Principles and Practice of Clinical Electrophysiology of Vision

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Visual Acuity Testing Principles

Lea Hyvärinen

Measurement of visual acuity is one of the most common clinical tests in eye clinics and private offices, yet it is quite often performed with inadequate accuracy when examining abnormal vision. Although we know that visual acuity values are affected by such variables as luminance and type of test,[2, 19, 20] we often have only one test for adult patients and one for children and rarely, if ever, measure visual acuity at more than one luminance level.

Visual acuity is a suitable test for the assessment of refractive correction and screening and assessment of amblyopia, where it is mostly used. It is also one of the basic criteria for classification of visual impairment, although such measurements do not always depict the degree of visual impairment as judged by patient's visual capability.

In clinical examinations we mean by "visual acuity" a measurement to assess the resolving power of the abnormal visual system either as (1) recognition of optotypes (Landolt-C, letters, numbers) or (2) resolving of gratings. We usually think of visual acuity as a measure of cone function in the fovea. When assessing abnormal visual systems we should be keenly aware that the visual acuity value may depend upon foveal, parafoveal, or even paramacular function and that it is usually related to cone but sometimes to rod function. In certain conditions, e.g., rod monochromatism, rods determine acuity at light intensities well above the normal cone light threshold.[16]

The aforementioned visual tasks involve different visual functions and result in different visual acuity values in abnormal visual systems. Therefore we should specify the tests and the luminance levels used.

LUMINANCE

In the normal visual system, visual acuity increases as a function of luminance of the white background from mesopic to high photopic luminance until glaring brightness is attained, at which point visual acuity starts to decrease. In abnormal visual systems, glaring brightness may be in the mesopic or midphotopic range of luminance levels[1, 7, 15] (Fig 57–1). In these cases we should measure the resolving power at the optimal luminance. This acuity and the optimal luminance should both be recorded. If the exact luminance value cannot be measured, it can be stated whether the measurement was in the low, mid, or high mesopic or low, mid, or high photopic range. Adult persons can define their optimal luminance level very accurately if given the opportunity of adjusting the illumination with a dimmer switch.

Visual acuity tests can also be used to quickly assess visual adaptation. After the initial measurement at the optimal luminance additional measurements approximately 2 log units above and below the optimal level give valuable information on the range and speed of visual adaptation (see Chapter 50). Infants

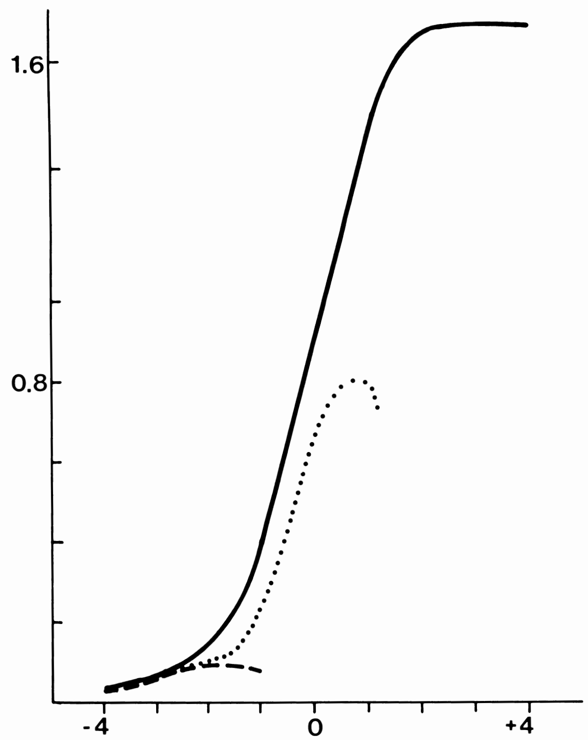

FIG 57–1.
Visual acuity as a function of luminance (millilamberts). In scotopic vision visual acuity is that of rods, around 20/200 or 0.1 at its best both in normal individuals and in complete achromats, in whom visual acuity then decreases when luminance increases *(dashed line).* In the normally sighted there is a linear increase in visual acuity in mesopic and photopic luminance until the plateau that is individually between 20/25 (0.8) and 20/10 (2.0) *(uninterrupted line).* In numerous disorders visual acuity may first increase as a function of luminance but, because of dazzle, rapidly decreases in the midphotopic range *(dotted line).* When the luminance increases above the optimal level of photophobic persons, they tend to blink so that the eyes are closed a longer time than normally and opened for only brief moments. Although the luminance of the test surface increases, the retinal illumination is apparently kept nearly constant. The fall in visual acuity values may be related to difficulties in fixation during the very short exposure time.

and young children with visual impairment may behave as though blind in normal room illumination and yet have measurable visual acuity in low mesopic illuminance. Since they cannot describe their vision, they should be assessed at both low and high luminance levels.

In some cases the spectral quality of light may affect visual acuity values. Selective absorption of some of the blue end of the spectrum (with filters of the Corning CPF or Zeiss Spezialfiltergläser type) may drastically improve visual acuity.

VISUAL ACUITY TESTS

Optotype Tests

The basic optotype, the Landolt-C, is rarely used in clinical assessments. It is, however, the reference optotype with which visual acuity is defined as being 20/20 or 1.0 when the Landolt-C optotypes with a gap width of 1 minute of arc can be correctly recognized. Normal visual acuity values have a range between slightly better than 20/10 (2.0) and 20/25 (0.8). (The gap of a 20/10 Landolt-C subtends *only* 0.5 minutes of arc at the eye and is on the order of a diameter of two foveolar cones [each 1.0 to 1.5 μm in diameter].)

Visual acuity charts designed according to the international recommendation (see Colenbrander,[4] Appendix 1) are based on British[3] or Sloan letters[5] (Fig 57–2). These letters are standardized to be equal to Landolt-C for normal foveal vision. Outside the fovea, letter acuity falls more rapidly than Landolt-C acuity as a function of eccentricity.[6] Therefore, in extrafoveal vision different charts give different visual acuity values even if they have been properly calibrated.

In countries where the alphabet does not contain all the ten Sloan letters, the selection of letters must be reduced. Other forms than letters can be standardized to function as optotypes.[13] The critical feature of good optotypes, equal recognizability, must be fulfilled (Fig 57–2).

Since visual acuity may be different when measured at different distances, both distance- and near-vision acuity values should be measured with the same optotypes. When visual acuity values are below 0.03 (20/600), distance charts can be used as near tests. That allows measurement of visual acuity down to 10/2000 or 0.005 when the chart is shown at 20-cm distance.

"Counting fingers," although frequently used, is not a quantitative method since neither the size of the fingers nor the contrast between fingers and their background is standardized. If it is used, the user should have a black surface behind his fingers, and he should know which visual acuity value his fingers correspond to at different distances.

Tests with different spacing of optotypes, line tests, single-symbol tests, and tests with crowded symbols may result in varying visual acuity values. The basic measurement of visual acuity is done with a line test. It is a common error to measure a child's visual acuity with a single-symbol test and infer from that value the text size that the child should be able to read later. The difference between the single-

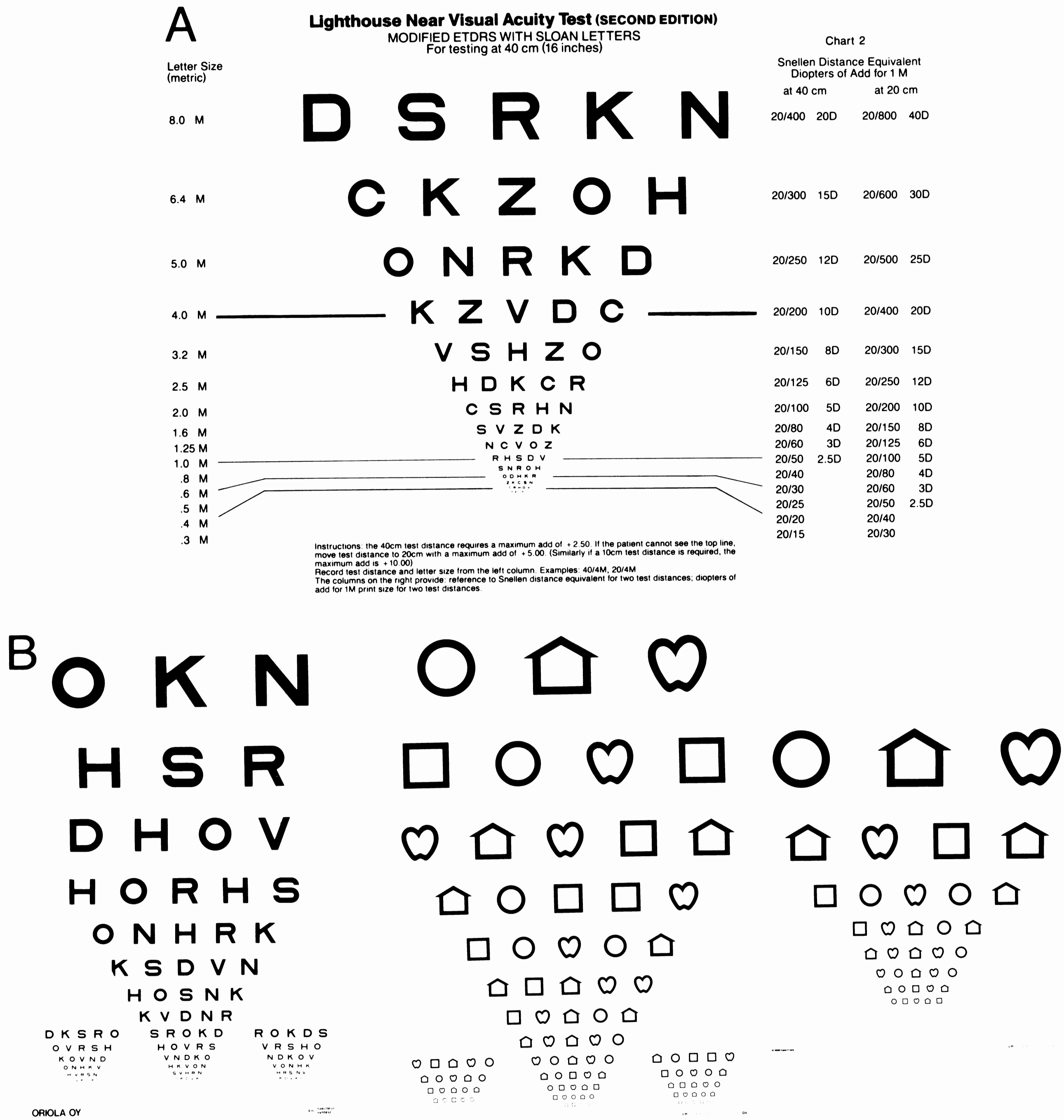

FIG 57–2.
New visual acuity charts designed according to the international recommendation. **A,** letter chart available at Lighthouse, New York. The original Bailey-Lovie chart is available at the School of Optometry in Melbourne. **B,** from left to right: (1) a modified letter chart by Oriola, Finland, with eight Sloan letters and three sets of lower lines; (2) LH optotype chart for children older than 5 years of age; and (3) simplified chart for children at the age of 3 to 4 years, Oriola, Finland, and Lighthouse, New York.

symbol value and that measured with crowded symbols may be two to four lines.

The texts used in the measurement of reading vision are difficult to standardize. Since it is impractical to use texts that avoid all capital letters, numbers, and lowercase letters with ascenders (as in d or h) or descenders (as in p or q), one solution might be to refer to the size of the text in "points," which is an internationally used standard in specifying letter size and spacing. For example this text is 10 point text with 12 point spacing. The smallest texts in this book are 8 point with 10 point spacing. This practice would give freedom of reading distance that should always be the distance preferred by the patient. During the test the patient should use proper refractive correction.

The readability of the texts should match the reading ability (grade level) of the person tested, and it should be equal throughout the text and not become easier when the text becomes smaller in size. When testing visually impaired dyslectic children, it is especially important to have suitable material to test how these two different factors affect reading performance.

When examining patients with abnormal visual function one needs several charts for distance-vision and near-vision measurements. Those who examine young children need an even larger selection of tests in order to always have available a test that might motivate the child to answer.[11, 17] Most of these tests are not very carefully standardized in terms of equal blurring of the individual optotypes, but it is better to get some acuity value, even with a less standardized test, than no value at all!

Grating Acuity Tests

Grating acuity tests are usually used in the assessment of visual acuity in infants and low-functioning older children. It seems to be a common practice to report the results to clinicians and parents as optotype acuity values instead of reporting the results in cycles per degree (cpd). The reasoning is that it is easier for clinicians and parents to understand the optotype acuity values than the newer concept of grating acuity. This not only underestimates the capability of people to learn new concepts, but it also may give wrong information in some cases. It is well known that the grating acuity of a person with involvement of the central visual field is regularly better than the optotype acuity. The difference may in extreme cases be up to 20 times.[8] Therefore both optotype *and* grating acuity should be measured when examining a patient with abnormal vision whenever possible.

There are few tests available for the measurement of grating acuity. The grating acuity cards[18] function well in examining infants and young children but not in examining adults.

The detection of small objects, dots, or balls is not a measure of visual acuity in the same sense as optotype acuity or grating acuity but gives some information about visual function in cases when nothing else can be measured.

LOW-CONTRAST VISUAL ACUITY

Assessment of visual functions at low contrast levels is becoming a routine task in diagnostic laboratories and low-vision clinics since it has been shown that in many common disorders like multiple sclerosis, macular degeneration, cataract, diabetic retinopathy, and glaucoma, changes in recognition of low-contrast information may occur before there are changes in visual acuity measured with high-contrast optotypes (for a review see Chapter 58). As an adjunct to regular contrast sensitivity measurement using grating targets, measurement of low-contrast visual acuity is a quick, cheap, and informative test.

There are half a dozen low-contrast charts, but in nearly all of them the lowest contrast is 10%. The Pelli-Robson low-contrast chart, the LH-5 contrast visual acuity test, and Mentor's B-VAT contain several contrast levels. The Pelli-Robson chart measures the lowest contrast at which the optotypes' corresponding visual acuity of 0.03 can be read, whereas the two other tests can be used to measure visual acuity at several contrast levels.[12]

The individual variation in the relationship between grating acuity and optotype acuity that we can measure at high contrast in both normal and visually impaired persons is present also at low contrast. It may increase slightly toward the lower contrasts.[14]

It is simple to roughly define the slope of the contrast sensitivity curve by measuring the optotype acuity value at high contrast, i.e., the usual visual acuity value and another at the lowest contrast where the person can still recognize optotypes.

PRACTICAL VALUE OF LOW-CONTRAST VISUAL ACUITY TESTS

Since changes in vision may affect low-contrast vision first and since the range of normal variation of visual acuity values is so great at all contrast levels, it would be of diagnostic importance if measuring low-contrast visual acuity was a part of routine measurements when young healthy persons are examined. Then the measured value would function as the baseline later in life.

In the assessment of persons with abnormal vision, the difference between the low-contrast optotype and grating acuities gives additional information about the nature of visual impairment: the greater the difference, the greater will be the difference between low-contrast near-vision tasks (recognition of forms) and visual orientation that uses long lines and corners as the basic information. A demonstration of this difference helps teachers, parents, etc., to better understand the reasons why a person with abnormal vision functions so differently in different tasks, the extreme being that a person with reasonably good visual orientation uses braille or talking books as his main source of written information.

STANDARDIZATION OF TEST SITUATIONS

International recommendations on the structure of the visual acuity charts[4] give a good foundation for all optotype tests. Similar recommendations on the structure of grating acuity tests should be developed.

Measurement of grating acuity is unlikely to become a part of assessment of the vision of normally sighted adult persons, but it is important in the examination of infants. When abnormal vision is examined, grating acuity is a function of the size of the stimulus.[10] A routine measurement should apparently include 1½- to 2-degree (or the smallest that the person can see) and 10- to 15-degree stimuli. Whenever the 10-degree stimulus results in unusually low values, then additional measurement at half the distance should be made. Measurements when using larger than 20-degree stimuli seem to have rather little clinical importance.

VISUAL ACUITY OF MULTIHANDICAPPED PATIENTS

Assessment of visual acuity in infants and severely multihandicapped patients often includes measurement of grating acuity by using the visual evoked potential (VEP). It should be remembered that this measurement only shows that the grating or checkerboard stimulus activates the visual cortex. It does not reveal whether the information is transferred further to associative areas and whether it can lead to a motor response. Brain mapping may give us further information on these functions once developed as a clinical tool. It may also give an explanation in cases where the VEP is extinguished but the patient has fairly good visual functions.

During the assessment of vision of low-functioning multihandicapped patients it is important to remember the effect of posture and medications on visual performance[9] and to involve special educators and care givers in the assessment.

In summary, when assessing visual acuity of an abnormal visual system the following are important:

1. Examine at optimal luminance level.
2. Select the tests and communication to fit the patient's needs.
3. Measure both optotype and grating acuity at high contrast and at low contrast.
4. Measure optotype acuity at a distance of 1 to 4 m and at near distance.

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