Searching for the Normal Vision. Measuring Visual Acuity in the 19th Century

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Abstract. This article aims to reconstruct and analyse the late-19th century debates about the standards used for measuring eyesight. It deals in particular with the creation of eye charts, one of the main tools used to assess visual acuity. My argument is organized as follow: I start by providing an account of the historical background against which modern eye charts were developed; the best-known of them will be discussed together with their characteristics. Next, I analyse the debates among ophthalmologists of the time about the definition of "normal eye" and "normal vision", and show the divergence between the ones theoretically formulated and the data collected during clinical researches. Finally, I consider the question of sight measurement, looking on the one hand at the specialists' desire to standardize a framework for measuring visual acuity, and on the other at the many obstacles in the way of achieving that aim.

Key words: history of ophthalmology, visual acuity, history of the senses, 19th century social history of medicine

Introduction

Medical and scientific knowledge on the vision and the eye improved greatly during the 19th century. This period saw great progress in understanding the structure and functioning of the visual apparatus; instruments were invented (most notably the ophthalmoscope in 1851) making it possible to explore the human eye as never before. Considerable advances were made in the diagnosis and treatment of many eye conditions, so as in surgery. It was during this period, too, that ophthalmology organized itself as a fully-fledged medical specialty.

One of the primary issues which occupied the particular kind of physicians who began to be called "ophthalmologists" was defining the "normal eye" and the "normal vision". These were the subjects of far-reaching clinical and laboratory studies and an impressive number of publications. Discussion on these topics continued over many decades, and revealed a great number of problems relating to the scientific and practical issues involved in measuring sight.

The object of this article is to reconstruct and analyse the debates about the standards used to define the "normal eye" and the "normal eyesight" in the second half of the 19th century. We shall be concerned in particular with the creation of eye charts, one of the main tools used to measure visual acuity. Though more than 150 years have passed since the first modern eye charts were produced, they are still current in medical practice and are regularly used by ophthalmologists in their consultations (1). The study of these devices raises many questions about the establishment of visual standards: the objectivation and quantification of a subjective sense; the problems arising from the delicacy of such measurements; the tension between theoretical research into the criteria for defining an ocular or visual norm and the practical application of those criteria.

This essay is divided into three parts. First, I shall describe the historical setting in which modern eye charts were developed, and introduce the best-known ones and their characteristics; next I shall analyse the debates among ophthalmologists of the day about the defining the "normal eye" and the "normal vision", and show the divergence between the definitions formulated and the clinical research conducted; finally I consider the question of sight measurement, looking on the one hand at the specialists' desire to standardize a framework for measuring visual acuity, and on the other at the many obstacles in the way of achieving that aim.

The birth of ophthalmology and modern eye charts

Modern eye charts begin to appear during the second half of the 19th century, a turning-point in the understanding of the visual apparatus, as well as in the organisation of knowledge and in medical practice concerning sight. Initially we see a considerable improvement in understanding of the eye and its functioning. The ophthalmoscope, invented by the Prussian physician Hermann von Helmholtz (2, 3) in 1851, made it possible to observe the interior of the living eye. The ophthalmometer, also invented by Helmholtz (in 1855) and refined by the French ophthalmologist Emile Javal (4-7), enabled to observe and measured the changes in the cornea's curvature. These two inventions significantly advanced understanding of the anatomy and physiology of the visual apparatus: where formerly most knowledge about the eye was limited to its anatomy as observed in dissection, its physiology being poorly understood, now its refraction and its accommodation mechanism could be observed, measured and described with exactitude (8).

The use of these new instruments was fundamental to the study published in 1864 by the Dutchman Francis Cornelis Donders under the title *On the Anomalies of Accommodation and Refraction of the Eye* (9). In that seminal work, Donders gives the first comprehensive description of the physiology of the human eye, formulating the laws that govern the processes of refraction and accommodation (10, 11). He also gives a precise description of the formation of images on the retina and of the functions of the photoreceptors in the eye. Though works by Kepler (12) and Descartes (13) on physiological optics had already made a considerable contribution to understanding of the visual function, they had remained virtually unknown in medical circles. University-trained physicians accordingly had only a very limited understanding of ocular physiology. Donders' account on the other hand was rapidly incorporated in medical training and clinical practice, and quickly acquired reference status.

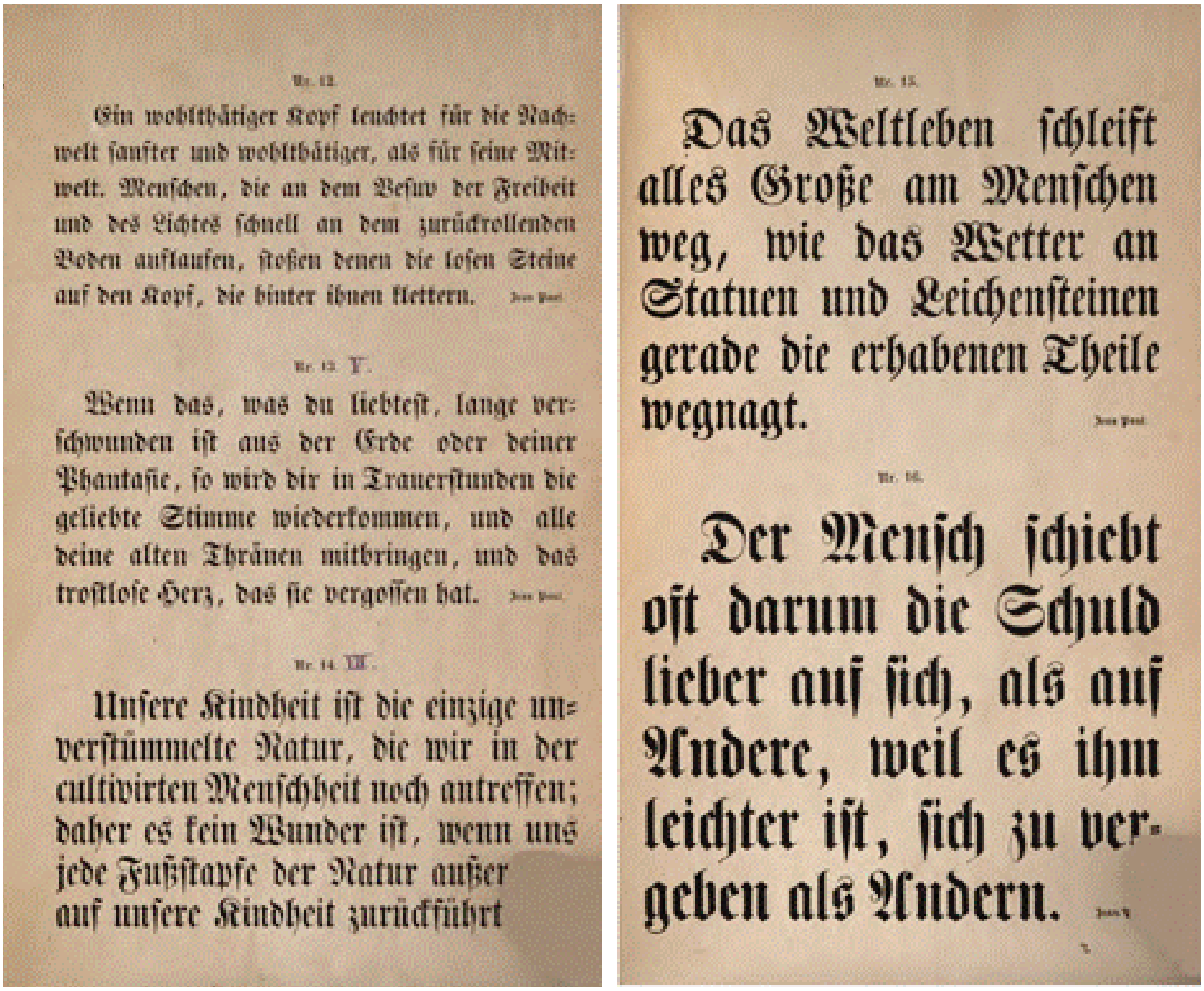
Notable advances were also made in the treatment of eye diseases, mainly those of the back of the eye (the retina, the macula) which could now for the first time be observed. Glaucoma and retinal disorders were accurately diagnosed with the ophthalmoscope. Eye surgery, too, improved, markedly as a result of experimentation with new operating techniques and the introduction of the asepsis (14).

The second half of the 19th century was also the moment where ophthalmology began to distinguish itself as a medical speciality in its own right (15, 16). This process can be traced from the start of the century, but from the 1850s onward it flowed more strongly and more widely. More and more specialized eye hospitals and clinics opened in Europe and the United States, and became centres of teaching and research; university chairs were created (15, 16) specialised reviews founded (Annales d'oculistique 1830, Archives d'ophtalmologie 1883 and the Transactions of the Ophthalmological Society of the United Kingdom, 1882. The American Journal of Ophthalmology was founded in 1862, and the German journals Archiv für Ophthalmologie and Klinische Monatsblätter für Augenheilkunde in 1854 and 1863 respectively), professional associations instituted and international congresses began to be regularly organised (The American Ophthalmological Society was founded in 1864; the Ophthalmological Society of the United Kingdom and the Société française d'Ophtalmologie in 1883).

One of the central issues of ophthalmological research was how to measure visual acuity exactly, for otherwise it would be impossible to determine the characteristics of the normal eye and normal vision. Systematic research began to be undertaken both in the laboratory and at clinics: hundreds of subjects had their sight tested with the aid of mechanical devices such as the ophthalmoscope and ophthalmometer. Eye charts were used as well, for subjective examination, and rapidly became indispensable: they proliferated during the second half of the 19th century in unprecedented numbers and diversity (17).

German physician Heinrich Küchler (1811-1873) is credited with inventing the first modern eye chart (18-21). In 1842, he created a chart for measuring distance vision; it consisted of words printed in Gothic characters in progressively bigger type, with 12 lines, the biggest at the top (Figure.1) (22). Küchler's chart was published only once, in 1843; it was not widely adopted, probably because it was difficult to use (17). Much more successful were the tests developed a decade later by the Viennese ophthalmologist Eduard Jäger (23-25), who in 1854 published charts containing many short reading extracts in German, French, and English, printed in increasing sizes (Figure. 2) (26). Jäger's tests became widely popular and were re-issued in many editions (17). Then in 1862 the Dutch ophthalmologist Herman Snellen (27-30) developed the chart which still bears his name, a chart of upper-case letters from the Latin alphabet in progressively smaller sizes (Figure. 3) (9). Its twelve lines are numbered, enabling visual acuity to be quantified and expressed in "twentieths". In 1875 a French physician, Ferdinand Monoyer (31-33), presented his charts for measuring distance vision, again using upper-case Roman letters (Figure. 4); they came in two scales, to be read at distances of 5 and 3 meters. Each scale had ten rows, and visual acuity was assessed in tenths. In 1888, the Swiss

Figure 1. Küchler's Eye Chart (1842)


Nr. 12.

Ein wohlthätiger Kopf leuchtet für die Nachwelt sanfter und wohlthätiger, als für seine Mitwelt. Menschen, die an dem Vesuv der Freiheit und des Lichtes schnell an dem zurückrollenden Boden auflaufen, stoßen denen die losen Steine auf den Kopf, die hinter ihnen klettern. Jean Paul.

Nr. 13. V.

Wenn das, was du liebtest, lange verschwunden ist aus der Erde oder deiner Phantasie, so wird dir in Trauerstunden die geliebte Stimme wiederkommen, und alle deine alten Thränen mitbringen, und das trostlose Herz, das sie vergossen hat. Jean Paul.

Nr. 14. VI.

Unsere Kindheit ist die einzige unverstümmelte Natur, die wir in der cultivirten Menschheit noch antreffen; daher es kein Wunder ist, wenn uns jede Fußstapfe der Natur außer auf unsere Kindheit zurückführt

Nr. 15.

Das Weltleben schleift alles Große am Menschen weg, wie das Wetter an Statuen und Leichensteinen gerade die erhabenen Theile wegnagt. Jean Paul.

Nr. 16.

Der Mensch schiebt oft darum die Schuld lieber auf sich, als auf Andere, weil es ihm leichter ist, sich zu vergeben als Andern.

Figure 2. Jäger's Vision Charts (1854)

ophthalmologist Edmond Landolt (34) invented a chart of geometrical figures which he called "broken rings" (Figure. 5). This chart shows a series of identically-shaped symbols whose orientation can be any of eight different directions. The diameter of each ring is five times its thickness, which is equal to the width of the gap. In the same year, the French ophthalmologist Henri Parinaud (35-37) presented his tests for close vision, a series of text extracts of decreasing size to be read at a distance of 33 cm (Figure. 6).

The history of sight testing goes back to antiquity. Visual acuity used to be measured with the aid of stars: in ancient Egypt the star Sirius in the constellation of *Canis Major* was used to test the sight of huntsmen; in the Middle Ages the Bedouin would use the ability to distinguish Mizar and Alcor, twin stars in the constellation of the Great Bear (38). Such methods were highly empirical, being designed to meet practical needs. The charts of the later 19th century were different in many ways. They were invented at a time when ophthalmology was becoming a fully-fledged science; the were designed by physicians, who developed them as scientific instruments which purpose was not only to measure human eyesight but to *quantify* it, and express it in the universal language of mathematics. They were the result of research and rigorous calculation, that took a great number of elements into account. The choice of the figures to be used (letters, figures, points

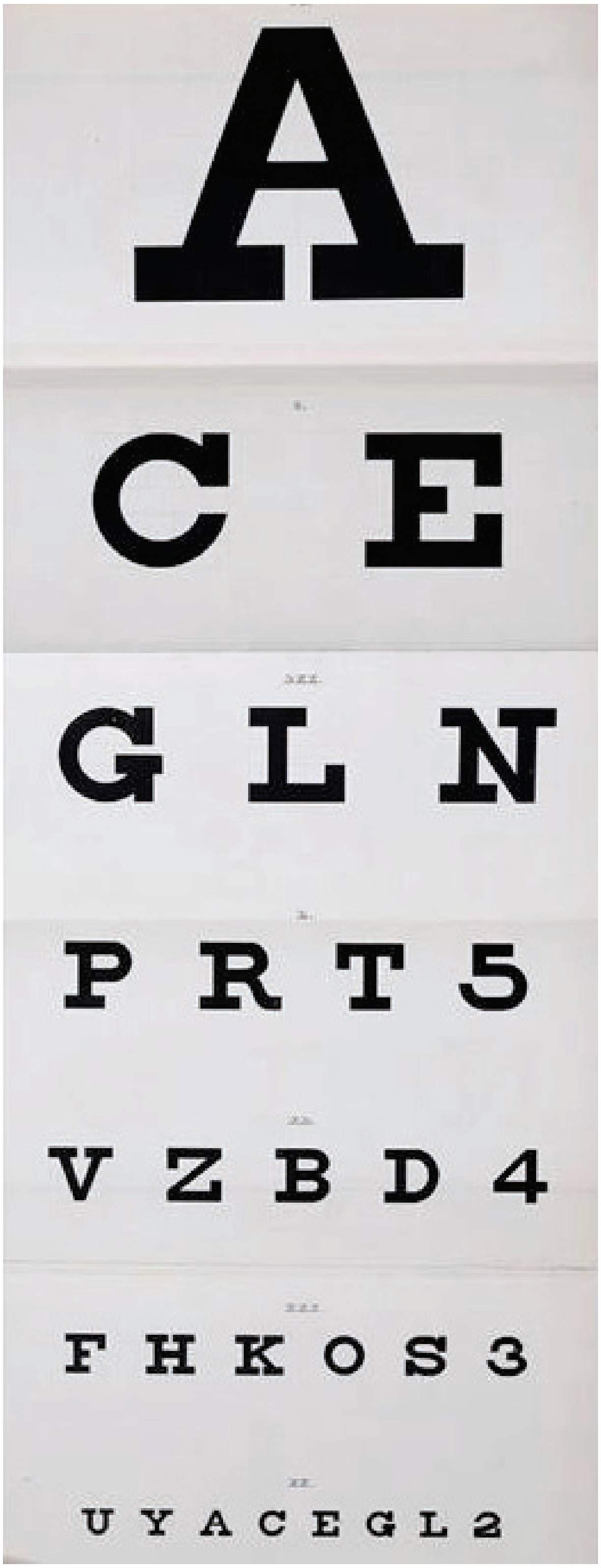


Figure 3. Snellen's Eye Chart (1862)

or geometrical patterns), their size and colour (7), their type of progression (algebraic or geometrical), the distance at which they should to be placed, the materials of which they had to be made of (paper, cardboard, or plastic), the amount of illumination needed to conduct the test as well as the quality of that illumination (daylight, gaslight, or electric light). All these elements were the subject of experimentation and thoroughgoing research, duly published in specialized professional journals. We can see ophthalmologists leaving nothing to chance in their quest for a scientific understanding of the human vision. Their aim in every case was to obtain impeccable and reliable instruments that would enable them to determine whether an individual's sight was normal or not.

"Normal" vision and "Normal" eye

Donders was amongst the first specialists to propose a definition of the "normal" eye". In On the Anomalies of Accommodation and Refraction of *the Eye*, he stated:

With regard to refraction, we call the structure of the eye normal when, in the state of rest, it brings the rays derived from infinitely distant objects to a focus exactly on the anterior surface of the layer of rods and bulbs; in other words, when parallel incident rays unite on that lay (9).

These are the conditions for having a good visual acuity vision. Donders' term for such an eye is "emmetropic" (from the Greek *emmetros* = "according to measure" and *ops* = "sight") (22). An eye failing to meet those criteria he calls "ametropic" (from the Greek *a+metros* = "without measure") (22). He also provided descriptions of the principal anomalies of refraction: *myopia* – which he initially called *brachymetria*, though afterwards he uses the commoner term (22) – and *presbyopia*. Myopia and presbyopia had been recognized since antiquity, but Donders was the first to define and describe them scientifically. His observations through the ophthalmoscope revealed two new types of anomaly: *hypermetropia* (the eye defect in which the image forms behind the retina), and *astigmatism* (the visual imperfection due to a defect in the curvature of the cornea). He also showed that, contrary to belief at the time, the opposite condition of myopia

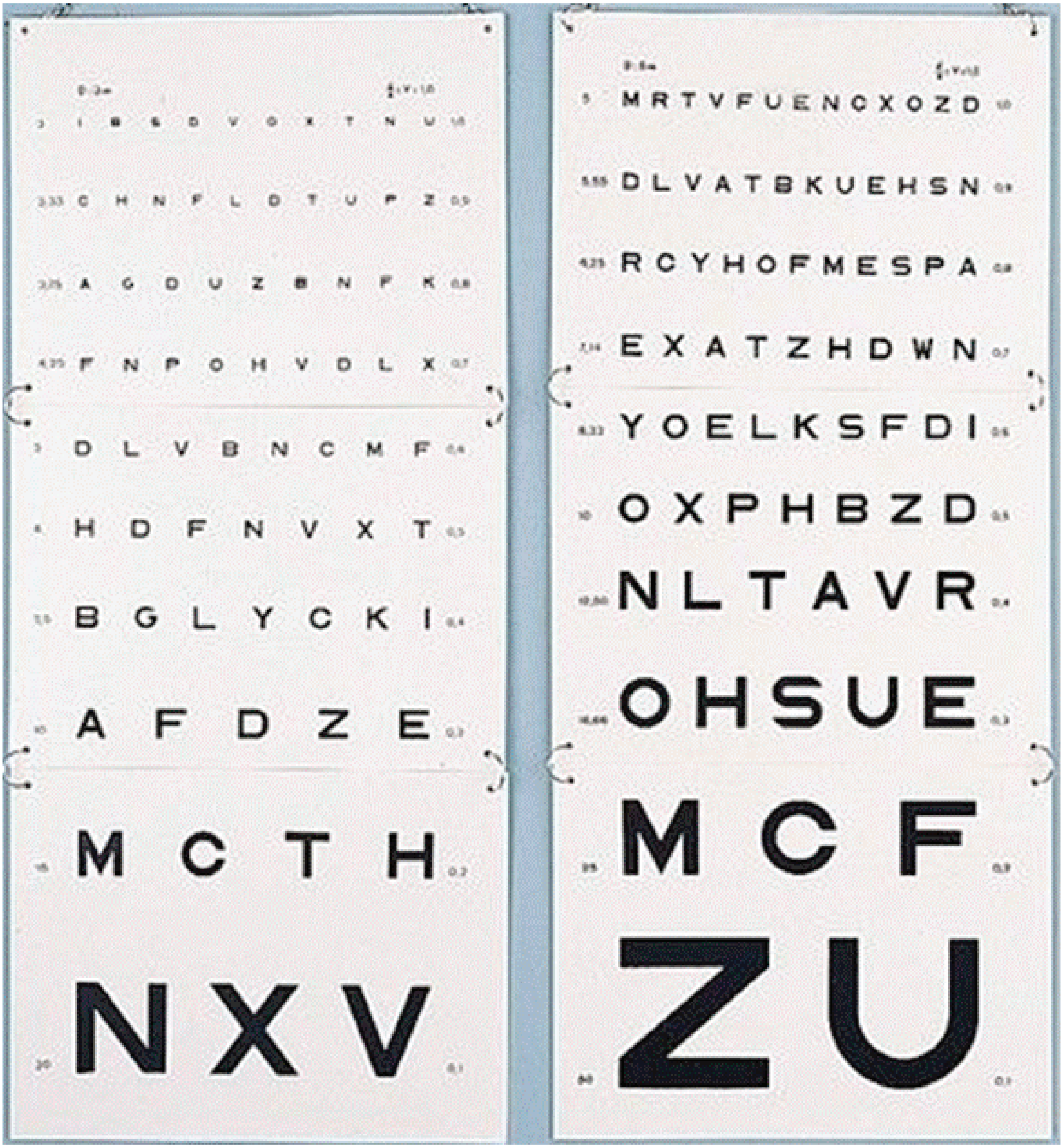


Figure 4. Monoyer's Charts (1875)

was hypermetropia, and not presbyopia, since the latter is an accommodative rather than a refractive anomaly (31). Doctors had formerly paid little attention to defects of refraction, and the commonest behaviour for a person having troubles seeing clearly was for centuries to visit a spectacle-seller, and choosing himself the glasses which he found did the most to improve his vision. Those conditions were now clearly seen by physicians as pathological, and in need of correction by means of optical lenses (glasses) or surgery (39, 40).

The definition of the "normal eye" proposed by Donders was very swiftly accepted in medical circles,

Figure 5. Landolt's Broken Rings (1888)

and almost immediately included in reference works. As early as 1865, we find it in Nysten's *Dictionnaire de medecine* (41); it appears then in the dictionaries of Jaccoud (1870), Littré & Robin (1873) and Littré & Gilbert (1908) (42, 43).

Having defined the emmetropic eye, Donders wanted to precise that such an eye was *normal* only so far as for what concerned refraction, not in any absolute sense, for it might be diseased or abnormal in other ways:

The [emmetropic] eye cannot be called a normal eye, for it may very easily be abnormal or morbid, and nevertheless it may be emmetropic. Neither is the expression normally constructed eye quite correct, for the structure of an emmetropic eye may in many respects be abnormal, an emmetropia may exist with difference of structure. Hence the word emmetropia appears alone to express with precision and accuracy the condition alluded to (9).

Nor was an emmetropic eye the same as an *average eye*. Its structure described in fact the optimal configuration of the eye's refractive apparatus, based on geometrical optics. Indeed, comparing this with the outcome of the clinical examinations of hundreds of individuals, Donders came to the conclusion that the emmetropic eye is <u>not</u> the commonest type in the population. He recognized hence that "In an absolutely mathematical sense no single eye is perhaps to be called emmetropic" (9), for in most cases the retina

Figure 6. Parinaud's Test For Near Vision (1888)

is positioned in front of or behind the point of convergence of the parallel rays from an object, meaning that most people are ametropic (9, 31).

Something similar occurred in the definition of "normal visual acuity". The first of such definition was proposed by Snellen (9), who in a paper published in 1863 defined the degree of visual acuity (S) (9) as the ratio of the distance at which a given object (d) subtends an angle of five minutes of arc (D), the angle of five minutes being that at which, according to his calculations, objects can be recognised as distinct by an emmetropic eye (27). Snellen defines visual acuity as the ability to distinguish objects of known size and shape at a certain distance. Normal visual acuity was the ability to read the bottom line of his chart (27). The eye chart accordingly became an essential instrument in its determination.

Normal visual acuity as defined by Snellen did not, however, correspond to average acuity. Clinical examinations showed, indeed, that young people's sight tended to be sharper than "normal", while among adults a below-normal acuity was much more common (46).

Ophthalmologists accordingly soon became aware of a discrepancy between their newly-established standard and "real-world" vision. And this was no mere detail, since their purpose in identifying the "normal eye" and "normal vision" was not just merely theoretical, but also practical. They aimed to define units of measurement, and a protocol that could be applied wherever individuals' sight needed assessing – in the army or navy, for instance, or on the railways, or in connection with occupational accident insurance (47). They therefore began to work towards measuring "average", "acceptable", or "satisfactory" eyesight (47), and to modify their charts, adapting them to the population groups where they have to be used, among whom there was sometimes had little or no education.

Measuring the eyesight

Ophthalmologists' debates about the measurement of visual acuity show that their ultimate ambition was to establish an exact science of human vision. Unlike philosophers, they were not interested in the "nature" of eyesight, in what eyesight was, but in its functioning, in how it came about. Their work aimed at making it objective by quantification. Accordingly, they developed a new vocabulary, with words such as "ophthalmometrology" (the science of measuring the anatomy and physiology of the eye), and "eidoptometry" (the scientific measurement of visual acuity, expressed in mathematical terms) (48).

This attitude is also connected with the ophthalmologists' quest for legitimacy. In nearly every country, in fact, they had to contend with resistance, and sometimes with open hostility, from the academic world of medicine, which was sceptical about "specialists". One factor strengthening such resistance was the historic prejudice against the "oculists", traditionally peripatetic surgeons with a dismal reputation – often outright quacks (15, 16). This explains why ophthalmologists were so keen to establish a body of knowledge that would satisfy the recognised criteria for a science, supported by objectively comparable statistical data (49).

Ophthalmologists' ambition encountered various difficulties. One set of problems arose from the debate about how to define visual acuity. Snellen's proposal was criticized by many of his colleagues, who regarded visual acuity not as the ability to *recognise an object by its shape*, but as the ability to *distinguish two neighbouring objects* as separate. They argued that recognizing the shape of an object (a letter of the alphabet, for example) was a *mental act* involving judgement, while counting a series of points was a proper *visual act* (50).

Another set of problems arose in connection with the very act of measuring vision. Such examinations were indeed complex. The usual procedure began with an "objective" examination at the ophthalmoscope, followed by a "subjective" test using the chart. The former could take many hours because of the adjustments required and the difficulties of wielding the ophthalmoscope. The eye-chart procedure, too, could last for hours. It often happened, therefore, that the results would change as the subject became tired during repeated measurements. The doctor's own sight, more or less acute, could also affect the results, as could the conditions in the environment where the examination was conducted (51).

Another factor that tended to frustrate ophthalmologists' ambition for exactitude was the ever-greater diversity of measuring instruments. More and more models of ophthalmoscope and ophthalmometer appeared as the years went by, and more and more types of eye-charts. The latter varied in their measurement units (feet, inches, meters), in the fractions used to express visual acuity (Snellen = 1/20; Monoyer = 1/10), and in the enormous variety of shapes and symbols – Latin alphabet's letters, numbers, points, squares, circles). This proliferation of devices was not always connected with scientific requirements but often with considerations of professional publicity or even commercial interest, for the sale of eye-charts was a lucrative business (25-27).

The matter was raised officially at the International Congress of Ophthalmology held in Lucerne in 1904, where a committee composed of some of the most eminent specialists of the day (52) was appointed to standardize the eye-charts used to measure visual acuity, and to establish an official international scale. That committee reported to the next congress (Naples, 2-7 April

1909), and presented a scale with two columns, one containing numerals and the other broken rings on the Landolt model. Though approved by a large majority, this scale did not prove sufficient to put an end to the debate. Articles expressing more or less serious reservations appeared in specialized journals within months (53). Ophthalmologists in general were sceptical as to the advisability of elevating this scale above those existing already (54). For eye-charts had in fact begun to be widely used well before the scientific community considered the establishment of a single standard. Often it were ophthalmologists themselves who championed the wider adoption of their own charts, and deployed what can only be called marketing strategies to that end. Jäger's charts are a textbook case: they appeared first as an appendix to his treatise Über *Staar Und Staaroperationen* (*On Cataracts and the Cataract Operation*) evidently intended for an international readership as it was published in the three main European languages (German, French, and English). They were in booklet form and printed on high-quality paper, making them convenient to handle and practical to use: this was an essential factor in their success. Jäger's second edition contained his tests in ten languages (26), and their popularity is evident from the ten official editions produced between 1854 and 1909, not to mention an unknown number of "pirate" versions (55).

Donders and Snellen followed a similar path, promoting Snellen's chart as the easiest to use and most precise in its results, and insistently claiming that only an examination of distance vision using his "optotypes" could provide meaningful data on visual acuity (55). Editions of the *Optotypi ad Visum Determinandum* in the Cyrillic, Greek, and Hebrew alphabets appeared from 1882 onwards. Snellen's charts rapidly became very popular: 32,000 reproductions had been sold by 1903.

It should also be noted that government-approved scales were used in many countries quite regardless of the approval or otherwise of professional ophthalmologists (56).

Conclusion

The invention of eye charts may be regarded as the starting point of a two-fold process, the standardization of the vision and its medicalization. This standard-setting was an expression of the desire of a body of specialists to grasp the subjective and mutable sense of sight in an objective way by applying the quantitative criteria that were the hallmark of the exact sciences. That effort was at odds with the much more variable results of clinical examinations, which revealed human vision as somewhat "rebellious" to this sort of objectivization, and with the practical requirements of measuring visual acuity, which compelled ophthalmologists to give up their ambitions of exactitude.

The establishment of standards for vision is a perfect instance of the way 19th-century science tackled and "tamed" the senses, determined to gain knowledge by disciplining them, preserving them, improving their performance and so rendering them fit to meet the needs of modernity (57).

This applies especially to sight, the master-sense in the ocular-centric world that was coming into being during the 19th century. Thus the primacy of the eye associated with modernity (58) proceeded alongside the methodical investigation of the organs of sight and the birth of ophthalmology. In the space of some twenty years this new branch of medicine put together an impressive body of knowledge, and established its own techniques of investigation and measurement as well as a protocol for diagnosis and treatment, at the same time organizing itself institutionally. However, despite their arsenal of knowledge, instruments, and supporting institutions, ophthalmologists were obliged to recognize the "imperfections" of human nature and to accommodate the needs of vocations other than medical science. To this day, there is no international standard for measuring visual acuity (59), and the persistence of debate on this question shows that although sight has long been medicalized, tension remains between human-established standards and human nature.

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