HINDSIGHT

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An early system for visual acuity chart letter sizes:

In the late 19th century and early 20th century various systems had been proposed and were being used for designating visual acuity and for the progression of letter sizes on visual acuity charts. Around the turn of the century a system proposed by Monoyer was in common use in France. In a 1906 paper the French ophthalmologist Armaignac criticized Monoyer's system and proposed a new one. The letter sizes suggested by Armaignac based on his empirical derivation method are remarkably close to the letter sizes on the Bailey-Lovie chart which is based on a logarithmic progression of minimum angle of resolution. A translation of Armaignac's 1906 paper follows. A short commentary on Armaignac and on his paper will appear in the May, 1998, issue of the *Journal of the American Optometric Association*.

TRANSLATION OF:

Armaignac H. De la nécessité d'adopter une échelle optométrique décimale universelle–présentation d'un type. Bulletins et Memoires de la Société Française d'Ophtalmologie 1906; 23:496-511.

Translated by David A. Goss, Indiana University, Bloomington, IN.
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On the Necessity of Adopting a Universal Optometric Decimal Scale– Presentation of a Model

by Dr. H. Armaignac (of Bordeaux)

For almost 200 years authors have been concerned with visual acuity and with the means of measuring it; some extremely remarkable studies have been done from the time of George Berkeley, in 1709, up to our own day, and it would take a whole volume in order to analyze only the works which have been published on this subject.

For a long time, in order to measure visual acuity one considered particularly minimum visible [visual acuity], and already in 1738 Robert Smith in his work *Compleat System of Optics* had found that an eye with good vision was able to distinguish a point subtending an arc of 40 seconds and of which the retinal image was about 3 microns wide. Later research of scientists has only confirmed this assertion.

However the theory of minimum visible [visual acuity] was not exclusive, even at the beginning of the last century; because in the very same work of Robert Smith one finds intercalated very important work of J. Jurin (Pergens, *Annales d'Oculistique*, March-April, 1906), in which it is a question, with numerous details, of minimum separable [visual acuity] to which Girard-Teulon was to return with as much knowledge as authority 100 years later and which was to serve as the basis of most optometric scales which have been published for more than forty years.

In 1752 and 1754 Thobias Mayer, in his two *works Nova methodus perficiendi instrumenta geometrica* and *Novum instrumentum goniometricum et Experimenta circa visus aciem*, cites numerous experiments which he had done on visual acuity and in accordance either with the principle of minimum visible or that of minimum separable. The author had also studied the influence of lighting and contrast on visual acuity and had arrived at conclusions that modern science has merely confirmed.

It would take too long to cite only the names of the renowned scientists who, in the second half of the 18th century and the first half of the 19th century, published important works on the study of vision; it is not within the parameters of my subject to undertake such a work, which moreover has been done with a great deal of erudition by Pergens in the March and April issues of the *Annales d'Oculistique*; I myself published in the *Revue clinique d'Oculistique* under the title: "Quelque mots sur l'acuité visuelle et les échelles optométriques," a rather long critical study in which I develop a part of the subject which I shall have the honor of discussing with you today.

I shall therefore speak only about optometric scales, and if, 26 years ago, I wrote in my aforementioned article the following lines: "Since the majority of optometric scales are sufficiently different from one another it would be desirable to do for optotypes what has been done for refraction and to ask an international congress, for example, to make up universal optotypes, without the name of the author, which it would be easy to make by selection, simply by using what is good and original in those which already exist. In this way, besides the advantage of using a fixed unit everywhere and always, as we do in refraction, we would be able to compare different tests. Each year we see new optotypes appearing and each oculist believes he is obliged to have his own scales, just as he has in his own ophthalmoscope"; today I find my former ideas truer and more appropriate than ever.

Permit me first of all a few words on the history of optometric scales.

The first truly serious [scales] seem to be the work of Henri Küchler and go back to 1835 or 1836. They were composed first of figures or figurines of animals, of customary objects, of farm instruments, etc., then of printed characters of ten different heights and perfectly graduated. Decimal scales were already invented! A few years later, in 1843, Küchler published his optometric scale formed of words of 12 different regularly increasing heights. The largest were 21 millimeters in height and the smallest 1.5 mm. Very likely these scales were made to serve only for near vision, because the author states that much larger characters are useless because the partially blind who are no longer able to read them are rarely cured; as for smaller characters, they are equally useless since those who can read them do not go to see an oculist.

In 1854, and almost at the same time, Stellwag von Carion, Smee, and Ed. de Jaeger constructed optometric tables but it is Snellen who receives the glory of having expressed measured visual acuity by numbers.

Based on the research of the astronomer Hooke and on his own personal experiments, Snellen found that in order to be seen distinctly, a square capital letter, black on a white background, must subtend an angle of 5 minutes, and since most letters are formed by three black lines separated by two

white spaces of the same width, either vertical or horizontal, it follows that each black or white line shaft subtends an angle of 1 minute and forms an image about 0.004 mm wide on the retina, that is to say, a little larger than that of a retinal element which is about 0.003 mm in diameter.

In successive editions Snellen modified and perfected his scales which, at first calculated in feet and inches, were finally established in meters and centimeters. These scales had, and rightly so, a great impact and were universally adopted. Then there arose from all directions, a number of imitations, that were more or less successful, more or less ingenious, some of which were undoubtedly not without merit, but they had the disadvantage of being too numerous; and the number has not ceased to increase each year.

In Snellen's scales, as in all the others, visual acuity was expressed by fractions, at times ordinary [fractions], in other instances part decimal and part ordinary [fractions].

This led to a bit of confusion and to too much diversity in the expression of visual acuity and necessitated certain calculations in order to establish a comparison between the fractions furnished by different scales.

It was then that Monoyer, in 1874, had the idea to eliminate this drawback and he constructed a decimal scale, on which each line, beginning with the smallest, indicated successively 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 tenths of normal visual acuity. this was a considerable improvement and the new scale was an immediate success, a success that has not diminished since in spite of its serious imperfections of which I shall have something to say presently and which were pointed out two years ago by our distinguished colleague Mr. Sulzer in the remarkable paper which he presented to us on *Acuité visuelle dans l'incapacité de travail.*

Monoyer's scale has been adopted by insurance companies for work accidents, by large railroad companies, by government schools, by military recruitment offices, etc., etc., all of which suggests sufficiently the importance that it has at the present time, and it is precisely on account of this importance that I come before you today to point out to you once again its imperfections and to appeal to your great authority to try to bring a remedy to it, as long as there is still time, by getting rid of these imperfections by adopting definitively the principle of decimal division of visual acuity, if not the principle of the physical construction of the scale.

Our colleague Mr. Sulzer had made a commendable effort two years ago, to have our Congress adopt a new scale which he had constructed and which certainly had great merit, but also the error, as far as many of use were concerned, of being too revolutionary by substituting gradations for the former degrees. A few months later at the instigation of our Society the question was asked again before the International Congress of Lucerne and there, again, after long and scholarly discussions they broke up without having adopted the world-wide international scale so long demanded by ophthalmologists. All they did was to name a commission to study the question anew.

What is the cause of this failure? It is perhaps the fact that many persons have made optometric scales. Each person has his touch of pride and agrees with difficulty to abandon that which he has invented, and that he thinks is good, in order to adopt the inventions of others. But, you will respond, you have also come, in turn, to bring us a new scale which you believe without doubt to be superior to those which already exist.

Be assured, I do not insist upon giving my name to a new scale; I restrict myself to pointing out to you the imperfections and defects of Monoyer's and to indicate to you a way to eliminate them by

presenting to you an actual tangible type which accomplishes all the desiderata, while asking at the same time for your approval and your criticisms.

What does one find wrong with Monoyer's scale? A single thing: the enormous difference which exists between the various steps, an insignificant difference between the letters which indicate 10/10, 9/10, and 8/10, and the considerable difference between those which indicate 1/10 and 2/10.

In constructing his scale Monoyer began by assuming, like Snellen and most modern authors, an angle of 1 minute for minimum separable and 5 minutes for an entire letter composed of five edges alternately black and white, which constitutes the unit of visual acuity. He used old-fashioned square capital letters which had these conditions, and since it was proven by calculation that the tangent of this angle of 5 minutes with [a test distance] of 5 meters had for a linear value 7.3 mm, he gave 7.3 mm (7.5 mm in round numbers) for the height to the letters which represent normal vision as a distance of 5 meters, and 73 mm, or ten times more, to the letters which have to be viewed at the same distance by an eye whose visual acuity is ten times weaker, that is to say, equal to 1/10 of normal conventional visual acuity.

Now he had found the two extremes of the scale; he still had to place the eight steps representing successively 2/10, 3/10, 4/10, 5/10, 6/10, 7/10, 8/10, 9/10. In order to calculate them, Monoyer simply divided 73 by 2, 3, 4, 5, 6, 7, 8, 9, and thereby obtained the eight intermediate gradations which then gave the complete series:

73/1:	1/10	=	73 millimeters
73/2:	2/10	=	36.5
73/3:	3/10	=	24.30 (25 in round numbers)
73/4:	4/10	=	18.25
73/5:	5/10	=	14.6 (15 in round numbers)
73/6:	6/10	=	12.11 (12 in round numbers)
73/7:	7/10	=	10.43 (10.50 in round numbers)
73/8:	8/10	=	9.12 (9.50 in round numbers)
73/9:	9/10	=	8.10 (8 in round numbers)
73/10:	10/10	=	7.30 (7.50 in round numbers)

As calculation and from a theoretical point of view, this is perfectly correct; but is it really the same from a practical point of view? One has only to glance at the scale in question to notice immediately the shocking irregularity of such a progression, which is neither arithmetic, nor geometric, nor regularly progressive: while the letter which represents 2/10 is two times smaller than that which represents 1/10 (inverse relation), that which represents 10/10 differs from that which represents 9/10 by only 1/16. It follows, as Mr. Sulzer has very clearly pointed out, and as I myself had the opportunity to observe thousands of times while examining railway agents, that it is not possible, in practice, to establish an appreciable difference between 10/10 acuity and 9/10 acuity. I might even add that sometimes with the difference in legibility between different letters, certain persons read the eighth line as badly as the ninth and tenth. Fortunately, as I had already pointed out 26 years ago in my aforementioned work, the maximum unit of visual acuity admitted first by Snellen, and then by Monoyer, is very notably below that which exists in reality among all persons who have very good visual acuity; these persons, in effect, are able to read easily letters 4.5 or 5 millimeters in height at a distance of 5 meters and with good lighting, that is to say, letters 1/3 smaller than those of the size which serves to indicate the maximum normal acuity. It follows that the unit chosen by these writers is not the maximum of human vision, but only good average vision. I am, moreover, totally in favor of that average unit chosen by most authors of optometric scales, probably with purpose; it is essential to keep it. All that

one could do, if need be, and I have acted in that way in my personal practice, would be to add to the decimal scale an eleventh line called optional or supplementary, which one would assign a value of 11/10.

I have said in the course of this paper that the optometric scale published in 1843 by Küchler was regularly progressive from the first line to the last and presented to the eye a harmoniously increasing series, whereas Monoyer's scale gives us considerable differences between the various steps. The latter were selected in an absolutely arbitrary way: much too close together for strong visual acuities, much too far apart for weak visual acuities. Monoyer's major error, in my opinion, was to apply to the determination of all the steps of his scale the very principle of determining visual acuity according to the subtended angle, although that appears, at first sight, paradoxical.

Indeed, it is indisputable that an eye which sees, at the same distance and with the same lighting, only a test object 2, 3, 4, 5 times larger, will have a visual acuity 2, 3, 4, 5 times weaker, but one must not believe for that reason that the difference between each of these fractions is the same; this difference decreases in an extremely rapid fashion as one moves away from the unit, as one moves away from the unit, as one can judge by reducing these fractions to the same denominator: 1/1; 1/2; 1/3; 1/4; 1/5 = 720/720; 360/720; 240/720; 180/720; 144/720; the difference between each of these fractions is successively 360/720; 120/720; 60/720; 36/720, or in decimal form: 0.50; 0.17; 0.08; 0.05, and if, as in Monoyer's scale each of these differences represents 1/10 visual acuity, one can see that these tenths have a curiously different value from one end of the scale to the other. Under these conditions it is evident that if one has to assess injury to vision caused by accident, as was the case in the report of our colleague Mr. Sulzer, the same number of tenths of reduction, with Monoyer's scale, will have a much different importance from the practical point of view, as the remaining visual acuity approaches one or the other ends of the scale. Thus, an eye which has lost, for example, 6/10, has undergone a loss of more than double the one that has lost 3/10; in effect, the difference of the first three steps is 0.04 of which the double is 0.08, whereas the difference between the first ten steps is 0.15, which is about two times more.

Since the mathematical principle of the measurement of visual acuity by subtended angle could not apply to the practical decimal division of the optometric scale, it was necessary to find another and, for that, one had only to return to the old-fashioned scale by Küchler or preferably to some of the more recent ones in which the authors tired to obtain a more or less regular gradation between the smallest and the largest letter in the scale. A certain number of them have been published, and some would even be excellent if each line, instead of being designated by an ordinary or decimal fraction, as a function of distance and with a variable denominator for each one of them, was simply numbered in tenths.

Having accepted an angle of 5 minutes as a maximum of average visual acuity, a square letter formed of three black elements or lines separated by two white elements of the same width has to have, as is known, 7.3 mm in height when it is placed at a distance of 5 meters. That is an excellent starting point, a unit that one could divide in any number of parts, but since the division into tenths is very convenient, perfectly adequate in practice, and has already been accepted for 32 years by ophthalmologists and a large number of administrations, it was entirely advisable to keep it.

In order to have 1/10 of this half one could take a letter ten times larger and one would then have the two ends of the scale; then the only problem would be to find the scale in which the differential value between the steps was, as much as possible, the same.

All those who have tried to determine these scale steps mathematically so as to make them agree with a practical and rational value, have gone astray. Not one progression whether arithmetic or

geometric gives a satisfying result, and I myself have for long months looked for the solution to the problem, without being more successful than my predecessors.

Based on the data which are used in printing for gradation of types, I had empirically constructed, judging by appearances, a series of 10 regularly increasing letters between 7.3 mm and 73 mm in height. Since this scale appeared to me to be very regularly graduated, I decided to measure precisely the height of each letter and to write these values in a series.

By studying these numbers carefully I finally realized that they form a regular progression of a very particular nature, the first term of which was 7.3, the last 73, and in which the ratio was formed by the common factor 1.46, having for successive coefficients the numbers 1, 3, 6, 10, 15, 21, 28, 36, 45; that is, that these coefficients themselves increase according to a regular arithmetic progression 1, 2, 3, 4, 5, 6, 7, 8, 9.

I obtained, by this means, the following series:

10/10	= 7.3	= 7.3
9/10	= 7.3 + 1 (1.46)	= 8.76
8/10	= 7.3 + 3 (1.46)	= 11.68
7/10	= 7.3 + 6 (1.46)	= 16.06
6/10	= 7.3 + 10 (1.46)	= 21.90
5/10	= 7.3 + 15 (1.46)	= 29.20
4/10	= 7.3 + 21 (1.46)	= 37.96
3/10	= 7.3 + 28 (1.46)	= 48.18
2/10	= 7.3 + 36 (1.46)	= 59.86
1/10	= 7.3 + 45 (1.46)	= 73.00

By slightly rounding off a few figures indicating the height of the letters from 7.3 mm to 73 millimeters one obtains the following values: 7.3; 9; 12; 16; 22; 29; 38; 48; 60; 73.

But I have already said that the test letter of 7.3 mm in height correlates with average visual acuity; in order to measure a greater acuity a smaller test letter is needed and I have adopted 7.3 reduced by a factor of 1.46 which gives 5.84, or in round numbers, 5.50, a few tenths of a millimeter more or less hardly affecting the legibility of letters intended to be seen from a distance of 5 meters, since the legibility of different letters of the alphabet of the same size and in the same lighting vary in rather great proportions.

The relation of 7.3 to 1.46 being 5, I was able to establish as follows the value of the visual angle corresponding to the different decimal fractions of visual acuity:

10/10	= 300″		= 5′
9/10	= 300″ + 60″	= 360″	= 6′
8/10	= 300″ + 180″	= 480″	= 8′
7/10	= 300″ + 360″	= 660″	= 11′
6/10	= 300″ + 600″	= 900″	= 15′
5/10	= 300″ + 900″	= 1200″	= 20′
4/10	= 300″ + 1260″	= 1560″	= 26′
3/10	= 300″ + 1680″	= 1980″	= 33′
2/10	= 300″ + 2160″	= 2460″	= 41′
1/10	= 300″ + 2700″	= 3000″	= 50′

and if I make the same calculation in order to have the optional 11/10, I obtain:

$$11/10 = 300'' - 60'' = 240'' = 4'$$

I feel that one should adopt for an optometric scale of letters large, square capital letters, similar to the letter E because they are formed, in general, of five parts or edges that are alternately black and white. It follows that the thickness of each horizontal or vertical edge subtends an arc of one minute, the average limit of minimum separable visual acuity.

Theoretically there might be interest in using only letters with the general form close to square and in eliminating the pointed letters A, V, Y, and those which have only vertical stroke, I and J, and some others like F, L, T, and U, but, in practice, this move except for the letters I and J is useless: first because the measurement of visual acuity is always, whatever one does, somewhat approximate, and secondly because of the fact that since letters can be confused, the difficulty of distinguishing one form the other without error remains the same.

The use of the scale of which I have just spoken assumes that the subject being examined at least knows the letters, but a great number of illiterates still exist in France, as in all other countries, and for these persons we have had to adopt in place of letters a sign that is easy to recognize and to designate. Among these signs, those which seemed to me to be the best are the round C, the U, and the E, which can be placed one after the other in such a way that the open portion appears successively on the right, on the left, up, and down. One can therefore simply tell the person being examined to indicate on each successive line the side of each sign on which the open part is found. If need be, for those who know the letters, one could measure their visual acuity by using successively two charts.

As for the alphabetical scale, I would like several models to be constructed, models which have the same dimensions, but which are formed from different letters, so that it would not be possible to memorize them, as could easily be done with a single scale that is easy to obtain.

Finally I realized, like many other authors, moreover, that letters had almost their maximum legibility when they were separated from one another by an interval at least equal to their own width and lighted by about 30 candlepower placed at a distance of one meter and shielded by an opaque screen from the view of the subject.

The interval which separates the different lines of the scale has to be equal to approximately two or three times the height of the letters for the first five or six rows starting with the smallest, and equal to a little less than one times that same height for the last four. A larger spacing presents no advantage and has the disadvantage of lengthening the size of the scale and of making it more difficult to light it uniformly.

As for the choice of letters for a universal international scale, one can easily understand that it must be subordinated to the necessities of each country since all the inhabitants who might be examined do not necessarily know the letters of the Latin alphabet. One should choose for each country the letters that are generally used in printed works; the main thing is that the proportion of the letters remain the same as in the standard scale. One could even, if one wanted, merely adopt as a universal scale, the scale signs about which I spoke a little while ago and which can be used in all parts of the world as well by those who know how to read as by those who do not.

Not only is it important to measure visual acuity but it is often indispensable to recognize and measure astigmatism which is sometimes an important factor in amblyopia after trauma to the eye. For

this determination one does not always have an ophthalmometer at one's disposal, but one can make up for it easily by simply using a clock face divided in the form of a star into 24 sectors of 15 degrees each. It follows that each hour after 12:00 corresponds to 30 degrees and each half-hour to 15 degrees. Since almost everyone knows how to read the hour on the clockdial or at least can distinguish the line or lines which appear blacker or more distinct than the others, it will suffice, in order to reveal astigmatism, that the subject being examined state that he sees on the clockdial certain lines which are blacker than the others.

The hours marked at the ends of the corresponding lines each represent 30 degrees; if one tries test spectacles in which the horizontal axis 0-180 has been arranged with 0 to the left, one will be able, almost automatically and instantly without previous calculation, to place in the spectacle the axis of the cylindrical lens with the direction corresponding to the astigmatism. For example, if the subject claims to see as blacker or more distinct the line of the clockdial corresponding to 4:30, it will be necessary to place the axis of the cylinder in the 135 meridian (4:30: $4 \times 30 + 15 = 135$ degrees); for 2:00 this would be 60 degrees; for 5:00, 150 degrees, etc.

I therefore believe that I should add to my plan for a universal scale a clockdial to be used for the determination and the easy and rapid measurement of astigmatism by Donders' method.

Kryptok:

A remarkable detailed account of the invention, development, promotion, and marketing of the KRYPTOK bifocal appears on pages 8 and 10 of the March 1998 issue of *Lab Talk*, vol. 26, no. 10, authored by Joe Bruneni under the title "KRYPTOK, The First Brand Name Lens." Included is a lot of information about the involvement of John L. Borsch, Sr.; John Borsch, Jr.; and Almer Coe.

Lack of documentary references suggests that the information derives from the author's personally accumulated files and his many years of participation in the optical industry.

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