ASPECTS OF VISION LOSS –

Visual Functions and Functional Vision

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Abstract

To promote consistency in terminology, this paper explores the distinction between Visual Functions, which describe how the eye functions and Functional Vision, which describes how the person functions in vision-related activities.

Adequate assessment of Functional Vision is essential to measure outcomes of vision rehabilitation. Consistent measurement will require the development of a unified set of criteria, better suited to use in rehabilitation than the current “participation” categories in ICF.

Whether vision tests are used to explore the underlying causes of eye disease or their functional consequences affects the ways in which they are administered and interpreted. This is explored in detail for letter-chart acuity (the most common visual function test) and reading (the most common functional vision test). At the group level a statistical relationship between visual functions and functional vision can be shown, but individual variations are too great to use this relationship for individual predictions.

Definitions of Ranges of Vision Loss are discussed that fit the visual function aspect as well as the functional vision aspect. In this context, the proper use of the terms “blindness”, and “low vision” and the more inclusive term “vision loss” is discussed. Labeling patients with residual vision as “blind” may have adverse psychological consequences.

For calculating a statistical estimate of functional vision, based on visual function measurements, the revised AMA Guides can be used. The AMA approach is useful for certain statistical and administrative applications, but should not be used to predict individual rehabilitative needs.

Introduction, Aspects of Vision Loss

Depending on the point of view from which vision loss is approached, different aspects will be seen. The terms “Visual Functions” and “Functional Vision” represent two such aspects. This paper will explore how making a clear distinction between these terms can help clarify issues that otherwise may seem confusing.

The basis of this discussion will be the four aspects of health and health deficits shown in Fig. 1. Although the distinction between impairments, disability and handicap had been made earlier [1,2], it was firmly established in the International Classification of Impairments, Disabilities and Handicaps (ICIDH, WHO-1980) [3] and its successor, the International Classification of Functioning, Disability and Health (ICF, WHO-2001) [4]. These aspects are not specific for vision loss, but can be applied to any organ system.

Two of the aspects relate to the organ (the body in ICF); they specify the structural and the functional condition of the organ system. Two aspects relate to the person; they specify the skills and abilities of the individual and how these affect participation in a social context. The four aspects are related, but the links are flexible and can be influenced by various interventions. Prevention is aimed at preventing various etiologic factors from causing structural changes or disorders. Treatment is aimed at reducing the functional deficits caused by such structural defects. Rehabilitation is aimed at reducing the impact of functional deficits at the organ level on the skills and abilities of the individual. Prevention, treatment and rehabilitation are health care interventions. A fourth group of interventions is aimed at reducing the social impact (“handicap” in ICIDH) and enhancing the social “participation” (ICF) of individuals with an ability deficit (‘dis-ability’ in ICIDH). These interventions may go beyond the individual and may involve the home, school and/or work environment; they are generally considered under the umbrella of social services, rather than under health care.

Fig. 1 – ASPECTS of HEALTH and RELATED INTERVENTIONS

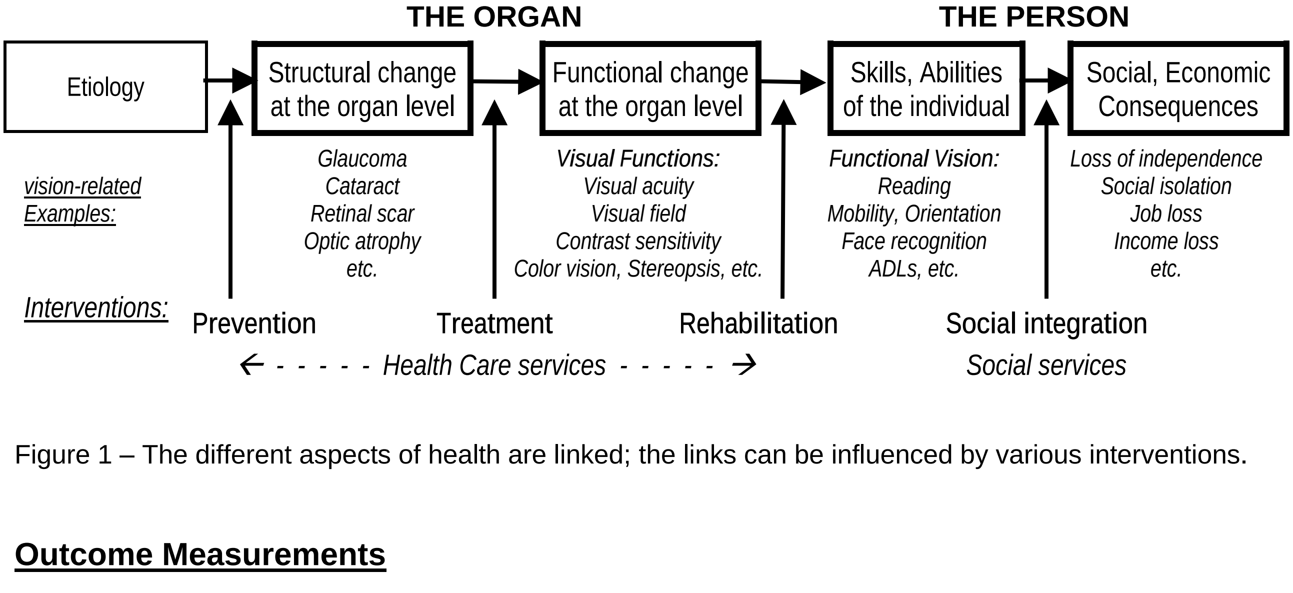


Figure 1 – The different aspects of health are linked; the links can be influenced by various interventions.

Outcome Measurements

Since there is increasing emphasis on ‘evidence-based medicine’ and since governments and other parties are reluctant to pay for interventions without a documented benefit, documentation of outcomes is important. Since the chain of cause and effect runs from left to right, outcomes can only be documented by considering the aspects to the right of the intervention.

The effects of prevention can thus be demonstrated by absence of disorders, by absence of functional loss at the organ level and by absence of ability loss at the personal level. To measure the functional (rather than anatomical) effects of medical and surgical treatments only the latter two options remain. For rehabilitative interventions, only one option remains: measuring the impact on Functional Vision, i.e. on the vision-related skills and abilities of the individual. In the context of this discussion, we will concentrate on vision-related abilities. The effects on social participation, although eminently important, will not be addressed in this paper. The reason is that participation in a societal context involves many more abilities than just vision-related ones. So, even if vision-related skills are improved, participation may still be restricted because of non-visual factors. In this regard, ICF [4] distinguishes “capacity” (= ability in a standardized environment) from “performance” (= actual participation in the “context” of an actual social environment).

In ophthalmology the measurement of organ functions is well developed. Measurement of individual visual skills and abilities lags far behind, but deserves increased attention if the field of vision rehabilitation is to gain the same respect and interest (from practitioners and patients alike) that the field of physical rehabilitation has achieved already.

In the field of vision, we use the term **Visual Functions** to describe how the *eyes* and the visual system function; we should distinguish this from **Functional Vision,** which describes how the *person* functions in vision-related activities. Under functional vision we consider vision-related Activities of Daily Living (ADL) such as reading and writing, orientation and mobility, face recognition. Under visual functions, we commonly consider visual acuity, visual field and contrast sensitivity, but this aspect also involves other functions, such as color vision, dark adaptation, stereopsis, to name a few. Visual functions are not limited to disorders of the eyeball; among congenital defects Cerebral or Cognitive Visual Impairments (CVI) are increasingly important. It is important to recognize this category, since CVI may exist while traditional functions, such as visual acuity, are normal [5]. Thus, these children may fall between the cracks, if eligibility for services is based only on traditional measures, such as visual acuity, and does not take into account the special problems created by their condition. The rehabilitative interventions needed by children with cognitive visual impairments are very different from those of children with reduced acuity [6] [7].

Categories for Activities and Participation

In this context it is important to mention some of the similarities and differences in terminology used to categorize the two aspects that relate to the person.

The aspect labeled “Skills and Abilities” in Fig. 1 was given the label “Disability” in ICIDH and “Activities” in ICF. The two terms cannot be separated, since specifying ability levels without specifying the activity to which they pertain is meaningless. One reason to avoid the term disability is that it has a negative connotation, especially in U.S. usage; another reason is that it is an overly broad term that blurs the distinction between the different aspects. In the “Americans with Disabilities Act” (ADA) it is equivalent to impairment (loss of organ function); in “Disabled Veterans” it indicates a loss of skills and abilities. In “being on disability” it indicates the economic condition of receiving disability benefits. The term “Activities”, in ICF, is preferred, because it is neutral and relates closely to “Activities of Daily Living” (ADL). When a term indicating loss is needed, the term “Ability Loss” is preferable over disability, since “ability loss” is clearly limited to the skills and abilities aspect and indicates that its measurement refers to a reduction of the residual ability, rather than to the addition of a vague entity called disability.

The aspect labeled “Social and Economic Consequences” in Fig. 1 was labeled “Handicap” in ICIDH; in ICF the label is “Participation”. Again, handicap was a negative term, participation is positive. In ICF the term “barriers” corresponds most closely to the handicap concept. In ICIDH a major dimension of handicap was loss of independence; the term participation stresses interdependence.

While the ability aspect relates mainly to activities that the individual can perform alone and that can be studied in isolation, the participation aspect may draw on a number of different abilities and can only be studied in a social context. E.g.: the ability to read Braille is independent of the ability to read print, yet one may compensate for lack of the other in the context of social participation. Thus, rehabilitative interventions must always consider both vision substitution (Braille, cane, talking books) and vision enhancement (magnification, illumination, contrast) [8].

Activities can be categorized from different points of view. ICF offers the same set of categories to categorize “Activities” as is used for “Participation”. This means that in ICF activities are categorized in relation to the participation aspect that they serve. E.g.: in ICF reading and writing (including both print and Braille) are categorized under “”Applying Knowledge”. This is consistent with the ICF emphasis on disability as “disablement”, a term used in the ICF drafts; curiously, the term enablement (i.e. rehabilitation) was never used in these drafts. A unified scheme for cataloguing and categorizing vision-related activities has not yet been developed. Since the use of vision is so pervasive in normal life, there are few human activities in which vision does not play at least a potential role. The term “Functional Vision” is meant to refer to a sub-set of activities in which vision plays a significant role.

Questionnaires [9] aimed at vision-related Quality of Life recognize various domains, but these are not always consistent. Massof [10, 11] has discussed the difficulties in deriving a true measurement from questionnaire results, as opposed to ordering (ill-defined intervals) or merely labeling (no scale) various visual attributes. ICF uses the perspective of the resulting disadvantage. For the selection of specific rehabilitative interventions and outcomes, a perspective related to the underlying organ function, in this case vision, would be more suitable. E.g.: reading print would be categorized under “vision-related activities”, for which vision-enhancement would be in order. Braille, cane use and talking books would be found under non-visual or vision-substitution categories.

Tests aimed at Causes vs. Tests aimed at Consequences

Traditionally, ophthalmology has focused on the prevention and treatment aspects of eye disease. The additional emphasis on vision rehabilitation is relatively recent. Consequently, tests aimed at early detection, differential diagnosis and grading of eye diseases (the left side of Fig. 1) have been developed more extensively than those aimed at identifying the consequences of vision loss (the right side of Fig. 1). Similarly, in public health ophthalmology and epidemiology, the traditional emphasis has been on early detection and prevention of eye disease. The additional emphasis on the consequences and socio-economic burdens of vision loss is more recent.

As a result, most traditional visual function tests show a bias towards the diagnosis of underlying causes. The following discussion will show that there are subtle but not insignificant differences between tests aimed at elucidating the causes of vision loss and tests aimed at predicting or estimating the consequences. The traditional diagnostic versions of many tests are not necessarily the most informative for use in vision rehabilitation.

History taking. A history taken for diagnostic purposes asks questions about symptoms that are typical for certain diseases. A history for rehabilitative purposes must ask questions relevant to the tasks the patient wants to perform. Note that patients usually state their complaints in terms of functional vision: "Doctor, I cannot read the paper". The clinician translates that into terms of visual function: "Visual acuity has dropped by two lines".

Color vision tests. The **Ishihara test** is well known. This test is exquisitely sensitive to even minor hereditary red-green deficiencies and is very helpful in tracing the x-linked pattern of such deficiencies in family trees. However, for testing the potential consequences in the workplace the test is too sensitive; it detects patients who will never have practical color problems. Furthermore, since it only tests in the red-green area, it can be defeated by the use of colored light or by the use of tinted lenses.

To test for practical consequences, Farnsworth developed the **D15 test**. It finds only those defects that are severe enough to have potential practical consequences. Also, since it tests around the spectrum, it cannot be defeated with colored lenses.

Visual Field tests Existing visual field tests have been developed to characterize and measure the field defects caused by glaucoma and other diseases. Programs for statistical analysis are available to enhance the diagnostic use of automated perimetry. However, from an automated field plot it is often difficult to predict what everyday functional problems the patient may experience. Goldman fields were easier to interpret in this regard, and a simple confrontation field that is useless to document glaucoma can often give us good information about practical problems.

Diagnostic field tests aim at finding the *worst* spots, relative or absolute scotomata that are typical for certain diseases. For functional vision, it is important to find the *best* spots that may be used to serve as a Preferred Retinal Locus (PRL) for reading [12].

Most diagnostic field tests are limited to the central 30 degrees, since that area contains the vast majority of all retinal cells. For mobility, however, the far peripheral field is important also.

Most diagnostic tests use small, threshold stimuli on an empty field. Real life vision, however, is concerned with the detection of mostly larger and often moving objects against a background that is never empty. The macular mapping test [13], which uses peri-foveal letter recognition, is more closely related to functional vision.

The peripheral field is particularly sensitive to motion; yet, automated perimetry has substituted static stimuli for the moving stimuli in the Goldman perimeter. There is an ongoing debate about the importance of this static-kinetic dissociation for functional vision.

Diagnostic perimetry needs to test each eye separately. For functional vision the binocular field is decisive.

In clinical perimetry the patient needs to avoid eye movements; most perimeters are equipped with fixation monitors to verify this. In real life, good scanning habits are essential for good spatial awareness. There are few tests that test for scanning and search strategies [14].

Dark adaptation. For diagnostic purposes the cone-rod transition and the endpoint after 30 or 45 minutes are most informative. In real life, when driving into a tunnel, the first few seconds may be decisive.

Electro-physiology. Tests such as ERG or VEP can help in diagnosing disease, but do not help in predicting the severity of the consequences.

Additional examples can be given for other tests. In the following section we will give special attention to visual acuity.

Visual Acuity

Visual acuity is by far the most commonly used vision test. It is the most prevalent yardstick for success or failure in clinical trials. Yet, its implications and interpretation are not always properly understood [15]. It is often regarded as a measure of the overall quality of vision, even though it measures only foveal function, which represents less than 1% of the retinal area.

For diagnostic purposes it is important to measure each eye separately and with best correction. Functional vision, however, is binocular vision. In a population survey aimed at finding eye diseases, it is advantageous to measure *best-corrected* visual acuity for each eye *separately*. For a survey aimed at the consequences of vision loss, *binocular* acuity with *presenting correction* is more relevant. Accordingly, one of the recommendations of a recent expert consultative meeting at the WHO was to base future health surveys on *binocular presenting acuity* [16].

A distinction is commonly made between *distance* and *near* acuity. Comparing distance and near acuity can give us information about the accommodative amplitude. For functional vision, the distinction between *letter chart* and *reading* acuity is more relevant. It may be said that letter-chart acuity is the most common visual function test, while reading is the most common functional vision test.

Letter-chart acuity is commonly measured at a distance, because that relaxes accommodation for refractive measurement. However, most Activities of Daily Living and particularly reading are performed at closer distances. For a survey aimed at the consequences of vision loss, a tabulation of distance acuity alone would include many un(der)corrected mild myopes, who do not necessarily experience ADL difficulties. Although this is not customary, it may be argued that if a single number is to be used, tabulating the 1-meter acuity [19] might give a better picture of functional vision problems.

Visual acuity is an excellent screening test since it is easy to administer and fairly reliably indicates whether an eye is normal or not. In this context the difference between 20/20 (1.0) and 20/40 (0.5) may be important, while the difference between 20/100, 20/200, and 20/400 (0.2, 0.1, 0.05) does not provide much help in the differential diagnosis. This explains why most clinicians feel little need to specify poor vision beyond vague statements such as Count Fingers or Hand Motions. Many also ignore measurements that are better than 20/20.

The situation is very different for Low Vision rehabilitation, where visual acuity predicts the magnification need. A person with 20/100 needs 5x magnification; 20/200 needs 10x, 20/400 needs 20x. Vague descriptions, such as Count Fingers, are meaningless.

Visual Acuity is expressed as a mathematical fraction. Given the limited clinical interest in accurate measurement, it is not so surprising that the numerical implications of that fraction are often ignored; 20/40 is interpreted as “driving vision” and 20/200 as “eligibility for benefits”, rather than as statements about the magnification need of that individual. Most practitioners are not comfortable converting measurements for different distances and from distance to near vision. The following section will address this issue.

Visual Acuity Calculations

Snellen’s formula defines standard acuity (1.0, 20/20) as the ability to recognize a standard letter (1 M-unit) at a standard distance (1 m), or, more generally, a letter of *n* M-units at *n* meters. For a subject who needs letters that are **2x** larger or **2x** closer, visual acuity is said to be **1/2** of standard acuity (0.5, 20/40). If the required magnification is **5x**, visual acuity is said to be **1/5** (0.2, 20/100), etc. The increase in angular letter size (MAR) indicates the visual threshold, while visual acuity is the reciprocal of that magnification threshold.

When dealing with underlying conditions and physiological optics, MAR is interpreted as "**M**inimal **A**ngle of **R**esolution" [17]. Bailey and Lovie introduced the term logMAR (= $\log_{10}$(MAR)) to convert the geometric progression of letter sizes to a linear scale [18]. When talking about the resulting reading ability, we think in terms of print size and reading distance. In that context, the same acronym MAR may be meaningfully interpreted as **MA**gnification **R**equirement. Recognizing that visual acuity is simply the reciprocal of the magnification threshold avoids the common misconception that visual acuity would measure the overall quality of vision or that it would denote a percentage of visual ability.

The numerical implications of Snellen's formula are easier to understand when referenced to a 1-meter standard than to a 20 ft.-standard. Further, a modification of Snellen's formula is needed to more easily compare the magnification requirement for letter-chart acuity to the magnification requirement for reading. The usual form of the Snellen fraction: **V = m/M** *(in which V = visual acuity, m = viewing distance in meters and M = letter size in M-units, where 1 M-unit subtends 1 min of arc at 1 meter, approx. 1.5 mm or 1/16 inch)* is useful for distance tests, where "m" is a whole number; the formula is awkward for near vision, since the numerator becomes a fraction-within-a-fraction. This can be avoided by inverting the formula [19] and substituting D = diopters for the reciprocal of the metric viewing distance, thus:

$$MAR = 1/V = M / m = M \times 1/m = M \times D \qquad \text{or: } \mathbf{1/V = M \times D}.$$

(in which V = visual acuity, M = letter size in M-units and D = viewing distance in diopters, which can be measured directly with an appropriate ruler).

This simple modification of Snellen's formula takes the usual awkwardness out of the conversion of reading acuities for different distances. Expressing the reading distance in diopters is clinically more meaningful than expressing it in cm or inches, since "D" refers directly to the reading add in presbyopes and/or the required accommodation in younger persons.

Fig. 2 applies the modified formula to various letter sizes and viewing distances. Note that the resulting acuity values appear in diagonal bands. This means that the same acuity value can result from different combinations of letter size and viewing distance. E.g.: A 4 M letter seen at 3 D (30 cm, 12") yields a magnification requirement (relative to 1 M at 1m) of 4x3 = 12 and a visual acuity of 1/12 or 20/250. At half the distance (double the reading add: 6 D) the patient should be able to read print of half the size (2 M). The same acuity value will also result from 1 M print (newsprint) at 12 D. This patient will need at least a 12 D lens to read newsprint, a statement also known as "Kestenbaum's rule".

The statement "at least" 12 D points to another important difference between visual function and functional vision measurements. Visual Function measurements are *threshold* measurements. Psychophysical measurement rules tell us that our measurements will be most accurate if we press the person to guess in a Forced Choice paradigm. ADL performance, however, is rarely done at the performance threshold (except for Olympic athletes). We prefer to perform at a supra-threshold level. The difference is known as the magnification reserve [20].

Legge has defined the functional reading level as the point where reading speed starts to drop off with smaller print size. Using a single standardized reading distance, Legge calls this the "critical print size" [21]. Speaking of *functional* reading acuity and *threshold* reading acuity allows us to use different reading distances as needed. The difference between functional and threshold acuity is the functional magnification reserve, schematically represented in Fig. 3. There are similar reserves for contrast and illumination.

Fig. 2 – PRINT SIZE and VIEWING DISTANCE

	40cm	30cm	25cm	20cm	16cm	12cm	10cm	8cm	6cm	5cm
	16"	*12"*	*10"*	*8"*	*6"*	*5"*	*4"*	*3"*	*2.5"*	*2"*
	2.5 D	**3 D**	**4 D**	**5 D**	**6 D**	**8 D**	**10 D**	**12 D**	**16 D**	**20 D**
5 M	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*	1/25 *20/500*	1/30 *20/600*	1/40 *20/800*	1/50 *20/1000*	1/60 *20/1200*	1/80 *20/1600*	1/100 *20/2000*
4 M	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*	1/25 *20/500*	1/30 *20/600*	1/40 *20/800*	1/50 *20/1000*	1/60 *20/1200*	1/80 *20/1600*
3 M	1/8 *20/160*	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*	1/25 *20/500*	1/30 *20/600*	1/40 *20/800*	1/50 *20/1000*	1/60 *20/1200*
2.5 M	1/6 *20/120*	1/8 *20/160*	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*	1/25 *20/500*	1/30 *20/600*	1/40 *20/800*	1/50 *20/1000*
2 M	1/5 *20/100*	1/6 *20/120*	1/8 *20/160*	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*	1/25 *20/500*	1/30 *20/600*	1/40 *20/800*
1.6 M	1/4 *20/80*	1/5 *20/100*	1/6 *20/120*	1/8 *20/160*	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*	1/25 *20/500*	1/30 *20/600*
1.25M	1/3 *20/60*	1/4 *20/80*	1/5 *20/100*	1/6 *20/120*	1/8 *20/160*	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*	1/25 *20/500*
1 M	1/2.5 *20/50*	1/3 *20/60*	1/4 *20/80*	1/5 *20/100*	1/6 *20/120*	1/8 *20/160*	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*	1/20 *20/400*
0.8 M	1/2 *20/40*	1/2.5 *20/50*	1/3 *20/60*	1/4 *20/80*	1/5 *20/100*	1/6 *20/120*	1/8 *20/160*	1/10 *20/200*	1/12 *20/250*	1/16 *20/300*

Figure 2 – The same visual acuity values can result from different combinations of viewing distance and print size.

Fig. 3 – THRESHOLD ACUITY and FUNCTIONAL ACUITY for READING

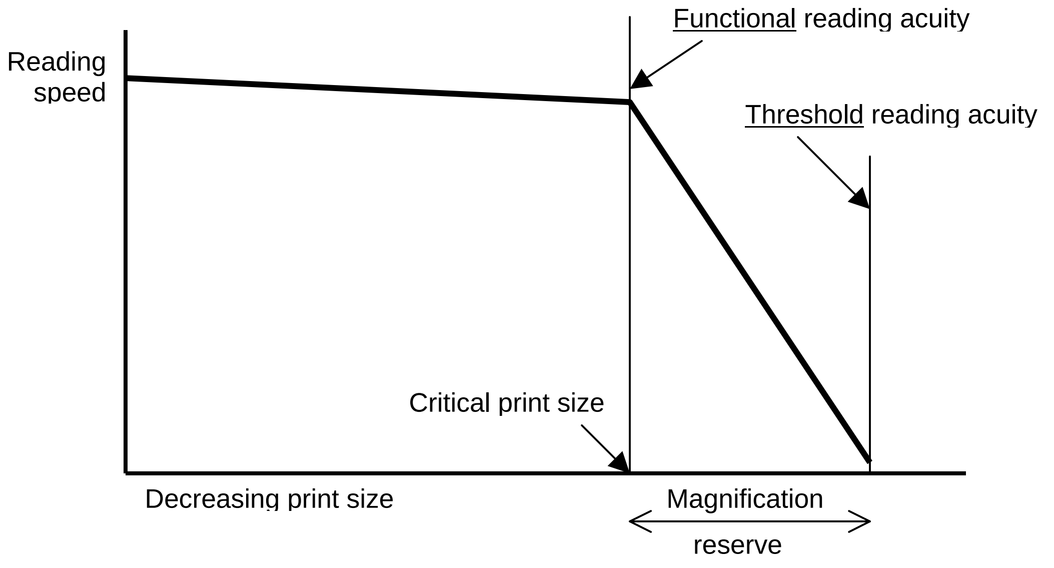
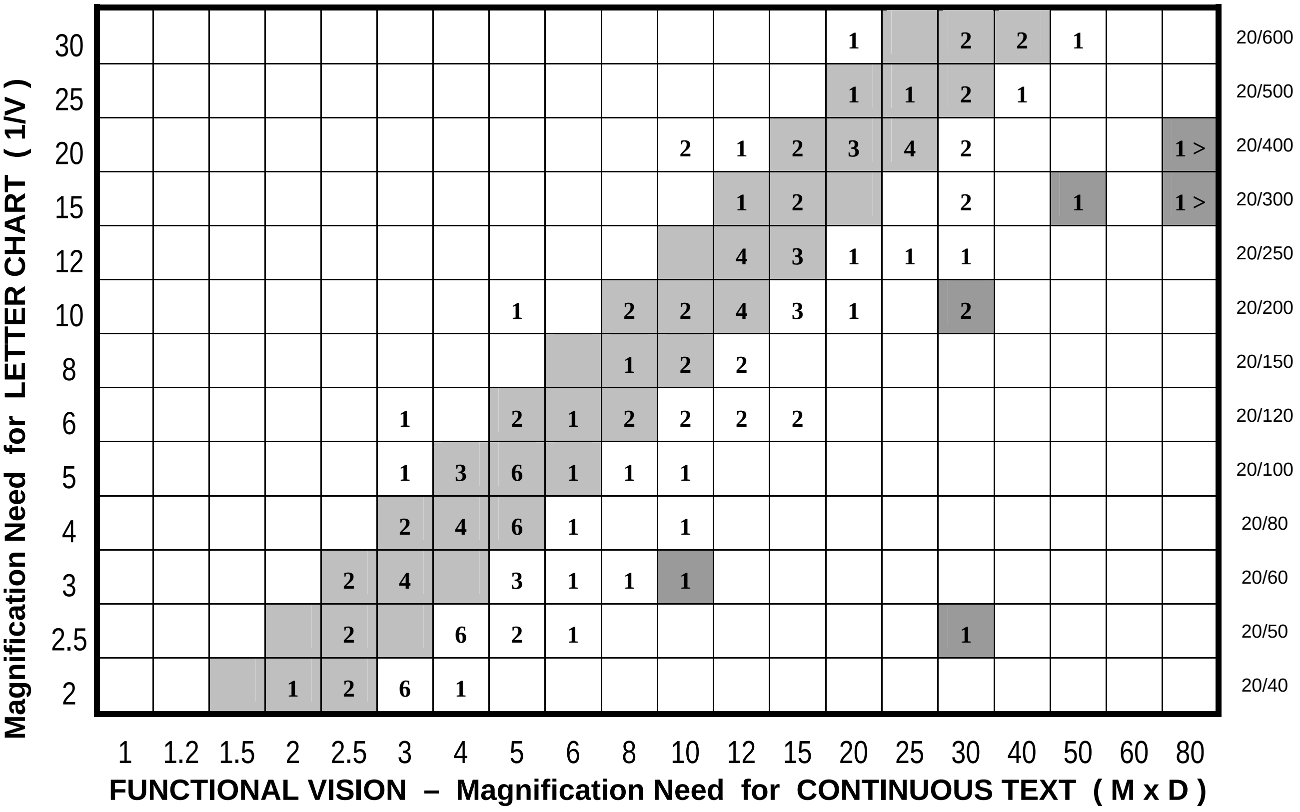


Figure 3 – Functional reading occurs at a print size larger than threshold. The difference is the magnification reserve, needed for reading fluency.

To test these assumptions on actual patient data, Fig. 4 plots the magnification need found with letter-chart testing against the magnification values patients preferred for actual reading performance. It is based, retrospectively, on a sample of 150 consecutive patients from the author's Low Vision service. If there were perfect consistency between reading acuity and letter-chart acuity, all values would fall in the gray band – most do.

There is also some spread to the right, i.e. towards more magnification need for reading. This reflects the "magnification reserve" needed for reading fluency. The amount of this magnification reserve is not the same for all patients. A few highlighted cases stray further from the diagonal band. Such cases should not be discarded as measurement errors, but be explored. In each case we found special conditions that explain the unusual behavior; usually we found that a small island was used for letter recognition and a larger, more eccentric retinal area for reading.

Fig. 4 – LETTER CHART vs. READING ACUITY



30														1		2	2	1			20/600
25														1	1	2	1				20/500
20											2	1	2	3	4	2				1 >	20/400
15												1	2			2		1		1 >	20/300
12												4	3	1	1	1					20/250
10								1		2	2	4	3	1		2					20/200
8										1	2	2									20/150
6						1		2	1	2	2	2	2								20/120
5						1	3	6	1	1	1										20/100
4						2	4	6	1		1										20/80
3					2	4		3	1	1	1										20/60
2.5					2		6	2	1							1					20/50
2				1	2	6	1														20/40
	1	1.2	1.5	2	2.5	3	4	5	6	8	10	12	15	20	25	30	40	50	60	80	

Figure 4 – Functional reading acuity and letter chart acuity usually are similar (gray band); sometimes more magnification is needed. Extreme differences (marked) must be explored.

Simple vs. Complex Environments

There are additional reasons why the correlation between visual functions and functional vision cannot be a precise one. When measuring visual functions, we strive for "pure" measurements, testing a single variable in a static environment. With Functional Vision, we rarely have that privilege. Even if we isolate one vision-related skill, such as reading, we have to deal with multiple variables, such as print size, contrast and illumination, in a dynamic environment. This is even more pronounced when we proceed to the participation aspect, where vision-related skills interact with non-visual ones. To participate in a meeting, one needs reading skills to read the announcement, travel skills to get to the meeting, cognitive skills to enjoy the presentation and communication skills to participate in the discussion.

Fig. 5 may clarify this further. Considering a distinct task, such as reading newsprint at 40 cm, we may find a fairly discrete cut-off for reading ability vs. print size, but when we add in the option of reading newsprint at 30 cm or at 50 cm, the curve for "generic reading" becomes much flatter. Adding other ADLs to the consideration will make the curve even flatter.

Fig. 5 – SIMPLE vs. COMPLEX ENVIRONMENTS

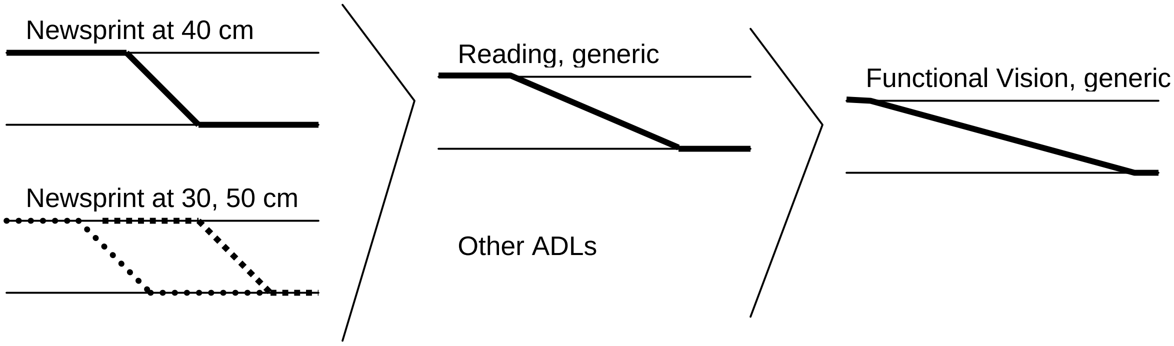


Figure 5 – Simple tasks may show a relatively sharp acuity cut-off. As tasks become more complex, the slope of the function vs. acuity curve will become less.

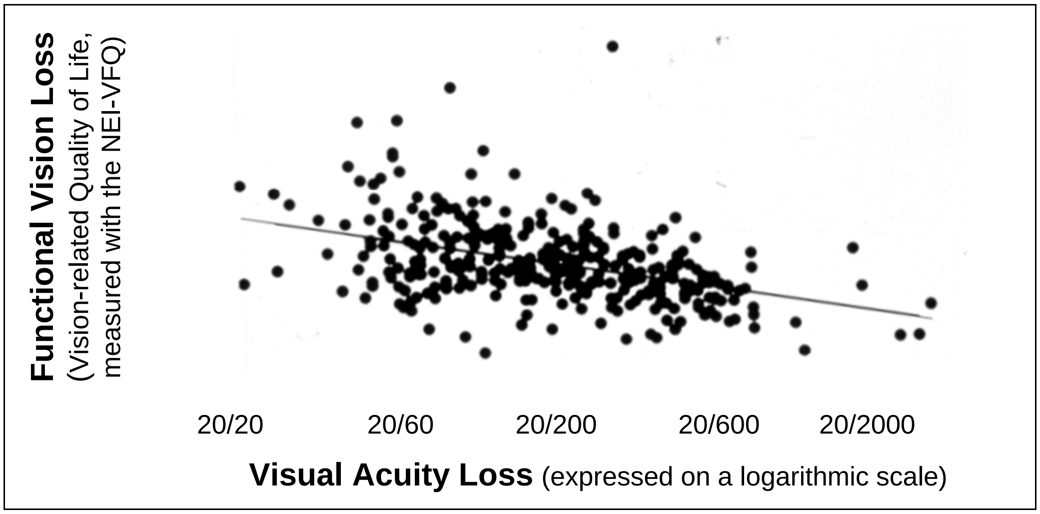
In Fig. 6 empirical data are used to illustrate this relationship. The horizontal axis represents visual acuity on a logarithmic scale. The vertical axis represents FUNCTIONAL VISION, as measured by the NEI-VFQ after Rasch analysis by Robert Massof [22] on data provided by Donald Fletcher. A statistician may be delighted to see a nice linear regression line. Massof used this graph as support for a logarithmic visual acuity scale and showed a similar graph for visual fields. A clinician, however, will note that the spread of individual points is so wide that, however valid the statistical correlation is, it is useless for individual predictions.

So, when we ask whether there is a correlation between Visual Functions and Functional Vision, the answer must be both YES and NO.

YES, there is a statistical correlation. We note that the regression line is straight when plotted against a logarithmic scale. This is an important support argument for the use of a logarithmic scale and for the validity of Weber-Fechner's law, which states that geometric stimulus increments give rise to linear increments in sensation. We also note that the line is smooth; there are no apparent breakpoints.

The answer has to be a resounding NO, however, if we try to use the statistical correlation to predict individual performance. The spread of individual points far exceeds the slope of the regression line; many individuals are above the highest point or below the lowest point of the regression line. This should not surprise us. There are totally blind individuals who are gainfully employed; there are normally sighted individuals who are unemployed. Around the 20/200 level, some individuals are near the top, some are near the bottom of the NEI-VFQ scale. A tighter correlation might have pleased statisticians; it would have been a disappointment for clinicians, because there would have been little room to influence the relation between visual functions and functional performance through vision rehabilitation.

Fig. 6 – QUALITY OF LIFE and VISION LOSS



Data from Donald C. Fletcher, MD
Presentation by Robert W. Massof, PhD

Figure 6 – A plot of Functional Vision vs. Acuity loss shows a definite statistical correlation, but the spread of individual points prevents any individual predictions.

This diagram can also be used to make a plea for truthful representation of data. Too often publications give only the regression line, which in this case would look reasonably impressive. That impression and the interpretation of the data change radically when the scattergram of individual points is added.

Eligibility Cut-offs

Administrators like to have simple eligibility cut-offs. This may apply to benefits, such as special education aid, an extra tax deduction or a disability pension, or to privileges, such as a pilot's license or a driver's license. In Fig. 6 we saw a straight, continuous regression line without break points. This means that we cannot use these or similar findings to define eligibility cut-offs. Different purposes require different cut-offs; 20/20 is commonly used for a pilot's license and 20/40 for a driver's license, 20/80 may be used for special educational assistance and 20/200 for tax benefits in the U.S.A., but in Europe the tax cut-off is often at 3/60 (20/400).

The Social Security Administration recently commissioned the National Research Council to prepare a report about disability determination for persons with visual impairments [23]. The 350-page report contains a wealth of information, but the final conclusion is that the setting of eligibility levels is a policy decision, not a scientific one. The same conclusion was reached in reports about the Salisbury Eye Evaluation (SEE) project [24].

We mentioned earlier the danger of using simplistic eligibility cut-offs for children with Cognitive Visual Impairments (CVI). This increasingly important group of children have special needs, yet may fall between the cracks if only visual acuity-based cut-offs are used [25].

Voluminous studies have failed to find a strong correlation between vision and traffic accidents. Many have wondered why this is, since the importance of visual input for driving is so obvious. The reason is that “driving safely” is not an isolated skill in the functional vision column of Fig. 1, but a form of social “participation”, that requires many skills, both visual and non-visual [26] [27]. The current debate over cell phone use and driving safety underscores that divided attention is an important source of accidents. Attention, however, is far more difficult to measure than visual acuity.

Another important factor in driving requirements is the establishment of a safety factor. A bridge designed for 5-ton vehicles is not supposed to fail at 5.5 tons. Similarly, a driver who reaches the 20/40 criterion in the DMV office is still supposed to be a safe driver after dark, in rain or in fog. A population study of older adults has shown that seniors may still have 20/20 acuity on a high-contrast test, but may drop to 20/200 under low-contrast and low-light conditions [28]. Is the 20/20 requirement for a pilot’s license based on higher visual demands for pilots, or on the desire for a greater safety margin?

Ranges of Visual Acuity Loss

So far we have shown that Visual Functions *(how the eye functions)* and Functional Vision *(how the person functions)* are closely related, but that there are also significant differences. We saw that visual functions are usually measured in a clinical environment where a single function can be measured in a controlled, static environment. Functional vision, on the other hand, usually reflects the influence of many factors in a less controlled, dynamic environment. This means that while visual functions can often be measured in great detail, functional vision must be described in broader categories.

Population surveys, which are indispensable for proper health care planning, have a need to categorize people in different groups, since individuals with mild vision loss differ from those with profound vision loss. The different groups are apt to suffer from different conditions, have different needs for treatment, different rehabilitation needs and present different socio-economic burdens for themselves and for the community. Hopefully, we can find a framework that can accommodate both the detailed scales of visual functions and the broader categories of functional vision.

For the classification of visual functions (primarily visual acuity and visual field) the International Classification of Diseases (ICD) [29] of the World Health Organization (WHO) is the primary source. The 6th, 7th and 8th revisions (1948, 1958, 1968) of the ICD contained only the category “Blindness”, reflecting a black-and-white dichotomy between the (legally) “sighted” and the (legally) “blind”. In ICD-9 (1978) the category title was expanded to “Blindness and Low Vision” and additional (numbered) sub-categories were offered. In ICD-9-CM (the Clinical Modification of ICD-9 for use in the USA) [30], the ranges were labeled, extended to the range of normal vision and defined in terms of a logarithmic progression of visual acuity values (as later promoted by the ETDRS charts). These ranges, which recently were reaffirmed by the International Council of Ophthalmology [31], are shown in Fig. 7. The six ranges were drawn so that they would accommodate most of the then existing definitions of “Blindness” in a mathematically simple scheme. Each range covers four lines on a logarithmic chart. The 2003 WHO consultative meeting recommended that these ranges should be based on *binocular, presenting acuity* [16].

The last columns of Fig. 7 offer two linear scales for calculations and averaging. The first is a letter count score, anchored at 20/20 = 100; this score is convenient since it awards one point for every letter read correctly on an ETDRS-type chart with five letters on each line. The other, the logMAR scale, discussed earlier, is a scale of vision loss, since larger values represent poorer vision. Letter count scores are often used to record responses in studies; the logMAR scale is often used for tabulations and graphical presentation in scientific papers.

Fig. 7 – RANGES of VISUAL ACUITY LOSS in ICD-9, ICD-10 and in ICD-9-CM

Named Ranges of Vision Loss (ICO, 1978, 2002, ICD-9-CM, 1978)		Numbered Ranges (WHO, 1978 ICD-9, -10)		Visual Acuity				Linear scales	
				Decimal notation	U.S. notation	6 m notation	1 m notation	Letter count	Log MAR
(Near-)Normal Vision	Range of Normal Vision	(The ICD does not code normal conditions)		1.6	20/12	6/4	1/0.6	110	-0.2
				1.25	20/16	6/5	1/0.8	105	-0.1
				1.0	**20/20**	**6/6**	1/1	100	0
				0.8	20/25	6/7.5	1/1.2	95	0.1
	Mild Visual Impairment (near-normal vision)			0.63	20/32	6/10	1/1.6	90	0.2
				0.5	20/40	6/12	1/2	85	0.3
				0.4	20/50	6/15	1/2..5	80	0.4
				0.32	20/63	6/18	1/3.2	75	0.5
Low Vision	Moderate Visual Impairment	**Low Vision - WHO**	Group 1	0.25	20/80	6/24	1/4	70	0.6
				0.2	20/100	6/30	1/5	65	0.7
				0.16	20/125	6/36	1/6.3	60	0.8
				0.125	20/160	6/48	1/8	55	0.9
	(20/200) Severe Visual Impairment		(6/60) Group 2	**0.1**	**20/200**	**6/60**	1/10	**50**	**1.0**
				0.08	20/250		1/12.5	45	1.1
				0.063	20/300		1/16	40	1.2
				0.05	20/400	3/60	1/20	35	1.3
	Profound Visual Impairment	**Blindness - WHO**	Group 3	0.04	20/500		1/25	30	1.4
				0.032	20/600	2/60	1/32	25	1.5
				0.025	20/800		1/40	20	1.6
				0.02	20/1000		1/50	15	1.7
(Near-) Blindness	Near-Blindness		Group 4	less	less	1/60 or less	1/60 or less	10	1.8
								5	1.9
	Blindness		Group 5	0.0	NLP	NLP	NLP	0	2.0

Figure 7 – The broad categories of Functional Vision (left) fit well with the more detailed scale for Visual Function (right).

Ranges of Functional Vision Loss

For the classification of functional vision, there are no broadly accepted precedents as exist for visual acuity. Fig. 8 provides a general functional classification that can be applied to many fields, as may be demonstrated with examples from the field of mobility as well as for reading performance. In the top range, the person can function normally and has reserve capacity, reflecting the fact that most ADLs are performed at a supra-threshold level. In the next range, that reserve is lost, but normal tasks can still be performed. With further loss the person needs some aids, but can still function fairly well. As the loss proceeds beyond the mid-point of the scale, performance becomes compromised. With further loss performance becomes marginal and at the bottom level the function becomes impossible or nearly impossible.

Fig. 8 – GENERAL ABILITY RANGES applied to MOBILITY and READING

RANGE	**PERFORMANCE**	MOBILITY	READING	ABILITY SCORE
	Exceptional ability	*(Athlete)*	*(Speed reader)*	*> 100*
Normal	Has reserves	*Can walk and run*	*Normal distance, with reserve*	100 ± 10
Mild loss	Lost reserves	*Can walk (not run)*	*Normal distance, no reserve*	80 ± 10
Moderate Loss	Normal with aids	*Walks with cane*	*Large print / low-power magnifier*	60 ± 10
Severe Loss	Restricted with aids	*Moves with walker*	*Slow with magnifiers*	40 ± 10
Profound Loss	Marginal with aids	*Moves in wheelchair*	*Marginal even with magnification*	20 ± 10
Near-inability	Near-impossible	*Passive mobility*	*Talking books, Braille*	0 – 10
Total Inability	Impossible			0

Figure 8 – Ranges of functional ability can be defined that can be applied to a wide variety of tasks.

This set of ranges can conveniently be fitted with a set of verbal descriptors, as shown on the left, and with a numerical scale shown on the right (a 100-points scale to be comparable to the visual acuity scale or a 10-point scale if smaller numbers are preferred). Note that, unlike the letter-count scores for visual acuity, these numbers are descriptive labels and do not represent actual measurements. Also note that the upper end of the scale is not truncated at 100, but can be expanded to cover performance that exceeds the norm (*E.g. the person is an Olympic athlete or a speed reader)*.

The conceptual validity of these ranges is supported by the fact that they fit well with the numerical impairment ranges for a variety of organ systems in the AMA Guides [39], even though the various AMA ranges were designed by separate committees and without the benefit of uniform guidelines. Indeed, there is no way to directly compare diverse impairments (visual, hearing, cardiac, musculo-skeletal, etc.). Comparable impairment scales can only be constructed through comparison to a common scale for ability loss, whether that scale is implied or explicit. E.g. the fact that benefit rules commonly equate a visual acuity loss to 20/200 with a visual field loss to a 20° diameter cannot be based on a direct comparison, since the two conditions are qualitatively different; it can only be interpreted as meaning that the ability losses for the two conditions are considered to be equally severe.

Fig. 9 provides a more detailed comparison of the visual acuity ranges from Fig. 7 and the reading ability ranges from Fig. 8. To facilitate the comparison a column has been added that expresses each visual acuity level as the distance at which average newsprint (1M) can be read.

Fig. 9 – RANGES of VISUAL ACUITY compared to READING ABILITY

Ranges of Vision Loss	**Visual Acuity** (How the eye functions)			Statistical estimates of **Reading Ability** (Functional Vision – How the person functions)		
	Decimal notation	Letter count	Can read 1 M at:	Ability Ranges	Reading Ability	Comments
Range of Normal Vision	1.6	110	160 cm	Has reserves (100 ± 10)	Normal reading speed Normal reading distance *Reserve capacity for small print*	Since newsprint is generally read at around 40 cm, this range has an ample reserve.
	1.25	105	125 cm			
	1.0	**100**	**100 cm**			
	0.8	95	80 cm			
Minimal Impairment	0.63	90	63cm	Lost reserves (80 ± 10)	Normal reading speed Reduced reading distance *No reserve for small print*	Individuals in this range have lost their reserve, but have no or only minimal vision rehabilitation needs. *(Driver's license and other criteria usually fall within this range.)*
	0.5	85	50cm			
Mild Impairment	0.4	80	40cm			
	0.32	75	32cm			
Moderate Visual Impairment	0.25	70	25 cm	Normal with aids (60 ± 10)	Near-normal with appropriate reading aids *Low power magnifiers and large print books*	Reading at 25...12.5 cm requires strong reading glasses (4D to 8D) or moderate power magnifiers. *(In the U.S. students qualify for special education assistance.)*
	0.2	65	20 cm			
	0.16	60	16 cm			
	0.125	55	12.5cm			
Severe Visual Impairment	**0.1**	**50**	**10 cm**	Restricted with aids (40 ± 10)	Slower than normal with reading aids *High power magnifiers (restricted field)*	Reading at < 10 cm precludes binocular vision. The small field of strong magnifiers slows reading. Vision substitution skills may be an adjunct to enhancement aids.
	0.08	45	8 cm			
	0.063	40	6.3 cm			
	0.05	35	5 cm			
Profound Visual Impairment	0.04	30	4 cm	Marginal with aids (20 ± 10)	Visual reading is limited *Uses magnifiers for spot reading, but may prefer talking books for leisure*	Use of non-visual skills increases as rehabilitation needs shift gradually from vision enhancement aids to vision substitution aids.
	0.032	25	3.2 cm			
	0.025	20	2.5 cm			
	0.02	15	2 cm			
Near-Blindness	Less	10	Less	(Near-) impossible (0 – 10)	No visual reading *Must rely on talking books, Braille or other non-visual sources*	In this range individuals must rely primarily on vision substitution skills. Any residual vision becomes an adjunct to the use of blind skills.
		5				
Blindness	**0.0**	**0**				

Figure 9 – The visual acuity ranges from Fig. 7 fit well with the reading ability ranges from Fig. 8.

In the "normal range", the distance at which newsprint (1 M) can be read is 80 cm (32") or better; this leaves an ample reserve for small print. In the next range ("mild loss") the reading distance is gradually reduced to 30 cm (12"), still adequate for the newspaper, but the reserve for small print is gone. Reading at 30 cm requires a regular +3 D reading add. For some purposes, smaller categories may be desirable. In this case the "mild" range could be further sub-divided into "minimal loss" (20/30, 20/40) and "mild loss" (20/50, 20/60); this would accommodate the common driver's license requirement of 20/40 or better.

The next range ("moderate loss") starts at 25 cm (10"). Note that this is the common reference distance for magnifiers. It also is the usual starting point for the category of "Low Vision". In this range some help is needed; some will use large print, others will use low-power magnifiers or stronger reading glasses, often with base-in prism to maintain fusion.

As visual acuity drops to 20/200 or below ("severe loss"), the reading distance becomes 10 cm (4") or less. At this distance binocularity cannot be maintained, even with prisms. Stronger magnifiers are needed with a correspondingly narrower field of view and reduced reading speed. Reading endurance is often reduced as well. When the reading distance drops below 5 cm (2") ("profound loss") reading becomes marginal. When the reading distance drops even further, below 2 cm (1"), visual reading is virtually impossible ("near-blindness").

These tables show that it is possible to define ranges of visual function that correspond well to categories of functional vision. Note, again, that this correspondence refers to statistical averages. As indicated earlier, individual performance may be better or worse. Also note that the dividing lines between the ranges do not represent stepwise increases in ability. The dividing lines in the table may be compared to mileposts along a road. They are useful reference points; however, the landscape does not suddenly change when we pass a milepost; rather the landscape changes gradually in the area between the mileposts.

Use of Ranges vs. Use of a Dichotomy

The concept of "Ranges of Vision Loss" involves more than a re-definition of categories for statistical use. It recognizes that there is a continuous gray scale, rather than a black-and-white dichotomy between those who are sighted and those who are blind. Under the old definition, it has been said that "More people are blinded by definition than by any other cause". Telling a person that he/she IS legally blind tends to categorize that person and leads to the assumption that "nothing more can be done". Telling a person that he/she HAS a severe vision loss describes an attribute of that person and invites the question what can be done to alleviate the problem [32].

In 2002 these considerations led the International Council of Ophthalmology (ICO) and the International Federation of Ophthalmological Societies (IFOS) to issue the following recommendations [33] about the use of various terms:

- The term **"BLINDNESS" should be used** only for **Total** and **Near-total Vision loss,** i.e. for cases with little or no residual vision that require **mainly vision-substitution**

The term "blindness", therefore, should not be used for individuals who have significant residual vision. For them:

- The term **"LOW VISION"** should be used for cases that have residual vision and can benefit from **vision-enhancement**

For a categorization that includes both Low Vision and Blindness:

- The term **"VISION LOSS"** can be used as a subsumptive term for **all** conditions, at any level, ranging from **mild** to **moderate, severe, profound** and including **total** loss.

The above terms can be used for the visual function, as well as for the functional vision aspect.

The term “VISUAL IMPAIRMENT” can also be used for all ranges (from Low Vision = partial impairment, to Blindness = total impairment), but indicates that the classification is based on a visual function measurement (acuity, field, etc.) rather than on an assessment of functional vision (e.g. the ability to read newsprint).

Using this terminology we would no longer launch programs aimed only at *avoidable blindness*, but, more broadly, aimed at *avoidable vision loss*. We would no longer speak about macular degeneration as a leading cause of *blindness*, but, more truthfully, as a leading cause of *vision loss*. The WHO and IAPB have set an example by dropping the word blindness from their current worldwide campaign, naming it **Vision-2020 – the Right to Sight.** [34]

Ranges of interest

Not all observers see these ranges in the same perspective. Clinical ophthalmologists, who want to differentiate “normal” from “abnormal” eyes, deal mostly with the upper two ranges, where there generally is no need for optical aids, other than refractive correction. Detail in the lower ranges is not very important to them, since it does not contribute to the differential diagnosis. This explains why vague terms such as Count Fingers and Hand Motions have persisted so long.

Those involved with Services for the Blind have just the opposite perspective. Their work concentrates on the lower two ranges, where the emphasis is on vision substitution, i.e. on the use of senses other than vision. For them, differentiation in the upper ranges is irrelevant, since there is no need for their services. Indeed, the ICD does not even have codes for the upper ranges. Low Vision rehabilitation concentrates its attention on the middle two ranges, where vision enhancement aids predominate. The beauty of a geometric progression of visual acuity values is that the needs of all three groups can be met within a single framework.

The ranges of mild loss and of profound loss are transitional ranges, where the emphasis first shifts from no aids to vision enhancement aids and later from vision enhancement to vision substitution. The transitions are gradual; at any given point one task may require certain aids, while another does not. When the listed ranges are collapsed into broader ranges, as in normal vision / low vision / blindness, differences of opinion may exist about the assignment of these transitional ranges. Some may consider a glass half empty, that others consider half full. In ICD-9-CM “profound loss” is considered at the bottom of the “low vision” category; in ICD-9 and ICD-10 the same range is at the top of the “blindness” category (Fig. 7). Most population surveys start the low vision category at “moderate loss”, but a few include the lower part of the “mild loss” category (Fig. 8) [35].

Calculating a Functional Vision Estimate

The fact that similar point scales (Fig. 9) can be used for visual function measurement (e.g. visual acuity) and for assessment of functional vision (e.g. reading ability) raises the question whether this relation could be used to derive a statistical estimate of visual functioning from a measured visual function. Before addressing this question, let us consider whether and when such calculations would make sense.

To plan and prioritize rehabilitative interventions for a specific individual, one needs to know the specific abilities and the specific needs of that individual. If a person has made successful adaptations in regards to reading, one might choose to address mobility next. Such decisions cannot be made on the basis of visual function alone. One needs an *ability profile* to differentiate between various abilities [36].

There are other applications, however, where visual functions can be used as a substitute for functional vision assessments. One area is in population surveys. Here, averaging over a population group reduces the effect of individual differences and the average burden of vision loss may be estimated for each of the ranges discussed in the previous section.

Another area is that of worker's compensation. Here, compensation is sought for various degrees of vision loss. Since it is deemed undesirable to punish those who have made a good adaptation by giving them a lesser compensation than those who have made a poor adaptation, individual differences are ignored deliberately. Ophthalmology was one of the first areas where assessment scales for worker's compensation were developed. In the U.S.A. Snell developed a "visual efficiency scale" based on employability estimates in 1925 [37] [38]. The AMA's Guides to the Evaluation of Permanent Impairment (AMA Guides) [39] used this scale until 2000, when it was replaced with a new scale, the Functional Vision Score (FVS) [40], which incorporates many of the concepts discussed earlier.

The AMA calculations involve several steps, which are summarized in Fig. 10. First, visual acuity is measured for OD, OS and OU. To allow calculations, the visual acuity values are converted to a linear score, the Visual Acuity Score (VAS), which is the same as the letter count score shown in Fig. 7. One point is given for each letter read correctly on an ETDRS-type chart. Next, the three VAS values are combined to a single Functional Acuity Score (FAS) for the person to obtain a statistical estimate of the acuity-related visual abilities of the individual.

When combining the FAS values 60% of the weight is given to the binocular value and 20% to each of the monocular values. This reflects the fact that normal vision is binocular vision, where information from the two eyes results in a single visual percept. The contribution of the individual eyes is not ignored, since the combination of two normal eyes is worth more than one normal plus one blind eye, even if the binocular acuity remains equal to that of the better, remaining eye.

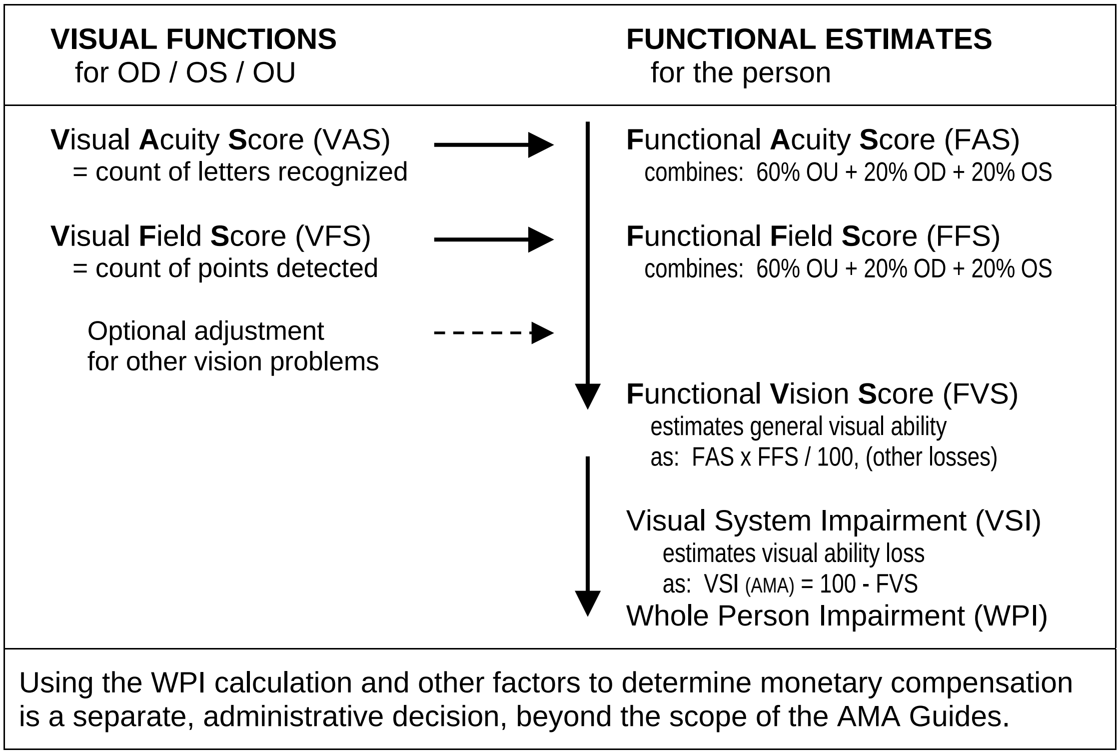
Similar calculations are made for visual fields, where one point is given for each point seen on a visual field grid. This results in a Visual Field Score (VFS) for each eye and a Functional Field Score (FFS) for the person. The grid is constructed so that the lower field receives 60% of the weight, the upper field 40%. The central 10-degree field (which is considered important for reading) and the peripheral field (which is considered important for mobility) receive 50 points each. This distribution conforms to the fact that the central 10 degrees correspond to 50% of the primary visual cortex; it also approximates values based on the logarithm of the field radius [10] and maintains the traditional equivalence between field loss to a 10° radius and acuity loss to 20/200.

The initial estimates are based on visual acuity and visual field, since these are the two most important visual functions and since formalized assessment methods are available. This does not mean that other vision problems are ignored. The AMA Guides allow for an individual adjustment if other, well-documented vision problems are present that are not reflected in the visual acuity or visual field loss.

The next step combines the Functional Acuity Score and the Functional Field Score to a single Functional Vision Score (FVS). This step makes no sense for the planning of individual vision rehabilitation, since the problems resulting from visual acuity loss are qualitatively different from those resulting from visual field loss. In the context of worker's compensation, however, it may make sense, since both losses are considered only from the point of view of their dollar compensation value. To make a comparison: one should not mix apples and oranges in a recipe for apple pie. However, if they are comparably priced, it may make sense to add apples to oranges in estimating one's grocery bill. It is important to recognize these different applications, so that the formulas are not used for situations in which they do not apply.

The AMA Guides contain two additional steps. The FVS is a positive score (0 = no ability, 100 = standard ability), whereas the AMA uses impairment ratings (0 = no loss = standard ability, 100 = total loss = no ability). The conversion is simple: the Visual System Impairment rating (VSI) = 100 – FVS. The "Whole Person Impairment" rating makes a further adjustment for severe and profound impairment to reflect the use of vision substitution skills; for a totally blind person (VSI = 100), the Whole Person Impairment (WPI) is set at 85%. A computer program to facilitate the calculations is reported in this issue [41].

Fig. 10 – FUNCTIONAL ESTIMATES in the AMA Guides



Using the WPI calculation and other factors to determine monetary compensation is a separate, administrative decision, beyond the scope of the AMA Guides.

Figure 10 – The diagram indicates how in the AMA Guides (5th edition) statistical Functional Vision estimates are derived from measured visual functions. The estimates are statistically valid, but cannot be used to predict individual performance.

Where Snell tried to make a direct estimate from visual acuity to employability in 1925, the current AMA Guides recognize a 2-step process. The Guides provide a number for Whole Person Impairment. To derive worker's compensation or other benefits from this number is a separate, administrative decision, which is outside the scope of the Guides.

Empirical validation

In the preceding section we have presented arguments for the conceptual validity of the Ranges of Vision Loss and for the AMA calculations, based on these ranges. Is there empirical validation also? Massof has pointed out that disability-rating scales were developed long before anyone addressed the problems of disability measurement. He points out that the current AMA rules have a conceptual foundation that was lacking in the previous ones, used from 1925 to 2000. The new rules also seem to be validated by two studies he performed, one for visual acuity (see Fig. 6) and one for visual fields (not shown) [10]. Additional validation studies are still desirable.

A recent study of 137 individuals – reported in this issue [42] - showed that the FVS correlated better than any of the other variables studied with self-assessed problems reported through the NEI-VFQ.

Summary

We have discussed the distinction between Visual Functions, which describe how the *eye* functions and Functional Vision, which describes how the *person* functions in vision-related tasks. This distinction is particularly important for vision rehabilitation, since visual functions define the input to the vision rehabilitation process, while improvement in functional vision is the desired outcome that needs to be measured.

We explored how this distinction affects different tests, in particular letter-chart acuity (the most common visual function test) and reading acuity (the most common functional vision test). We also explored how ranges of vision loss can be defined for population studies and how statistical ability estimates can be calculated, as in the revised AMA Guides. Such statistical estimates, however, cannot be used for individual predictions.

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