUMBERS AND LETTERS

Standard Latin (Western) letters are the most prevalent optotypes used in many Western countries. The Sloan letters C D H K N O R S V Z, and British Standard letters D H N U V F R P E Z C K include curves, straight and angular lines. Curved and angular lines may provide secondary cues. The letters A B G I J L M Q T W X Y are not included, since they either have major secondary cues, such as the pyramidal shape of the A, which are recognizable even when blurred, such as the T or Y; or have closely packed lines which are confounding due to contour interaction, such as the M and W. In the research presented here, the letters Y X A and T, which are not normally included, are compared to the accepted U V O and H.

Since different letter shapes are found in many cultures, this may negatively influence the ability of some patients to answer with certainty and accuracy when presented with Latin letters. As populations continue to intermix, the use of letters may cause inaccurate recording of the VA in certain patients. Apart from specific cultures, e.g., Arabic, Siamese and certain Indian sub-continent languages, the shape of the Hindu-Arabic (Western) numbers is becoming universal. It may be beneficial if the optotypes are based on numbers, rather than letters.

USING GRADED INCREASING CONTOUR INTERACTION TO DEFINE THE END-POINT OF RECOGNITION WITHIN THE SAME SUBTENDED VISUAL ANGLE.

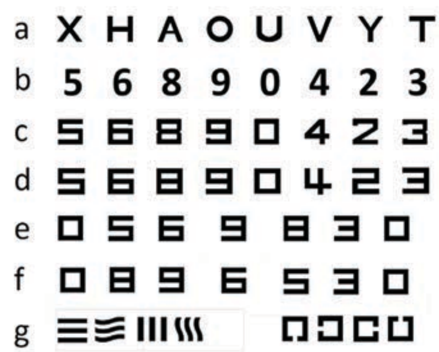
A new design of numbers may improve the standardization of the test chart. The numbers used in the number chart are 2, 3, 4, 5, 6, 8, 9, and 0. The numbers 1 and 7 are excluded because they are too easy to recognize even when very blurred. The number of choices is two less than in the letter chart, but is still sufficient to determine the VA. The numbers are box-shaped, on a 5 x 5 grid, to reduce secondary cues.

The first row of numbers (b) are traditionally-shaped optotypes. The optotypes proposed here are shown in Figure 3, row (c). The 4 and the 2 retain their angular form, acting as secondary cues, to act as a baseline for comparison to a standard VA measurement.

The 0, shaped as a box, has very little contour interaction. This is followed by the 3 with a slightly greater contour interaction. The open space of the central arm of the 3 is a secondary cue. The 5, 6, 9, and 8 have very little secondary cues. The 5 has an increased contour interaction compared to the 3. The next stage is the 6 and 9, with one factor of the optotype missing, while the 8 has the maximum amount of contour interaction.

The original design (Figure 3, row d) reduces the secondary cues to a minimum. For example, compare the 8 in row d to that in row c. This proved to be too stylized for younger children to comprehend. To improve patient comfort and support a better response, a small amount of secondary cues was added, as shown in row c. In a further modification (rows e and f), space was added next to the central number to reduce crowding. The stylized 4 acts as a baseline for comparison to standard charts. By presenting an 0 on either side of the numbers and asking the patient to compare the two 0s, it may be possible to determine if there is a reduction in the contra- or ipsilateral visual pathways. A noticeable difference may indicate neurological changes.

Figure 3: *Comparison of the structures of letters to standard numbers and to numbers with reduced secondary cues. The first row of numbers (b) have secondary cues for recognition. The numbers in (c) were designed to reduce secondary cues, and incorporate different levels of contour interaction. In (d), the secondary cues are further reduced. The bottom two rows (e and f) include spaces to reduce crowding The 0s at each end are used to compare the contra- and ipsilateral visual pathways.*



Figures 4a-c demonstrate how secondary cues can lead to a correct answer, even when the target is blurred. Even when blurred, the standard letters and numbers retain their shape and can be recognized. This can be seen, for example, in the waist of the number 8, the square top and curved bottom of the number 5, the diagonal lines of 2 and 7, and the pyramid shape of 4.

Figures 4a, 4b, 4c: *Blurred images of letters and numbers. Although blurred, the shape of the optotypes, and the luminance variations across the shape, allow a correct recognition to be made in certain cases. The shapes in the C and Wave Charts, row (g), are more difficult to distinguish.*

a) *b)* *c)*

An advantage of the proposed design is that the number 5 can be flipped horizontally to create 2, and 6 can be turned vertically/horizontally to form 9 (rows c and d). This also reduces differences in secondary cues as the targets are the same shape as in the C chart.

By placing 9 next to 8 and 5 next to 6, separated by one factor of contour interaction, the examiner can monitor the level of VA within the same visual angle.

THE WAVE AND C CHARTS ARE ADDED AS A BASELINE COMPARISON.

When recording the visual acuity using traditional charts, some optotypes of the same size are incorrectly recognized, while smaller targets on the following line are seen. This has resulted in the use of various notations; e.g., $6/6^{+}$, $6/6^{-2}$, 6/6 partial. However, these notions do not signify which targets were seen and which were reported incorrectly. To overcome this problem, it has been suggested that a new notation be introduced by scoring the VA per letter.[37-39] Use of the stylised numbers presented here grades the difficulty of recognition under the influence of the contour interaction.

Recognition of an image from previous experience is discussed later. Using this approach, numbers have an advantage over letters as the basis for designing optotypes.

PATIENT RESPONSES TO BEING EXAMINED

Thus far, the physical attributes of the visual system have been noted, with little consideration of the human response. Riggs[38] points out that, when investigating the resolution ability of the eye, the criteria should be sub-divided into *detection*, *resolution*, *recognition*, *identification,* and *verbalization*. Riggs notes that the response of the patient is dependent on various factors: *the physical structure of the target,* i.e., the minimum angle of resolution of the target; *the history of the patient*, i.e., the previous experience of the patient with the chosen symbols, and the *psychological makeup of the patient*.

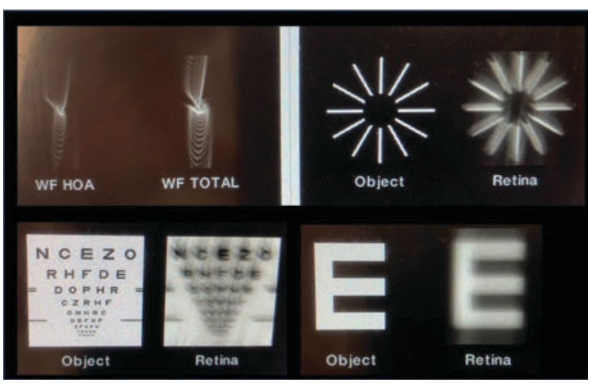
As opposed to a scientific experiment where a participant is chosen with the ability to understand the task and answer honestly, a clinical examination requires a method whereby the end-point can be verified, even against the will of the patient.

Detection requires that the patient is able to exhibit understanding of the task required and be comfortable in achieving the result. This may be compromised when examining young children, someone who has not received sufficient education, someone from a different culture, someone with reduced mental ability, or a person under psychological stress. These patients require an appropriate target and a method for producing an answer.

RESPONSE AFFECTED BY SIZE AND BLUR

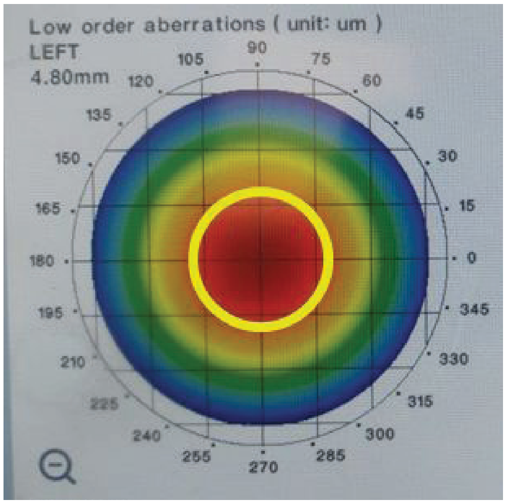
The failure to correctly identify an optotype is influenced not only by the size of the target but also by the amount of blur. The size of the target, which, by definition, is the recorded VA, assumes a perfect optical system. Apart from the blur caused by ametropia, the cornea and lens structure, the structure of the retina and the neurological function of the visual pathway should also be considered. In clinical practice, there are occasions where the patient may respond correctly in recognizing the target, but will mention that, while the target can be seen, it is not clear or sharp. Investigation of the point spread function of the eye (PSF, Figure 5) and the Amsler grid may explain this response.[39] A greater deterioration of recognition, caused by an increase in the PSF, is more likely to confuse the correct response when viewing targets having a more complex contour interaction. The angle of distortion, as noted on the PSF, will also affect different optotypes within a single line. In some ways, this questions the validity of defining the VA of a patient when increased PSF is evident. Noting the PSF when measuring the VA should now be considered in the clinical examination. The advent of instrumentation that includes examination of the PSF makes this possible. Unfortunately, a universal standard of grading the effect of the PSF on the VA is not yet part of the clinical examination.

Figure 5: *The distortion of a target when the Point Spread Function is of low quality.*



In an eye in which there is a greater amount of variation in the corneal and lenticular structures (Zernike map, Figure 6), distortion of the peripheral area can be reduced by giving excess minus. The patient accommodates to return the point of focus to the fovea. This creates a reduced pupil as a by-product. The blur is reduced. The image perceived is sharper, but smaller. Although the patient reports that the image is sharper, on questioning, the patient can no longer readily differentiate between numbers such as 5 and 6. The peripheral blur has been reduced but the reduced size of the perceived image has increased the destructive effect of the contour interaction.

Figure 6: *Distortion of the peripheral cornea, and/or lens as shown on a Zernike map. A smaller pupil, indicated by the yellow circle, reduces the distortion, making the image appear sharper but smaller.*



PSYCHO-PHYSICAL ASPECT OF VISUAL INTERPRETATION

Further factors that may affect the ability of the patient to respond with the correct answer include their emotional and psychological states. In certain cultures and for some personalities, especially with other people in the room, a patient may feel that the failure to answer "correctly" has the ramification of being judged.

If the practitioner is aware of these pressures on the patient, the stress can be reduced by altering the mode of questioning. Instead of asking the patient what optotype is being presented, the patient is asked to differentiate between two known targets. The targets are presented in a graded level of difficulty. Initially the patient is shown a 2 and a 4; both are easily recognized. This gives the confidence of success. The patient is then presented a 0 and a 3. This is followed by a 5 and a 6, then a 6 and a 9 and finally a 9 and an 8. At each stage, differentiation becomes harder. Telling the patient that we are looking for the threshold of success and difficulty in recognition removes the success/fail model. Since there are many successful answers, the patient now feels more comfortable.

Traditionally, VA charts start with a large figure and then reduce the size in stages. In most scientific experiments, especially those relating to vision, this is reversed. The subject responds to the first moment that an increasing stimulus is perceived. This is to prevent memory, experience, fatigue and boredom from influencing the result.

As noted before, the matter of success/failure and self-esteem can create tension. In the Large-to-Small model, the patient moves from success to failure, and the end-point is failure. If this order was reversed, could a better psychological result and possibly more accurate measurement be obtained? If the shapes of the larger targets are recognized, will this allow a better interpretation of smaller targets? Do fatigue and boredom reduce the response?

The psycho-physical aspect of visual perception and interpretation was considered in depth by Frisby.[40] Quoting Sutherland,[41] Frisby notes that the ability to recognize an object and respond correctly depends on its "sameness" in terms of structural description. Sutherland presents the case of the letter T, presented in many formats and fonts. This is demonstrated in Figure 7. As long as there is a horizontal line at the top and a vertical line below, the structural description can be distorted or blurred, but the subject should still recognize "the letter T". The visual system examines patterns as a symbolic description and compares them to a stored description. The response of the patient, on which the VA is based, reflects interpretation rather than resolution. As noted, this is influenced by experience, education and cultural adaption.

Rohrschneider et al.[42] compared the results obtained using Landolt rings and numbers. The results showed a high correlation with both optotypes. The VA with numbers was 0.13 greater than that with the Landolt C. This corresponds to about 1 line on the Snellen chart. This indicates that form recognition plays a role in determining the final status of the visual ability. The results obtained can be compared to the C chart.

Figure 7: *The letter T in different formats. To an educated, Western-culturally educated person, the recognition and response will be correct, whereas a non-Western-educated person, or a young person, may only recognise and respond correctly to a limited number of shapes and symbols.*

RESEARCH: TO ESTABLISH THE SUCCESS RATE OF OPTOTYPE RECOGNITION, USING DIFFERENT DESIGNS, AT DIFFERENT LEVELS OF VA.

Method

To support the argument presented, a limited research study was carried out by three independent researchers and the author. Test charts of differing VA sizes were prepared for display on a computer screen, placed 6 metres from the subject (Figure 8a,b). The chart showed various targets and the traditional sans-serif letters. The target size ranged from 6/7.5 to 6/4. All targets had to be attempted.

Figures 8a, 8b: *The Number, Letter and Shape charts used in the research.*

The study showed a major reduction in the success rate of recognition when the size was reduced from 6/5 to 6/4. Since a VA of 6/4 has little significance in daily life and is rarely examined in clinical work, the discussion here relates to the success rate on moving from 6/7.5 to 6/5.

The participants in this study were recruited from the practice patient base. They consented to their participation after having been informed of the purpose, method and terms of the research.

Twenty eight (28) subjects with VA of at least 6/6 were randomly selected. Subjects with any pathology, previous laser surgery or astigmatism above -0.75 DC were not included. Subjects with oblique astigmatism of more than 20° from the vertical or horizontal were excluded. The subjects used their habitual prescription, and only the right eye was tested.[45] The second eye was covered by an occluder, but kept open, to prevent creating a reduced pupillary aperture by the lids.

The subject was asked to read each chart and instructed to give a single answer, without guessing or hesitation. The number of correct answers was recorded.

Fourteen (14) subjects were asked to read the chart from 6/7.5 to 6/4. After a break, they were then asked to read the chart in reverse order, from 6/4 to 6/7.5. This order was reversed for the next 14 subjects.

Results

The optotypes were divided into numbers, letters and shapes. Four optotype sizes were used: 6/7.5, 6/6, 6/5, and 6/4. However, as mentioned before, the 6/4 size was not considered in the following discussion. The results are shown in Table 1.

Table 1: *Correct Recognition of Numbers, Letters and Shapes*

	0	2	4	3	5	6	9	8	U	V	Y	X	A	O	H	T								
Large-to-Small																								
6/7.5	27	28	28	28	27	27	24	25	27	27	26	25	27	27	26	26	26	26	26	26	24	24	24	24
6/6	27	28	27	27	24	18	16	19	27	26	27	26	27	27	27	27	25	26	26	25	24	23	24	24
6/5	27	27	26	25	15	13	12	10	26	19	20	20	27	23	20	25	23	24	24	23	22	21	23	23
6/4	23	25	25	21	9	5	2	2	24	16	15	14	20	20	14	24	11	13	12	12	6	5	7	8
Small-to-Large																								
6/4	22	24	25	23	11	6	7	6	23	14	15	16	20	18	15	24								
6/5	26	26	27	26	18	18	16	17	25	23	22	22	25	22	20	25								
6/6	27	27	26	27	24	24	21	22	26	26	25	25	26	26	26	27								
6/7.5	27	28	28	28	27	26	26	27	27	27	26	27	27	26	26	27								

Values represent the number of subjects (of the total 28) who made a correct identification.

With the 6/7.5 target, which is well within the ability of the subjects, the numbers and letters were correctly identified by 26-28 of the subjects, except for the numbers 9 and 8, and the letter X. This can be explained by the increased contour interaction of these shapes. Interestingly, the 6 and 9 are the same shape, but rotated. When tracking from top to bottom, which could be the natural flow, the open space at the bottom of the 9 becomes darkened as the closed section in the top section is retained on the retina. In the 6, the open space at the top of the optotype does not affect the bottom section. This effect continues with all of the sizes (number of patients with a correct response: 6/7.5; 6=27, 9=24; 6/6 6=18, 9=16; 6/5 6=13, 9=12; 6/4 6=5, 9=2.)

The target symbols in the C chart are equally recognizable in all directions (26 subjects). In contrast, it was more difficult to recognize the optotypes in the Wave chart (24 subjects).

With the 6/6 target, which was the base level of VA chosen for the subjects, 26-27 subjects identified the letters correctly. The number optotypes were graded into two groups; the first group (0, 2, 4, 3) had more open shapes, with a lower level of contour interaction, and more easily noted secondary cues, and the second group (5, 6, 9, 8) had fewer open shapes and hence increasing contour interaction. The secondary cues are reduced. The first group showed a high level of recognition (27-28 subjects). In the second group, the success rate decreased as the contour interaction increased. The number 5, with 2 open spaces, was correctly identified by 24 subjects. The numbers 6 and 9, each with a single open space, were correctly identified by 18 and 16 subjects, respectively. The number 8, which has maximum contour interaction, was correctly identified by 19 subjects. With the C chart, 25 subjects identified a vertical opening and 26 identified a horizontal opening. The targets in the Wave chart were identified by almost the same numbers of subjects, except that slightly fewer subjects correctly identified the vertical wave.

With the 6/5 chart, a target size that some subjects could not easily recognize, the letters show a range of differences. The accepted letters U, V, O, and H were correctly identified by 26, 19, 23, and 20 subjects, respectively, while 20, 20, 27 and 25 subjects identified the discarded letters Y, X, A, and T. The A (correctly identified by 27 subjects) has major secondary cues, since it is shaped like a pyramid, similar to a normal 4. The U and V, although close in shape, show a major difference (26 vs. 19). This may be due to the lower contour interaction of the U compared to the V. The inverted pyramid of the V would be expected to give a secondary cue. The different responses to the pyramidal shape of the A (27) compared to the inverted shape of the V (19) is not readily explained. A pyramidal shape may be more culturally acceptable than a V.[43,44] The open space of the T (25), which provides secondary cues, gives a much higher rate of success.

For numbers, the open shapes of 0, 2, 4, and 3 are more easily recognised (by 25-27 subjects) than the more closed shapes (5 was identified by 15, 6 and 9 were identified by 13 and 12, and 8 was identified by 10). Again, the C chart shows that it is slightly easier to identify a horizontal opening compared to a vertical opening. The Wave chart shows that these are equally likely, with perhaps a slight reduction for the vertical wave.

If we consider the C chart as the basis of VA for recognition (by 23 or 24 subjects) and 6/5 as the standard that can normally be achieved by many subjects, V,Y,X, and H have a lower rate of recognition (by 19 or 20 subjects) while U, A and T have a higher rate of recognition (by 25-27 subjects). The absence of Y, X, A, and T in the Sloane and British standard charts seems valid, and the present results suggest that V and H should also be excluded.

With the number chart, open numbers are easier to recognize, while closed numbers are more difficult to recognize. The difficulty in recognition follows a pattern determined by the amount of contour interaction. Taking the C chart as the basis (recognized by 23-24 subjects), the open numbers were recognized by 25-27, while the closed numbers were recognized by 10-15. Of the closed numbers, the easiest to recognize was 5, followed by 6 and 9, and finally 8 This is the basis of the design of the number chart. The chart allows the vision achieved at a specific size to be graded by the contour interaction.

The Wave chart shows a reasonable match at 6/5. Taking the C chart as the basis (recognized by 23-24 subjects), the Wave chart was recognized by 21-23. At the level of 6/4, the success rate is much lower (5-8). Since the chart is designed for children, non-verbal patients and patients not educated in Western symbols, 6/6 is sufficient. The 6/4 chart is not discussed.

Table 2 shows the decrease in recognition as the size of target is reduced. The open numbers show a uniform gradient. As the contour interaction increases, the recognition rate drops. While 4 has an increased contour interaction, it also has a highly significant secondary cue. The closed numbers have a much greater decrease in recognition. The letters are more difficult to compartmentalize. U, A and T show little change. U and T have little contour interaction while A has secondary cues. V, Y, X and H have increased contour interaction. The C and Wave charts are stable.

Table 2: *Change in recognition with a reduction in the size of the optotype.*

	0	2	4	3	5	6	9	8	U	V	Y	X	A	O	H	T								
6/7.5	27	28	28	28	27	27	24	25	27	27	26	25	27	27	26	26	26	26	26	26	24	24	24	24
6/6	27	28	27	27	24	18	16	19	27	26	27	26	27	27	27	27	25	26	26	25	24	23	24	24
6/5	27	27	26	25	15	13	12	10	26	19	20	20	27	23	20	25	23	24	24	23	22	21	23	23
Change 6/7.5 to 6/5	0	1	2	3	12	14	12	15	1	8	6	5	0	4	6	1	3	2	2	3	2	3	1	1
6/4	23	25	25	21	9	5	2	2	24	16	15	14	20	20	14	24	11	13	12	12	6	5	7	8
Change 6/7.5 to 6/4	4	3	3	7	18	22	22	23	3	11	9	7	7	7	12	2	15	13	14	14	18	19	17	16

Values represent the number of subjects (of the total 28) who made a correct identification.

Table 3 compares the reduction in recognition when viewing targets Large-to-Small and Small-to-Large. There is a minor difference in the results for most optotypes, from which no conclusion can be made. However, the numbers 5, 6, 9, and 8 do show a major difference, with better recognition when starting from Small-to-Large. A likely explanation is fatigue and/or boredom increasing as the test progresses. In the Large-to-Small direction, as the optotypes get smaller there is a greater need to concentrate on the minor differences in the shape of the optotype. With the Small-to-Large direction, fatigue and boredom have not yet set in. This is also seen for V, Y and X. This validates the concept of Small-to-Large as being both more scientific and more accurate. Snellen's design, which set the standard in 1862, remains the norm. It is doubtful if a change could ever be accepted.

Table 3: *Comparing the Correct Recognition of Numbers and Letters, Large-to-Small, and Small-to-Large.*

	0	2	4	3	5	6	9	8	U	V	Y	X	A	O	H	T
Large-to-Small																
6/7.5	27	28	28	28	27	27	24	25	27	27	26	21	27	27	26	26
6/6	27	28	27	27	24	18	16	19	27	26	27	26	27	27	27	27
6/5	27	27	26	25	15	13	12	10	26	19	20	20	27	23	20	25
Change 6/7.5 to 6/5	0	1	2	3	12	14	12	15	1	8	6	1	0	4	6	2
Small-to-Large																
Change 6/5 to 6/7.5	1	2	1	2	9	8	10	10	2	4	4	5	2	4	6	2
6/5	26	26	27	26	18	18	16	17	25	23	22	22	25	22	20	25
6/6	27	27	26	27	24	24	21	22	26	26	25	25	26	26	26	27
6/7.5	27	28	28	28	27	26	26	27	27	27	26	27	27	26	26	27

Values represent the number of subjects (of the total 28) who made a correct identification.

DISCUSSION

As noted, the measurement of visual acuity can have significant impact in the legal and medical environment. Especially in busy hospital clinics, the measurement of visual acuity is often delegated to auxiliary staff, who may not use the same method for defining the end-point as an experienced practitioner. The auxiliary staff may also differ between patient visits. The accepted end-point recorded may therefore differ for patients with the same condition. This may influence the decision for further treatment by the consultant looking at dry data. In 1982, the US National Eye Institute developed the Early Treatment Diabetic Retinopathy Study (ETDRS) chart and a protocol for vision testing. This has become the gold standard for testing visual acuity.[45]

The standard letter chart shows uncontrolled variations in optotype recognition, making grading within a single line of targets problematic. The number chart proposed here shows graded changes that are dependent on the contour interaction. A clear end-point is noted, due to the design of the optotypes, and should therefore be reproducible when different practitioners examine the same patient. Both the C chart and Wave chart, which have one/ two shapes, are stable within a single size, and show a stable and significant change when there is a reduction in size. The Wave chart has advantages for children and non-verbal patients. A further point noted in practice is that the use of a mirror can cause confusion in direction with certain children. There are inconsistencies with the direction of the C and E charts, which do not occur with the Wave chart.

The factors that influence correct recognition, and expression of this recognition, are varied. Psychological aspects should not be ignored. Asking a nervous or self-conscious patient to compare known numbers, rather than a quiz of which optotype is being presented, can help to reduce tension. The recorded data represent a fixed, immutable, statement of ability. The assumption that the size of the optotype signifies the VA is simplistic, and should not be accepted as the definition of VA. The variation of subtended angle, contour interaction/crowding phenomenon, point spread function, cultural recognition, intelligence, experience and psychological stress all play a role in defining the answer given. This should be taken into account by practitioners, especially in a hospital or legal framework. ●

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