RR-74-14

TECHNOLOGICAL PROSTHETICS FOR THE PARTIALLY SIGHTED: A FEASIBILITY STUDY

John Page

September 1974

PREFACE

This preface is intended as a cover note to the report of a feasibility study on the application of technological prosthetics for the partially sighted. This study was carried out in the formative stages of the IIASA Bio-Medical Programme. It surveys the need for a quantitative analytical approach to the social problem of rehabilitation policy posed by the existence of partially sighted populations. These groups are large in number but have not achieved salience and hence remain submerged and invisible within the whole population.

The community, in developed countries, is both aware of its blind population and makes social provision for its care, but is not in general actively aware of its severely visually impaired. The latter group represents a population at least five times larger than that of the totally blind, and is handicapped both economically and socially.

A primary question addressed by the feasibility study was the extent to which further research in this general field of social systems analysis would be appropriate within the IIASA programme. In conjunction with this consideration was the further question whether the analysis proposed would be immediately useful, with prospect of near-term impact, to national Ministries of Health and to other agencies responsible for rehabilitation. Our preliminary answer, as spelled out in detail in the report attached, is affirmative to both of these questions Rehabilitation is an area of concern in all developed countries, and to achieve adequate policy response, an analysis of the type described would be necessary. Moreover, the full study proposed demands a broad cross-section of systems analytic techniques. In several areas of the full study it will be noted that the systems methodology itself must be strengthened to deal with the problems.

Specific areas of systems inquiry should include the following:

(i) <u>Definition and measurement of the problem.</u> The report shows that we need a more broadly applicable index of partial sight, based on the functional capability of the individuals in question. The attempt should be made to reduce the multiple attributes of sight to a vector measure of minimal dimension This is a problem frequently faced in contemporary systems analysis as societal standards are designed to capture with minimal complication as many aspects as possible of a problem situation. With better definition of the parameters of partial sight, the existing statistical data becomes more meaningful as an indicator of the size of population who would benefit from wide-spread availability of technological prosthetics. Because the existing census statistics are based upon a variety of standards and definitions, it may, however, be necessary to invoke synthetic statistical techniques to infer from these data the functionally defined populations at need.

(ii) Technology Assessment. This would involve the systematic prognosis of ongoing research and development having possible applications to visually impaired individuals. The assessment should draw upon existing systems methods for evaluating the potential of new technologies across a spectrum of possible user requirements. As methodology in this area is rudimentary, attention should be paid to the possibility of developing a prototype technique for evaluating multiple objective technology. Such a technique might be based upon aggregating technological value over a broad range of uses with special attention paid to the need for additional marginal research to tailor the general technology for specific purposes and to enhance the prospect for spin-off applications.

(iii) Interdisciplinary Linkage. The success of this study depends critically upon the coordination and combination of different scientific perspectives. An opthalmological input is required to understand and to describe the effects of eye malfunction in terms of remaining operational vision. This must however be extended by clinical input from optometrists and other specialists who are more closely concerned with the care and training of low-vision patients, in order to provide a functional description of the capabilities of their patients. The input from clinicians would be linked with that of technological experts in order to obtain better definition of design objectives, related logically to the functional requirements of the partially sighted. Different technological solutions may be necessary for different clinical conditions and different functional requirements. An input from such behavioural sciences as sociology would be vital in describing and measuring the social impact of partial sightedness. Finally, there are problems of organi sation requiring the assistance of management scientists. They would both outline the infrastructure necessary to support the wide-spread application of technological prosthetics and suggest an optimal set of uses for the recommended prosthetic. Social analytic procedures would also be necessary in the cost/benefit study.

The combination of these different disciplines will not be easy but should be more readily achieved at IIASA than elsewhere. The Institute itself is structured about a recognised need for harmonious inter-disciplinary work and its experience in coaxing close collaboration between scientists of different backgrounds is growing. The ophthalmological, clinical, and technical expertise required can be obtained through the literature and with limited consultancies. Sociological and managemental counsel would be obtained from the Large Organisations Project of IIASA while help in precise social analysis could be provided by the Methodology Project.

I. INTRODUCTION--AIMS OF THE STUDY

Technological Prosthetics as an Area for Systems Analysis

With the growth of technology, the increasing possibility of spin-off, or utilisation of a technology for purposes other than those for which it was developed, has become apparent. Moreover, once one new application has been made, it may suggest other developments which could be made in the new field of application.

The bio-medical area is a growing field for the application of technologies such as miniaturised electronics. There are in fact a wide variety of technological prosthetics which are available for prescription by clinicians, ranging from heart pacemakers for certain coronary conditions and dialysis machines for acute kidney malfunctions, to improved artificial limbs. It was thought that a study of the process by which technological prosthetics are applied in the health care system would be an appropriate area for systems analysis. Specifically, a better understanding of the process from the initial concept, development of an actual device and its application to particular disabilities, through its evaluation and acceptance (both by clinicians and patients), to general application as a standard treatment, would give a basis for policy guidance. For this purpose it would be necessary to develop means of relating cost to social and individual benefits of particular prosthetics. For practical reasons, a generalised analysis would be difficult. However, a study of one field of application--not necessarily a single prosthetic device--might not only provide policy guidance in the health care area concerned, but could also indicate whether the methods used were of more general value.

Reasons for Study of Visual Impairment

Out of the many possible disability/prosthetic systems, the problem of severe visual impairment was selected as the prototype study area: blindness is a universal problem. A WHO study group points out that the "case for the elimination of unnecessary blindness is justified not only on humanitarian grounds but also by its social and economic consequences. In terms of economic loss, blindness is the most expensive of all causes of serious disablement." [1]

The WHO study group estimates that there are tens of millions of severely visually impaired persons in the world today. Moreover, the incidence of blindness and severe visual impairment is likely to rise in the future, both because of world population growth and because of extended life expectancy. Some types of blindness are preventable in the sense that they can be controlled by attacking the infections or diseases which cause them. Trachoma and onchocerciasis are diseases which result in several million cases of blindness or near blindness in the developing countries in tropical or subtropical regions. Xerophthalmia, while apparently not an infectious disease but rather a condition associated with severe malnutrition, could also be classed as a cause of blindness which could be eradicated by preventive medical and social measures.

There remain other major causes of blindness, however, for which no specific preventive measures can presently be applied; these affect the developed and developing regions alike. In some cases (e.g. cataract and retinal detachment), surgery may restore useful sight, but in others (glaucoma, retinal degeneration, diabetic retinopathy, and optic nerve atrophy), the conditions are largely irreversible. Prosthetics are therefore vitally important in these cases.

What is the magnitude of the problem? In discussion of the strategy for prevention and treatment of blindness, the WHO group considered that as much as two-thirds of the world's blindness is preventable, and twenty percent of it (that due to cataract) is curable. In Section III of this report, the available statistics on blindness and partial sight will be examined in detail, but it is sufficient here to note that there is a substantial hidden population not represented in national or international statistics of "blindness" and not part of the so-called "blindness system." To this population must also be added those who are blind by the current legal definitions but who have sufficient residual sight to benefit from prosthetics.

While the size of the problem and its economic and social consequences are adequate strategic reasons for selecting visual aids as the area for a prototype study, there are also tactical considerations. They centre on the selection of the subsystem of technological prosthetics for partially sighted persons rather than aids for totally blind persons.

1) A break-through in applying technology to rehabilitation of victims of severe visual impairment has occurred in recent years: closed-circuit television devices (CCTV). While fully developed from a technical point of view, they are not at present a routine prescription. There is thus a practical situation needing analysis, which has a policy content.
2) Sufficient numbers of CCTV aids are already in service to make it at least theoretically possible to evaluate performance in terms

of actual operational use, as distinct from laboratory or clinical results. The study could proceed on the basis of accessible data.

3) In addition to the development of CCTV aids, there are research and development in applying this type of technology to the wider population--the totally blind. A basis therefore exists for broadening the scope of the study if initial results are promising, and thus for studying these types of technological aids as a total system.
4) Initial inquiries showed that sufficient agencies and institutions were interested in the problem as a whole, and thought the study proposals relevant to it, to provide a possibility of success. In particular, they promised access to data and cooperation in other ways.

The Technological Perspective

Untill recently, the only aid available to enable persons with severe visual handicaps to read was Braille. But it required special and prolonged training to obtain reasonably fast reading speeds and was applicable only to materials published in Braille. Nevertheless, reading speeds of 70 to 125 words per minute can be achieved by the trained Braille reader. Another traditional mode of communication was the replacement of sight by hearing in, for example, the so-called "talking books." While there was several early attempts to use television techniques for image magnification, practical CCTV devices have only been available for the past few years; they are now in limited production in a number of countries. There have been attempts to replace sight electronically by use of the tactile or audio senses; a device of the first type, for conversion of printed matter into tactile impression of the letters themselves, has been successfully developed by Linvill et al. at Stanford University. The other handicap which blind or severely visually impaired individuals experience is restricted mobility, and for this purpose an ultrasonic torch is now commercially available. It transmits a pulsed ultrasonic beam with variable frequency, the echo signal being mixed with the transmitted signal and fed into earphones. With this device it is possible to estimate distance and structure of objects at a range of a few meters. Similar head-mounted ultrasonic pathfinders are under development. In the research stage are more elaborate devices which convey to the wearer a tactile impression of nearby objects. Finally, basic research on the direct electrical stimulation of the visual cortex is now in progress.

The Feasibility Study

While the initial indications were promising, it was felt necessary to look at some of the problems in greater detail to assess the practicability of meeting the general objectives stated above. In particular, it was necessary

a) to examine the degree to which existing statistics of blindness and partial sight could be related. This would not only to give a reasonably reliable figure of the total population likely to benefit from these aids, but would also provide a basis for quantitative estimation of the degree to which the need could be satisfactorily met by different types of prosthetics;
b) to survey briefly available clinical data to determine whether thresholds could be defined for the various types of aids, i. e. measurements related to remaining vision which might define the limits of usefulness of particular aids; and
c) to test the practicability of collecting data on actual operating effectiveness of systems currently in use.

Finally, on the organisational level it was advisable first to learn how health care and social security systems operate in support of the partially sighted and blind population. This paper presents the results of this feasibility analysis and discusses the data immediately available.

II. DEFINITION OF BLINDNESS AND PARTIAL SIGHT

To permit useful discussion of the available statistical information it is necessary first to look at the definitions of blindness and partial sight commonly in use. The first point to note is that objective definitions in terms of measurements are not universal and indeed may have only limited usefulness in practice. However, since the available statistics are often quoted in terms of measurements of visual acuity it is necessary to understand the various standards proposed.

Visual Acuity Measurements

These measurements are essentially a ratio based on the smallest symbol (e. g. a letter) an individual can identify on a standard chart. We compare, for example, a person with defective vision with one having perfect vision; if the latter can identify a symbol at a distance of x units and the person with imperfect vision can only identify it at y units of distance, then the visual acuity of the person with defective vision is $\frac{y}{x}$. In the published literature, various different numbers for the base value x are often quoted and this can cause some confusion, but generally the figures most often quoted for x are 10, 20, and 60. If very low acuities are being measured higher base figures are necessary one one therefore often encounters base figures in the hundreds. In this report, we will try to avoid confusion by reducing all such figures quoted to a decimal fraction, i.e. 0.1, 0.05, etc.

However, it is necessary to recognise the limitations of the measurements, and to emphasize in particular the inaccuracies which may occur in reducing measurements to a standard decimal notation. All visual acuity measurements are based on ability to read symbols (most usually letters in the case of adults, familiar outlines in the case of young children of pre-reading age), but different chart systems exist, and more important, the degree of contrast between ambient illumination and the charts themselves may not be optimum for a low-vision patient. In practice, there may be differences not only in actual visual performance (in terms of remaining useful functional vision) between subjects having the same reduced visual acuity--measurements made according to one chart and test distance system and another--but also in the measurements themselves. They may differ for a low vision patient depending on the measurement techniques used. Mehr, Frost, and Apple [2] stress this point in a survey of forty low-vision patients at the Western Blind Rehabilitation Center in Palo Alto, California (USA). They point out that two patients whose visual acuities according to their previous ophthalmic records were for example 1/200 and 2/200 respectively, were found on examination by the special low-vision techniques practised at the Center, to have much better visual acuities--10/40 and 10/60 respectively. While the differences may be extreme, this is not an isolated example: most other trial reports discussed in later sections of this report comment on the need for special procedures if the visual acuity of low-vision patients is to be accurately assessed.

Therefore, while for the sake of simplicity visual acuity measurements in this report have been reduced to decimal fractions, the reservation should be made that these fractions may not be comparable because of

a) the difficulty of relating one measurement system (type of chart and working distance) to another, and
b) the inherent weaknesses of the method of chart reading at standard distances and in ambient illumination for low-vision patients.

International and National Definitions of Blindness and Partial Sight

From a brief inspection of available data, it is clear that there is no universal system of recording "blindness" or "partial sight" in terms of measurements of visual acuity, however inexact such measurements may be as an index of useful vision. For several years, however, WHO has been increasingly concerned with the problems arising on an international scale in the collection of adequate statistics; the question of uniform definitions is of obvious importance in this regard. A 1966 WHO report [3] identified as many as sixty-five definitions of blindness, and in 1969, the Twenty-Second World Health Assembly adopted a resolution requesting the Director-General "to undertake a study on the information which is at present available on the extent and all the causes of preventable and curable blindness."*

The study was undertaken by means of a questionnaire submitted to governments. WHO published a report on its findings in March 1972 [4]. This report was submitted to the Twenty-Fifth World Health Assembly in May 1972, following which a new resolution** was adopted. In this, the Director-General was requested to obtain additional data on visual impairment and blindness, to promote further studies on the most efficient and economical means of preventing blindness, to assist Member States in educational programmes related to blindness .... Following this resolution, a study group was set up in late 1972. In its report, the Study Group recommended a new series of definitions of blindness and visual impairment. These are presented in Table I.

*WHO 1971 Handbook of resolutions and decisions of the WHA and the Executive Board, 11th ed. 87 (WHA 22.29).

**Off. Rec. WHO 1972, No. 201, Resolution WHA 25.55.

Table 1

Categories of Visual Impairment and Blindness[a]

Category of visual impairment[b]	Visual acuity (with both eyes, using the best possible correction) maximum less than	minimum equal to or better than
1	6/18 3/10 (0.3) 20/70	6/60 1/10 (0.1) 20/200
2	6/60 1/10 (0.1) 20/200	3/60 1/20 (0.05) 20/400
3	3/60 1/20 (0.05) 20/400	1/60 (Finger counting at 1 metre) 1/50 (0.02) 5/300 (20/1200)
4	1/60 (Finger counting at 1 metre) 1/50 (0.02) 5/300	Light perception
5	No light perception	
9	Undetermined or unspecified	

[a]If the extent of the visual field is to be considered also, patients with a field of less than 10° but more than 5° around central fixation should be placed in category 3 and patients with a field less than 5° around central fixation should be placed in category 4, even if the central acuity is not impaired.

[b]These categories are intended to correspond with the fourth digit of the numbering system used in the International Classification of Diseases. In this system, the digit 9 customarily signifies "unspecified".

The group further recommended that "while each country must define blindness in relation to its own social and economic conditions (preferably using the standard categories given in this report), there is need for an internationally accepted definition of blindness for the purposes of compiling international statistical data. The group recommended that this definition of blindness should include categories 3, 4, and 5." The above table was accepted as an amendment to the WHO international calssification of diseases and from the point of view of international classification (not yet apparently reflected in current national statistics) the threshold of blindness and partial sight would appear 0.05 but with adjustments for visual field impairment.

On the national level, the following brief notes summarise the position in two countries only, the U.S.A. and the U.K. While much more information will be necessary for the study proper, these notes may serve to indicate some of the problems which will be encountered in the analysis of the way in which the "blindness system" operates, or fails to operate, for the severely visually handicapped person.

A definition of blindness (and of partial sight, when such a definition exists), is on the national level not simply a research tool or a guide to compilers of health statistics; rather is it a social or legal instrument which determines how the community will deal with particular individuals with visual handicaps. Many countries have a legal definition of blindness based on visual acuity measurements in their social security legislation. For example, in the United States a person is considered "blind" if his best corrected visual acuity is no greater than 0.1 or if his visual acuity exceeds 0.1 but the diameter of the visual field does not exceed 20^{o} in any direction. There appears to be no similar administrative definition for partial sight. Other countries use legal definitions related to functional considerations, tied in some way to visual acuity measurements. For example, the United Kingdom defines a blind person as one* "so blind as to be unable to perform any work for which eye sight is essential." This, however, is associated with visual acuity measurements in three categories. A person is legally blind in the UK if his best corrected visual acuity is 1/20 (0.05) or below, but may be considered blind if the visual acuity lies between 0.1 and 0.05 with considerable restriction of the visual field. With a visual acuity better than 0.1 he may be regarded as legally blind if severe restriction of the visual field is also present. In the UK partial sight is defined as follows:

"1. There is no statutory definition in the National Assistance Act, 1948, of partial-sight, but the Ministry of Health has advised that a person who is not blind within the meaning of the Act of 1948, (see Appendix III) but who is, nevertheless, substantially and permanently handicapped by congenitally defective vision or in whose case illness or injury has caused defective vision of a substantial and permanently handicapping character is within the scope of the welfare services which the local authority are empowered to provide for blind persons--but this does not apply to other benefits specially enjoyed by the blind, e.g. pension at age 40, additional assistance grant.

2. The following criteria should be used as a general guide when determining whether a person falls within the scope of the welfare provisions for the partially-sighted, as well as in recommending, where the person is under 16 years of age, the appropriate type of school for the particular child concerned:—
   - (i) for registration purposes and the provision of welfare services the following persons may be regarded as partially-sighted — those with visual acuity:
     - (a) 3/60 to 6/60 with full field;
     - (b) up to 6/24 with moderate contraction of the field, opacities in media, or aphakia;

---

*Definitions as given in UK Ministry of Health circular 4/55, published 2 March 1955.

(c) 6/18 or even better if there is a gross field defect, e.g. hemianopia, or there is marked contraction of the field as in pigmentary degeneration, glaucoma etc.

(ii) for children whose visual acuity will have a bearing on the appropriate methods of education –

(a) severe visual disabilities--to be educated in Special Schools by methods involving vision – 3/60 to 6/24 with glasses;

(b) visual impairment--to be educated at ordinary schools by special consideration—better than 6/24 with glasses.

NOTES

(a) Infants and young children with congenital anomalies unless obviously blind should be classed as partially-sighted and referred for hospital supervision and care until aged 4 and then be reviewed.

(b) At age 4 and over--binocular corrected vision should be the criterion.

(c) All in (ii) (a) and (b) above should be re-examined every 12 months–or earlier if there is reason to suspect any worsening.

(d) In making recommendations about persons under the age of sixteen, examining ophthalmologists should bear in mind that there are other factors (see paragraph 13 of the Circular) which may influence local education authorities in their decision about the special educational treatment to be provided."

Functional Definitions of Blindness

The imperfections inherent in visual acuity measurements as a measure of blindness and partial sight, whether or not they are associated with qualifying statements relative to field defects, have resulted in suggestions that more operational definitions should be used. For example, in arriving at the recommended international definition listed in Table 1 above, the WHO Director-General's report [4] stated that there was a further need for clarification in definitions. In that report, the questionnaire responses of many participating countries demonstrated the need for extending definitions outside the range of simple visual acuity or visual field measurements. The concepts of "economic and social blindness" were mentioned, and these concepts have been elaborated by other authors. The lack of clear definitions reflects the difficulty of dealing with that part of the population which has only partial sight and is therefore handicapped in earning a living or in social relations. For example, in Table 1 quoted above, categories 1 and 2 were described as partial impairment of vision and social blindness respectively. With category 3, true blindness begins--the term "virtual blindness" being used to describe those individuals in this category, and category 4, total blindness.

Several workers in the field have commented on the incomplete or unsatisfactory nature of definitions of blindness and partial sight related solely to visual acuity and visual field measurements. Genensky [5] , for example, concludes that, from the viewpoint of regulatory social security agencies, definitions based on the functional capabilities of the visually impaired population would be more logical. He has in fact proposed a series of four classifications as follows:

1) functionally blind or nonfunctionally sighted,
2) functionally sighted,
3) functionally sighted with aided mobility, and
4) functionally sighted with neither sighted literacy nor sighted illiteracy.

The classifications he gives are specifically related a) to the mobility of the individual and b) to his ability to read and write (hence the need to exclude illiteracy due to non -visual handicaps). A key concept in Genensky's functional classification scheme is an attempt to define a "visually impaired person"; this concept is important both from the general social considerations discussed above and in the limited context of this report. We are trying here to establish 1) what is meant by the words "the partially sighted population", 2) how large this population is, and 3) within what ranges technological prosthetics are particularly applicable. Genensky's revised definition states that a person is "visually impaired if the visual acuity in his better eye with corrective lenses does not exceed 20/70. or if the visual acuity in his better eye, with or without corrective leneses, does exceed 20/70, but his visual field is so restricted that he is unable to maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or a cane." [6] This revised definition includes a visual acuity measurement, but Genensky expresses misgivings about quoting a precise limit:

"... by doing so, there is always the chance that I may exclude from the ranks of the visually impaired, people who need one or more of the services that are provided or should be provided to the partially sighted." [6] While for the reason stated above, visual acuity measurements, unless qualified by a statement of precise functional limitations, are unsatisfactory as a general all-purpose definition, they could be used as an indication of the threshold below which the partially sighted population begins for the purpose of this study. It will be observed that 20/70 (0.285) very closely corresponds to the WHO category 1--partial impairment of vision (maximum visual acuity 0. 3). Further light on the subject is provided by Goldish [7] in a study concerned with the establishment of the U. S. market for visual aids and services. Goldish has commented extensively on the question of measurement standards for visual handicaps. From this different point of view he comes to virtually the same conclusion as Genensky: he points out that the types of aids and services depend on the extent to which visual function is impaired, rather than on visual acuity numbers. There are however indications that there is a rough correlation between visual functioning and ranges of visual acuity numbers. He suggests the following definitions:

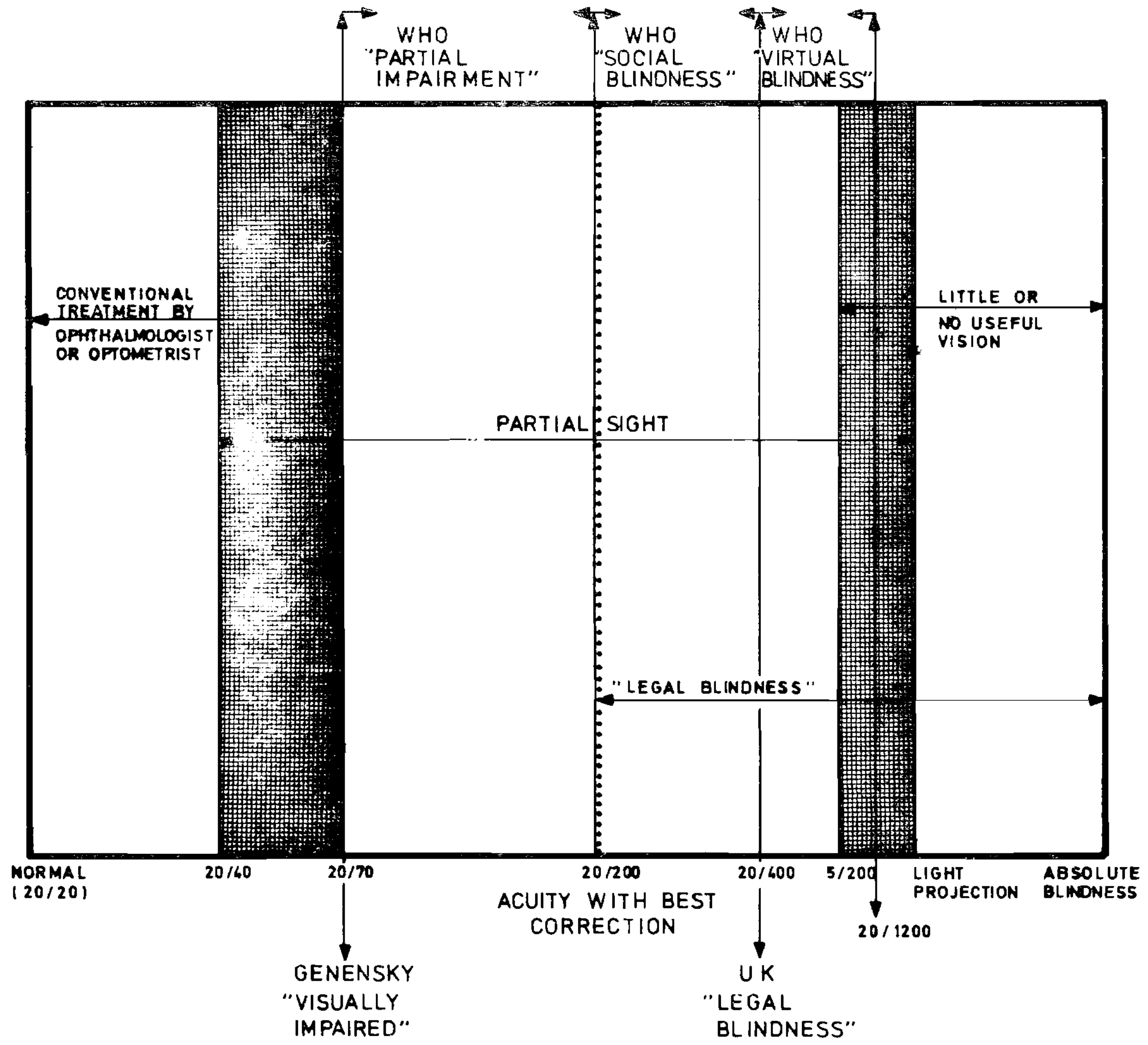
Visual malfunction--wearing of corrective lenses
Visual impairment--"trouble seeing," even with corrective lenses
Severe visual impairment--"legal blindness", "blindness" or "inability to read newsprint even with corrective lenses."

He suggests that the threshold between visual impairment and severe visual impairment correspond to visual acuities of about 0. 3 or 0. 2 and it is these figures with which he associates the severely visually impaired U. S. population. In another paper Goldish and Marx [8] indicate what they believe to be the boundary values for eye malfunctions. While the upper limits of visual impairment can lie anywhere between a visual acuity of 0. 5 and 0. 3, the part of the visually impaired population falling within these two limits can usually have their visual function restored to acceptable limits by conventional ophthalmological treatment. There exists a similar boundary area at the lower and of the scale, i. e. where severe visual impairment merges into functional blindness. These limits lie between 0. 025 and the point at which the individual is able to perceive light but has little or no useful vision. The US definition of legal blindness (at least as far as the visual acuity measurement is concerned) represents paractically a median point of partial sight (severe visual impairment) at a visual acuity figure of 0. 1.

In Table 2 the WHO standards are compared with the boundary conditions for partial sightedness and blindness suggested by Goldish and Marx with the tentative visual acuity threshold suggested by Genensky for visual impairment. The legal definition of blindness for the U. K. is also added.

It will be noted that there is some measure of agreement as to where partial sightness begins in terms of visual acuity, i. e. between 0. 3 and 0. 25. True blindness (in terms of useful vision remaining) must begin at the level defined by WHO as "virtual blindness," i. e. at a visual acuity of 0. 017, although Goldish would put this a little higher at 0. 025. This bandwidth, i. e. from 0. 3 to 0. 02, will be used to define the partially sighted population in this report.

TABLE II. THE APPROXIMATE BOUNDS OF PARTIAL SIGHT IN TERMS OF VISUAL ACUITY



Other Factors in Definition of Partial Sight

Although from a purely statistical point of view a definition of partial sight in terms of the bandwidth of visual acuity given is adequate for this study, there are further social consequences which must be employed as a qualification.

First, the omission of any reference to the remaining visual field could exclude a fraction of the partially sighted population whose central visual acuity is above 0. 3. It is for this reason that Genensky, in his functional classification scheme distinguishes between "functionally sighted" and "functionally sighted with aided mobility." Both classes are "visually impaired," but the first is able to "maneuver safely in an unfamiliar environment without the aid of a sighted person, a dog, or a cane," while the second is not able so to manoeuvre. Severe restriction of the visual field is in itself a specific handicap in movement.

The second consequence is concerned with the relation of legal definitions to operational or functional considerations. In the two countries for which data has been examined for this feasibility study, it seems apparent that the legal definitions of blindness do not relate solely to that part of the population which is truly blind--i. e. little or no useful vision--but neither do they include any particular fraction of the partially sighted. Yet many of the partially sighted are handicapped socially and economically, particularly in their reading ability: the threshold of reading newsprint for example is usually regarded as about 0. 4 in terms of visual acuity.

III. STATISTICAL DATA

Size if the Severely Visually Impaired Population

On the basis of questionnaire responses from the WHO member governments, the WHO Director General's 1972 report [4] to the Twenty-Fifth World Health Assembly estimated that there are ten to fifteen million "blind" people in the world. It is a difficult problem to establish with any degree of consistency what is meant by "blind" in the above context. For example, the USA statistics included in this computation gave a blind population of 385,000 which other sources show to be the number of legally blind persons registered in the USA in 1960. The WHO estimate is based on fragmentary and non-homogeneous data. But even assuming that all the reporting countries have a definition of "legal blindness" similar to that in the US, the total world population of partially sighted, i. e. those who are socially or economically blind in terms of the WHO recommended classification, must amount to at least three times this number, i. e. thirty million. Genensky [6] points out that an estimate of this kind, which is based on the ratio of partially sighted to legally blind in develcped countries such as the USA, must be an underestimate since it is reasonable to assume that the incidence of partial sightedness is significantly lower in developed countries. While it is impossible to quantify this difference, weight is lent to this supposition by comparison of the blind rates per 100,000 of population quoted by WHO [4]: whereas for developed countries the range is approximately from 50 to 200, the rate for developing countries can be as large as several thousand. For the purpose of this feasibility study, however, we can limit the analysis to the USA and the UK as examples of developed countries for which reliable statistics exist.

U. S. Statistics

In a report issued in 1971*, the US National Academy of Sciences considered that in 1970 there were approximately 420,000 legally blind persons out of a total population of 203.2 million in the USA. Similar figures have been quoted by other sources. At that date there were an additional 1.28 million Americans who were unable to read newspapers with best corrected vision, i. e. with visual acuities of less than 0.4. On the basis of these figures Genensky [6] concludes that by 1973 there would be 1.33 million individuals outside the qualification of "legal blindness."

---

* Rehabilitation Engineering - A Plan for Continued Progress (Committee on Prosthetics Research and Development of the National Academy of Sciences)

To these should be added approximately 436,000 legally blind, making an estimated total of 1,766 million partially sighted plus legally blind persons in 1973. Using figures based on the sample of partially sighted persons subjects in the RANDSIGHT CCTV research, Genensky also concludes that about 70% of legally blind persons are in fact partially sighted within his definitions. Thus, he concludes that the true population of partially sighted persons in the USA in 1973 amounted to 1.64 million. The upper threshold of this population corresponds to these with visual acuity measurements of between 0.1 and 0.3 illustrated in Figure 1. Goldish [7] concludes that approximately 6.4 million individuals met his definition of "visual impairment" in 1970 in the USA; of this total--using his threshold value of "severe visual impairment" of 0.3 to 0.2 visual acuity--about 1.7 million individuals should be classified as "severely visually impaired." There thus seems to be considerable agreement on what constitutes the partially sighted population of the USA who are not functionally blind but who are handicapped to the extent of not being able to read normal type. This is about 1.6 million, in contrast to a true functionally blind population of 130,000. It should be pointed out, however, that the legally blind population may itself be underestimated, resulting in a possible increase of the numbers of functionally blind persons noted above. At any event, the number of partially sighted persons compared with the total population of the USA in 1973, is not insignificant: 0.77% of the total.

UK Statistics

The United Kingdom Ministry of Health and Social Security compiles elaborate statistics and analyzes them in almost every conceivable breakdown of age, sex, and other parameters including some twenty major causative eye conditions. A report on the trends in these statistics for the years 1948 to 1962 has been published by the Ministry of Health following a study by Sorsby [9].

These statistics relate to the information published annually in the Register of the Blind and Partially Sighted. The compilation is based on forms completed by individuals wishing to be classified as registered blind or partially sighted. Forms are then referred to the Department of Health and Social Security by the ophthalmologist or general practitioner concerned with the case, or by the National Assistance Board social security) or other lay sources. Sorsby tabulates the statistics of these referral sources and shows that in the higher age groups the referral source is mainly non-medical organisations. He comments that this makes blindness statistics dependent on social rather than ophthalmological factors, and concludes that "... the number registered annually will continue to represent only a portion of a larger--and perhaps very much larger--number."

The partially sighted section of the register has been maintained since 1951. Since the mode of accession to this register is, however, the same as that for the Blind Register it would be reasonable to assume that the numbers recorded cannot, for the same reason, give an accurate picture of the incidence of partial sightedness in the UK. Moreover, there is a further substantial difficulty in interpreting the underestimation of the partially sighted in the register: while the registered blind persons obtain social security benefits (state retirement pensions at the age of forty and additional assistance grants, etc.), these benefits do not apply to the partially sighted population who are entitled only to welfare services which can be supplied by the local authority. Thus there is much less motivation to register than there is in the case of those coming within the blind definition. There is considerable agreement that under these conditions a large number of the partially sighted do not bother to register. If we take the figures for blind registrations in 1962 and partially sighted registrations in the same year from the report referenced, we obtain a figure of 96,500 + 26,100, i.e. a total of 122,600. The population of England and Wales as a whole for that year was 48.2 million: the total registered blind and partially sighted represent 0.254% of the population--the "registered blind" element representing 0.200% of the population and the registered partially sighted representing 0.054%.

These figures are clearly incompatible with the figures for the USA derived above. Firstly, the total proportion (0.254% of the population) is three times less than that of the USA. Secondly, while one would expect that the proportion of "registered blind" in the UK would be less than that in the USA (by reason of the lower visual acuity limits--0.05 as compared with 0.1--no field restrictions in either case), one would not expect the relative proportion of blind to partially sighted persons to be reversed in the two sets of statistics. It is always possible that the incidence of both blindness and partial sight is different in both countries. But the genetic and cultural differences are not, at first sight, so dissimilar as to give such totally incompatible results.

It has been suggested that the statistics for partial sight in England and Wales err by at least 50% owing to the lack of motivation to register. The Partially Sighted Society of the UK is studying the incidence of partial sight based on available information from local social services in the UK. It is reported that the trends emerging in this study indicate that the figure of a 50% underestimate in the National Register is itself an underestimate. Whatever the eventual results of this survey, there still remains a substantial unexplained difference between the UK and USA statistics.

A full study of the statistical data will be a necessary part of an eventual project, but the immediate need is for a cross-check of the statistics from the USA with other developed countries. This would at least allow a judgment as to whether the UK statistics could in any way be projected to give a more meaningful result in the terms of this study.

The Relation of Age to Severe Visual Impairment

Blindness and partial sight are, to some extent, age-dependent conditions. It appears that for the USA, over 60% of the severely visually impaired are aged 65 or over. A break-down of the partially sighted population by persentage in three age groups is given in Table 3.

Table 3

Age Groups of the Partially Sighted
USA, England, and Wales

Age Groups	USA	England and Wales
over 65	64%	63%
25 - 64	32%	23%
under 25	4%	14%

The US data are estimates by Goldish [7] ; no particular year is quoted. The figures are based on that part of the visually impaired population with visual acuities of 0. 1 or less with best correction. The England and Wales figures are from the Partially Sighted Register and refer to the year ending 31 March 1972. They follow the UK criteria for the partially sighted, i. e. visual acuity between 0. 05 to 0. 1 (greater with visual field restrictions).

It is impossible to estimate how the relative proportions of partially sighted persons in the three age groups chosen are affected by the general inaccuracy of the Register as a measure of the total partially sighted population in England and Wales. But the marked difference between the percentage of young people shown by the figures for England and Wales and the estimated percentage of the similar age group in the USA may be noted. However, the general point that well over half the partially sighted population is over retirement age is well illustrated by both sets of figures. So far as the England and Wales figures are concerned, the trend in new registrations during the year quoted showed a rather greater proportion of the elderly and a somewhat lower proportion of the remaining two age groups (only 7.3% of the new registrations were under 25, 17.3% being between 25 and 64, and 75.4% being over 65).

If these proportions are borne out by examination of the statistics from other countries, we could make an estimate of the number of individuals likely to benefit from

a) special educational facilities
b) assistance to maintain their earning capacity, and
c) purely social assistance.

Such statistics would be useful in a future cost-benefit analysis of technological aids for partially sighted persons because they would permit some division into economic benefit and social benefit groups. However, it would be unsound to break down the analysis into economic benefits for the younger age groups on the one hand, and social benefits for the older age groups on the other, since all age groups would presumably share the social benefits of increased scope of their activities. Nevertheless, the quantification of the economic benefits to those in the school age and the working age groups will be important.

Other statistical break-downs are possible, e.g. by sex and by eye defect, but these seem hardly relevant at this stage in the study. Of more importance for future examination is the degree to which severe visual impairment is related to ability to carry on normal activity, and to what extent other chronic conditions occur together with the conditions causing severe visual impairment. Some data exists on this latter point in the US statistics, but a detailed examination has been deferred since these issues are secondary to the objectives of the feasibility study.

Conclusions

The available statistics from the USA will permit reasonably accurate estimates of the partially sighted population which could benefit from technological aids of all types. The estimates from two sources are in close agreement. It is unfortunate that the extremely detailed statistics published by the UK in the Blind Register and the Partially Sighted Register are probably considerable underestimates (in the view of one author by over 50% in the partially sighted case). A study of the partially sighted population of the UK being carried out by the Partially Sighted Society may give useful pointers to the adjustment of the statistical tables based on the Register, but, for the moment, there seems little to be gained by attempting to extrapolate from the UK statistics.

It can be said, however, that the feasibility of collecting the type of data required for the study proper has been demonstrated. The immediate next step should be to confirm that the inferences drawn from the USA figures can be cross-checked by a study of the available statistics from other countries of similar cultural and genetic characteristics.

IV. PROSTHETICS FOR THE SEVERELY VISUALLY IMPAIRED

The Relevant Eye Conditions

Eye conditions resulting in severely defective vision are customarily divided into two general groups: anterior segment and posterior segment pathology. The first group essentially consists of defects of the refractive material (i. e. the lens of the eye), and the second group includes severe malfunctions of the retina or optic nerve. An example of this first type of condition is cataract; macular degeneration of the retina is one of the more common manifestations of posterior segment defect. In Krieger's clinical trial of patients' reaction to optical aids 222 patients (24%) had refractive material disorders as against 695 (76%) having retinal and optic nerve malfunction [10]. In a Genensky et al. trial of CCTV systems, 61 subjects (75%) were found to suffer from malfunctions of retina or optic nerve, one from defects of the refractive material alone, and 19 (23%) from both [11]. In both trials, the high proportion of macular degeneration in posterior segment defects was stressed: in the case of the Krieger series 306 subjects (33%) suffered from this condition, while in the Genensky CCTV trial a total of 26 (32%) had this type of condition.

It is inappropriate here to attempt to describe all the many eye conditions which comprise the pathology of severe visual impairment. It is sufficient to note that the most frequent malfunctioning of the refractive material (cataract) can often be corrected by surgery, while the retina and optic nerve malfunctions cannot be corrected (with the exception of retinal detachment). In practical terms, most of the retinal and optic nerve conditions result in a direct loss of vision which may be accompanied by visual field restrictions. Many such patients are not only unable to distinguish an object clearly, but, because of the destruction of the light sensitive issue of the retina (the so-called cones and rods), their perception of contrast is also below normal. The image on the retina is thus defective in outline, and unless the object is much more brightly illuminated than for a normally-sighted person, it is not bright enough to provide the visual centres of the brain with adequate information about the object.

A degree of anterior segment malfunction is common: almost half the population of developed countries such as the USA require spectacles to correct such conditions as myopia, etc. However, these conditions seldom result in impairment of vision so severe that they cannot be corrected by spectacles or contact lenses. Densities and irregularities of the refractive media, including cataracts, result in more serious vision loss, and patients suffering these conditions are in general to be included in the severely visually impaired population.

For treatment of the severe visual impairment by low vision aids, it is generally agreed that the actual pathological conditions are not criteria for the prescription or non-prescription of an aid. There seems to be no particular correlation between types of eye malfunction and the nature of the aid prescribed. The extent and location of damage is more important than the particular pathology causing it. However, different eye conditions are associated with different problems in prosthetic prescription. Individual patients may have conditions which, for example, prevent them from reading or writing without visual aids, while the main problem of other patients may be distance vision as it affects their mobility. In Krieger's sample, about 65% of patients gave as their greatest need improvement in close vision while around 25% required improved distant vision as first priority.

Optical Aids

Before the advent of CCTV systems, the majority of visual aids for the severely visually impaired were lens systems of one kind or another. Their characteristics have been described in detail by Sloan [12]. Krieger, in his clinical trial of 917 patients [10], listed, in addition to standard lenses, four general types of distance aids which he prescribed. They include monocular and binocular telescopes, multiple pinhole spectacles, and contact lenses.

Of these, the use of high power wide-angle telescope systems in the shape of conventional binoculars has been described in detail by Genensky [6]. He points out that this commercially available item can assist the severely visually impaired person to a surprising extent. He has described how the use of binoculars played an important, if not vital part, in his own ability to benefit from a normal high school education. He has a visual acuity of 0.0267 in one eye only, with severe field restriction. Not only do such binoculars provide the necessary magnification (5 x seems to be the average requirement), but their light-gathering power helps also to solve the contrast problem many partially sighted persons encounter in distinguishing, for example, street signs or traffic lights.

For near vision, Krieger lists nine aids preescribed for the subjects in his trial, from unifocal and bifocal high power spectacle lenses to stand magnifiers and multiple pinhole spectacles. The following observations may be made about optical aids for near vision:

1) None of the single or spectacle clip-on high power lens systems solve the problem of contrast required for reading in a normally lighted room: patients whose conditions require black/white contrast intensification cannot read with them without an addi-

tional powerful light source.

2) Some stand magnifiers have high-power light sources incorporated; these can be useful particularly if their mountings are arranged so that movements in all directions can be easily provided (e. g. for scanning a line of text).
3) Most clip-on lens systems have a critical focus such that the material to be read must be held at a precisely fixed distance from the eye; the remainder of the visual field is totally out of focus. This may cause fatigue.
4) For stand magnifiers or handheld supplementary magnifying lenses, the problem of distortion is an additional handicap if large magnifications are required. The lens must be large to permit easy location of a line of print (or a group of words), in its context but only the centre of the lens provides an undistorted image. Thus, rather precise and exact movements are required of the user of handheld or standmounted magnifiers in order to read with any degree of comfort and speed. The edge distortion phenomenon can cause fatigue. A Fresnel lens overcomes some of these difficulties.

While spectacle-mounted near vision aids and handheld magnifiers have the great advantage of portability, the critical focal length of the former, and the need for a relatively powerful external light source to solve the contrast problem encountered by many severely visually impaired persons, constitute a fundamental disadvantage. Nevertheless, a simple hand magnifier with built-in battery illumination is sometimes a vital aid outside the home or place of work, since it enables the individual to read previously prepared notes of telephone numbers, addresses, and other small items of important data. Stand magnifiers with built-in illumination, especially if equipped with a Fresnel lens (such as the Heidelberger Grossflaechenlupe [13]), are practical working aids for those whose magnification requirements do not exceed four to six times, but they are not easily portable.

Electronic and Electro-Optical Aids

While the idea of using electronic means to provide a magnified and contrast-enhanced image is not new, the current closed-circuit television (CCTV) systems which are commercially available for the visually handicapped have been developed as a result of the work of S. Genensky and the Randsight team at the Rand Corporation (USA).

CCTV uses a small television camera, mounted either vertically or horizontally, which views the object to be read (or the writing surface) either directly or (with horizontally mounted camera systems) by a mirror.

The signals generated by the camera are fed into a normal TV monitor screen, placed at a convenient height and distance for the viewer. The operator can select the most appropriate degree of magnification (up to 25x in the case of most systems) and can adjust the image for the desired degree of black/white contrast in the same manner as with a normal TV receiver. In some versions, changes in magnification are obtained by vertical movements of the camera (which may or may not have a supplementary lens system) but this may be most conveniently done, although at extra cost, by a normal zoom lens attached to the camera body. Since contrast reversal has been found to be valuable in a large proportion of the users, almost all commercially available CCTV systems provide for the image on the screen to be reversed at will electronically, i.e. black letters on a white background or white letters on a black background.

An important feature of the more recent designs is the XY platform on which the material to be viewed is mounted. It is a problem, when using a CCTV system at high magnification, to manoeuvre the reading material in such a manner as to scan a line of print without losing one's place. The so-called XY platform, which permits movement in the two horizontal directions with some degree of in-built friction, facilitates the smooth scanning of a document at even the highest magnification. A more detailed description of the features of CCTV devices is given in the Annex.

When compared with optical devices, several important advantages are claimed for CCTV aids:

a) CCTV is totally adjustable for any magnification and contrast condition required. Optical devices on the other hand are most usually of fixed magnification (therefore needing exact matching to an individual patient's requirements); an optical aid has no flexibility in the contrast available to the user.
b) Less training is required for the use of a CCTV aid than for the corresponding optical system. The user need only familiarize himself with the controls and acquire a moderate level of dexterity in hand movements to permit fast scanning of reading material with the XY platform.
c) Once he has found a satisfactory position for the components of the system, the user can read or write without having to maintain a particular fixed posture, thus eliminating fatigue, a very real problem with stand magnifiers and other aids.

The disadvantages of these systems are primarily their cost (about $1,500 at current production levels for the better type systems), their lack of portability, although at least two designs are intended to be hand-carried over short distances. Furthermore, they are not suited for distance viewing except in particular situations where the system can be set up beforehand (e.g. classrooms, offices). Several types have swivel cameras for viewing blackboards, wall charts, and other distant surfaces.

A further type of electronic aid may also be mentioned here since, although this is primarily for the blind or virtually blind, it is a development and extension of the CCTV principle. The device is known as the Optacon [14] and was developed by a team at Stanford University, headed by Professor Linvill. The name, Optacon, is an abbreviation of optical-to-tactile converter: this exactly describes the function of the device. A miniaturised television camera, no bigger than 8"x6"x2", is held in one hand and a line of print is scanned with it. The signals are fed into a tactile pad, resulting in an imprint of each letter or word being sensed on the user's other hand held in contact with the pad. The device was first commercially available in late 1971 and by the and of 1973, over 500 devices were in use in several countries. The device has been used by a surprisingly wide spectrum of professions including computer programmers. Considerable practice is required to gain satisfactory reading speeds (thirty to fifty words per minute). It is not necessarily a substitute for Braille or audio aids.

Other Aids

In a full study of technological aids for the partially sighted, it will be necessary to consider other non-technical possibilities. For example, large-print editions of certain books or texts had been published for several years by some institutions and social services, and, at least for a proportion of the partially sighted population, the value of such aids should not be forgotten. For this feasibility study, no attempt has been made to investigate fully the use of large-print books. Such books, however, are carried by many of the larger public libraries in the UK and are available as part of the services provided locally to the partially sighted. In the USA, as reported by Goldish and Marx [8], there was a boom in the production of large-print books during the middle sixties but the products were not well received, perhaps owing to their nature. They were oversized, heavy, photoenlarged versions of regular editions. Few copies were sold and the selection of titles was limited. The number of publishers of large-print books declined from thirty to two by 1973 and the authors quoted consider that sales are unlikely to exceed 100 volumes per title.

In a full study of that part of the partially sighted population which overlaps with the virtually blind, i.e. with visual acuities of 0.025 or lower, the use of Braille as a reading aid must be considered. Such a study would have to take into account the relative effectiveness of other methods, e.g. the Optacon or possibly CCTV, and the availability of

Braille texts and the training requirements. Extensive data on the use of Braille exist but no attempt has been made to cover this aspect of the subject in the present study.

V. THE EFFECTIVENESS OF LOW VISION AIDS

The purpose of this section of the report is to present some of the available evidence systematically linking improvement in visual performance with the use of low-vision aids. While improvement of a partially sighted person's mobility in unfamiliar surroundings is an important social objective, the main emphasis here is improvement of visual ability by restoring the individual's capacity to read and write.

The data presented are from trials, ranging from formal clinical trials reported in the ophthalmological literature, to studies of subjects' performance in using particular aids, to user reactions to aids in normal daily use. The ideal would be to have truly comparable information based on all possible types of aids under controlled conditions, i.e. matching clinical trials and rigorous analysis of aids in daily use so that measurements of performance could be correlated with type of eye condition, type of aid, and remaining visual acuity. No such comprehensive trial has yet been identified in this feasibility study. The immediate problem, therefore, is to bring together the results from very different types of trial and user assessment. In the following paragraphs, results of four different trials will be discussed.

Clinical Trials

Several major clinical trials of aids for the partially sighted have been undertaken in recent years. Unfortunately, none of these have included CCTV as an alternative since, until the last two to three years, these devices were not available on a wide scale as a normal part of the equipment of hospital ophthalmological departments. There are records of several major trials carried out in the late 50's and early 60's on optical aids for low vision patients, for example, one of 350 patients at Moorfields Hospital, London (Moffatt) (15), reporting a reading ability of 85% of subjects with the help of visual aids, and a second at the National Institute for the Blind and Partially Sighted at Copenhagen (Braendstrup and Skydsgaard) (16), in which 65% of 1,000 patients were able to read with visual aids.

The Krieger Trial

The most recent major clinical trial seems to have been that of Krieger (10) who analysed the results obtained from 917 patients between 1957 and 1966. Of the 917 patients, 575 were clinic and 342 were private cases. So far as can be determined, cost (either of treatment or of prosthetics) was not a factor. After examination and refraction, each patient was prescribed the visual aid which seemed most suited to his condition. Once an aid had been prescribed, clinic patients were given instructions in its use. When their aids had arrived, the patients paid a follow-up visit to the clinic and were invited to return in six months to check on the results obtained. The same procedure was adopted for private patients, except that for this group it was possible to give them fuller instruction and training in the use of their aid, and to establish a schedule for its initial use (e. g. ten minutes per day for the first week, increasing steadily during subsequent weeks). Krieger concludes that the differences in follow-up and training procedures contributed very largely to the difference in performance between the two groups.

Out of the total of 917 cases, visual aids were prescribed in 440 cases (223 clinic and 217 private). Thus, presumably it can be inferred that the initial positive response (in terms of an improvement in distant or near vision) was around 48%. The majority of those who were not prescribed aids had too low a residual visual acuity to achieve any worthwhile improvement in vision. But some either failed to complete the examination schedule or were not able to respond to training and rejected the prescribed aid.

The relation of this "initial success ratio," i. e. 48% of the total number of patients, with visual acuity is given in Table 4 below. It should be noted that the visual acuity measurements quoted relate to uncorrected distant vision acuity. They are not therefore strictly comparable to visual acuity thresholds for severe visual impairment discussed in earlier sections in this report.

Table 4

Uncorrected Distance Visual Acuity and Initial Success Rate

Visual Acuity	No. of Patients	No. of subject to whom aids were prescribed	Initial success rate in each group (in %)
Below 0.0025	66	6	9
0.0025 - 0.0125	106	43	41
0.015 - 0.025	298	153	51
0.0275 - 0.0375	171	82	48
0.040 - 0.05	176	88	50
0.0667 - 0.286	100	68	68
Total	917	440	48

In 1965, Krieger began a follow-up study of the 440 patients who appeared to have had initial success with visual aids. Patients were contacted by questionnaire, and a sample of 250 was established based on the first to reply, such that equal numbers of private and clinic patients occurred in the sample. Of the 250, 139 (or 55%) indicated they were "satisfied with their aids," i. e. they used them daily. This result is significant, but unfortunately it is impossible to draw precise inferences from Krieger's results without making unjustified assumptions about the nature of the 250 sample. It may be noted that his objective was not so much to produce success statistics as to show how far clinical procedures affected success. At one limit, we can assume that the 250 sample was totally representative of the 440 who had initial success; in this case, the sustained success rate over the 917 cases as a whole would be 55% of 48%, i. e. 26.3%. On the other hand, if we assume that all the "satisfied" patients were sufficiently motivated to respond to the follow-up approach immediately, thus becoming included in the 250 sample, the sustained success rate would only be 139/917, i. e. 14.8%. Obviously, neither assumption is true but something of the order of 20% might be a reasonable guess.

The differential breakdown of visual acuity measurements in the 250 patient sample and the 139 of them who said that the aid prescribed met their needs, is shown in Table 5.

Table 5

An Analysis of 250 Recall Patients, by Distant Vision

	Recall of 250 cases		Meets needs	
Distant vision	Number	Per cent	Number	Per cent
Light perception	0	.0	0	.0
Hand movement	0	.0	0	.0
Count fingers	0	.0	0	.0
0.0025 - 0.0125	19	7.6	3	2.2
0.015 - 0.025	68	27.2	39	28.0
0.0275 - 0.0375	53	21.2	31	22.3
0.04 - 0.05	67	26.8	37	26.6
0.0666 - 0.2857	43	17.2	29	20.9
Total	250	100.0	139	100.0

Krieger emphasizes the difference in percentage of private and clinic patients who come within the category of satisfaction of need: 64% of the private cases were thus satisfied as compared with 46.4% of the clinic patients. "Success" could be measured more precisely with the 82 patients (out of 250 in this sample) who returned for reexamination in the recall study. Three categories were established:

1) "successful"--the aid was used with relative ease almost daily for more than one hour
2) "fair"--almost daily use of the aid but for less than one hour and with some difficulty
3) "failure"--aids presented too many difficulty to be effective.

Of the 82,70% were regarded as successful, 12% as fair and 18% as failure. It is difficult to compare these percentages with the ratio of those whose questionnaire reply stated that "their aid met their need."

This brief summary of certain points which emerge in this very extensive trial leaves out of account major areas of the analysis performed. For example, Krieger compares the total 917 with the recall sample of 250 and the "satisfied" of 139 in terms of age groups, age of onset of eye condition, education, and pathology, contrasting in each case clinic and private patients. He also gives some interesting data in the relation of illumination requirements to the pathology. Krieger's conclusions embrace the whole range of treatment of partially sighted patients with many different types of optical aids. The following seem points particularly relevant for this study:

a) While the test and examination routines are relatively simple and require only fifteen to twenty minutes more than the time needed for an ordinary examination and refraction, success depends on careful training and instruction in the use of the aid prescribed. This factor was probably responsible for the significant difference in sustained success rate between the clinic and the private patient groups.
b) Population characteristics were not, on the whole, an indicator for successful treatment, although there was a tendency for the younger and more educated to respond better.
c) Visual acuity measurements or the type of ocular pathology are not in themselves determining factors for success. More important is the location and extent of the damage.

Trials Using CCTV Systems

Up to the present, the most detailed evaluation of patients' performance with CCTV aids is that reported by Genensky and his colleagues [11].

The Randsight Trial. From one point of view this trial can be considered as an evaluation of the prototype equipment known as RANDSIGHT I, equipped with an XY-platform (earlier Randsight developments had not included this important feature). However, the results include a wealth of clinical and performance data, and hence are valuable in linking such parameters as remaining visual acuity pathology with actual performance--a necessary datum point for this study.

A total of eighty-one subjects for whom data was available were included in the trial population: this was not a random sample since it was composed of individuals who, hearing in various ways of the Randsight development work, came to the Rand Laboratories in Santa Monica (or were brought by relatives) in the hope that they could be helped. The main criterion for a subject's inclusion in the test sample was that he not have had prior exposure to a CCTV system. After relevant case history data were recorded, the subject's best corrected visual acuity was measured and he was then shown how to operate the equipment. After about five minutes practice, the following measurements were made over a period of about 30 minutes:

a) Linear magnification of the print on the screen
b) Preferred reading distance
c) Reading speed.

After this point, the subject was encouraged to try to write using the apparatus and those who wished to do so, were rated in terms of the legibility of their handwriting, both to themselves and to others. Before summarising the results of the Randsight trial, it may be opportune to comment briefly on the representativeness of the sample. In terms of pathology, macular degeneration predominated--both with respect to the posterior segment conditions, and to the sample as a whole--to almost the same extent as in the Krieger sample. Table 6 shows that, in terms of age, Genensky's sample compares with the estimate of the breakdown of the U S. partially sighted population given by Goldfish [7].

Table 6

Comparison by Age Breakdown

Genensky		Goldish	
Over age 60	46%	Over age 65	64%
20 - 59	46%	25 - 64	32%
7 - 19	8%	up to age 24	4%

Genensky's sample is, as would be expected from the way in which it was assembled, biased in favour of the younger and middle-aged groups who will be presumably more motivated to seek amelioration of their disability than the group over age 65 whose eye conditions may be associated with the general onset of senility. Genensky himself comments that the circumstances of selection probably produced highly motivated subjects who additionally had sufficient means to pay the costs of transportation over (in some cases) long distances.

The results of the trial were expressed in terms of reading and writing ability grouped in three classifications: successful, moderate, and unsuccessful. For reading ability, these classifications were coded S, M, and U. The successful subjects were those who during the half-hour period of use of the apparatus achieved reading speeds of 31 or more words per minute. The moderate group included those who could read between two and 30 words, and the unsuccessful subjects were those who could not read more than two words per minute.

For writing ability, three groups were established, coded s, m, and u. Successful subject had legible, well-spaced writing. Those whose writing was badly spaced or not easily legible to others, were in the moderate group, and those who wrote poorly or not at all were considered unsuccessful. Forty-five of the 81 subjects rated an S for reading and 39 rated an s for writing; 67 rated either an S or M for reading and 56 rated an s or m for writing. These scores--based on the subjects' performance with the apparatus during the half hour period when measurements were taken--reflect only the lower portion of any learning curve which may be applicable. Genensky himself comments that a person whose reading rate is as low as 20 words per minute on first introduction to CCTV can expect to double his reading rate over time. He himself has a remaining visual acuity (in one eye only) of 0.0267--well below the mean of his sample--but can read at a rate of 125 words per minute. A detailed breakdown [11] of reading speed for the sample as a whole is given in Table 7.

In terms of visual acuity measurements, the subjects ranged from 0.4 to light preception. Forty-five of the subjects (over half) had acuities between 0.2 and 0.05; of the remainder, 5 had visual acuities in excess of 0.2, and 31 had less than 0.05. Thus, the experiment in fact covered all parts of the range of the partially sighted population; we do not know how the sample compares with the partially sighted population as a whole in terms of visual acuity. It is of some importance, however, to indicate the degree of initial success in ability to read as compared with visual acuity in the sample. Although Table 8 does not appear in the report by Genensky et al , it has been constructed from their data.

Table 7

Reading Rates Achieved by Subjects

Reading Rate (wpm)	No. of Subjects
0 to 2	14
3 to 10	1
11 to 20	6
21 to 30	6
(a)	9
31 to 39	13
40 to 49	4
50 to 59	8
60 to 69	6
70 to 79	5
80 to 89	1
90 to 99	3
100 to 109	1
110 to 119	2
120 to 190	2
Total	81

(a) The subjects represented in this line of the table rated an M for reading, but the exact rate at which they read could not be determined. It ranged between 3 and 30 wpm. This was due to one of several causes: the subjects were either too nervous to perform consistently, or they tired easily, or they showed marked signs of senility.

Table 8

Reading Ability Using CCTV

Visual Acuity	Number of Subjects (n)	S	% $\frac{S}{n}$	M	% $\frac{S + M}{n}$	U
0.4 - 0.2	5	4		-		-
0.2 - 0.1	20	17	84%	2	96%	1
0.1 - 0.06	9	6		3		-
0.07 - 0.05	16	7	52%	7	92%	1
0.05 - 0.04	8	5		2		1
	4	1	47%	2	74%	1
0.04 - 0.03	2	1		-		1
0.03 - 0.025	5	2		1		2
0.025 - 0.02	2	-		1		1
0.02 - 0.01	6	1	17%	3	58%	2
unassessable + light perception + finger counting	4	1		1		2
	81	45		22		12

Note:
For two subjects (children) reading results were not scored.

Table 8 indicates that while reading ability is not directly correlated to visual acuity, there is an approximate relationship between the two. In general, people with relatively high residual acuity scored better than those with little remaining residual visual acuity. In individual cases, many other factors affect a person's ability to read with the CCTV: the presence and location of scotomas, for example, are important. An examination of Genensky's data shows that 18 subjects had no scotomas and of these, 15 rated an S for reading, 2 an M, and 1 a U--a considerably higher success rate than the sample as a whole. Of the 53 subjects who had scotomas, 28 rated an S, 16 an M, and 9 a U. (The presence or absence of scotomas in the remaining 10 of the sample as a whole was not definitely determined.) A further factor in reading ability using CCTV was whether the subject, had, because of age or long existence of an inhibiting eye condition, "lost" the habit of reading.

It can be concluded that only within broad limits can visual acuity measurements be used as an indicator of the likely performance of subjects with CCTV. It is interesting also to analyse the characteristics of the unsuccessful reading group [12]. The results may be summarised as follows:

a) With two exceptions, all unsuccessful subjects were in the very low visual acuity range around 0.05 to 0.01 and light perception/ finger counting. Of the two exceptions, one had both cataracts and scotomas.
b) All but one had scotomas.
c) There seems to be no real difference in the ocular pathology of the unsuccessful subjects compared with the sample as a whole except that six out of the twelve unsuccessful subjects had cataracts.

There are limits to the useful inferences which may be drawn from numerical manipulation of the data. The following cases, if nothing else, establish that some individuals will perform unexpectedly:

Sex and Age	Visual Disorder	Best distance acuity in each eye: Right	Left	Reading rate in words per minute
male 73	diabetic retinopathy retinal circulation Bell's palsy scotomas	not assessable		60
male 18	cataracts (congenital) scotomas	LP*	0.015	37
male 82	glaucoma, cataracts scotomas	n.a.**	0.017	30
female 38	scarred retina	0.016	0.022	20

*Light Perception
**not assessable

One young man (21 years old) with a recent war injury and scotomas--visual acuity in one eye of 0.1 (unassessable in the other)--could read 35 words per minute at a working distance of one inch and a twelve times linear magnification.

The magnification requirements of the partially sighted population vary considerably. Table 9 shows the linear magnification choices of eighty-one subjects for reading and writing.

Table 9

Linear Magnification Required for Reading and Writing

Linear Magnification	Number of Subjects Reading	Writing
1x to 2 1/2 x	7	32
3x to 4 1/2 x	23	14
5x to 6 1/2 x	13	7
7x to 8 1/2 x	8	2
9x to 10 1/2 x	14	-
11x to 12 1/2 x	9	-
13x to 14 1/2 x	2	-
15x to 16 1/2 x	1	-
17x to 18 1/2 x	1	-
19x to 20 1/2 x	-	-
21x to 22 1/2 x	1	-
Unknown	2	26
Total	81	81

While a substantial number of subjects (47) require 1x to 6 1/2x magnification--within the range of most head-worn optical aids or stand magnifiers--the wide spread of the magnifications required (up to 22 1/2x) is an indication of the flexibility of CCTV in meeting the subject's needs. Genensky draws specific attention to the fact that, of those subjects who chose to take part in the writing test, nearly all of them required less magnification for writing than for reading.

The Heidelberg Tests. A further trial has been carried out by Blankenagel and Jaeger [17] to investigate the reaction of partially sighted patients to CCTV devices. The sample consisted of 45 patients who required magnifications of more than 8x--the authors consider that beyond 8x magnification purely optical aids are impractical. The requirement for magnification was based on preliminary tests using reading charts with large letters viewed at a distance of 25 cm with standard illumination. Blankenagel and Jaeger conclude that the ability to read such charts is a fairly reliable indicator of whether the patient will be able to benefit from a CCTV aid. The whole examination and test using CCTV took between one and a half and two hours per patient. Out of the 45, 31 were able to read relatively quickly and without fatigue, while three were able to read only with great difficulty, and eleven had no success. Noting that ten of the eleven failures had severe cataracts, the authors suggest that patients with posterior segment defects who also have cataracts, but who were not previously considered for cataracts surgery, could in fact benefit from such surgery since with the aid of CCTV their reading ability would be restored.

It is possible from the results of this trial to draw tentative conclusions on the types of eye condition for which CCTV is an effected prosthetic. Cases of macular degeneration predominated (as in the other trials discussed above) and for these, patients without refractory material defects were able to read relatively quickly and easily. The four persons with optic nerve atropy were all able to learn to read in a short time. Of the 12 cases of glaucoma, 8 were able to read although they learned slowly and had difficulties; the four failures were those whose condition was complicated by cataracts. The difficulties experienced by the glaucoma patients are worthy of note: some of them tended to skip lines or words and they all preferred negative contrast (i. e. white letters on black). This result suggests that such patients might have benefitted from the so-called "electronic window" with which some of the Genensky prototypes were equipped. This device blanks out the screen except for the line of print being read.

Comperative Trials Using CCTV and Optical Aids

The literature so far examined is, unfortunately, insufficient to enable a complete and definitive comparison of performance. Some of the earlier papers on this subject described results of using CCTV aids without an XY-platform which is essential if satisfactory results in terms of reading speed are to be obtained.

Mehr, Frost, and Apple have reported[2]on a series of tests (1973) on forty subjects in which modern types of CCTV systems were compared with low vision optical aids. The subjects were chosen from veterans undergoing rehabilitation training at the Western Blind Rehabilitation Center in Palo Alto, California. Also included in the test group were some who had applied to the Veterans Administration for the free loan of a CCTV system after hearing about the device from other sources. As part of the normal evaluation procedure of the Center, all subjects had a low vision examination; their vocational or recreational need to perform tasks such as reading and writing were also established. Based on this inquiries and examinations, the subjects were divided into two groups: those recommended for CCTV devices (28), and those not recommended (12).

The criteria for inclusion in the group recommended for CCTV were developed from the initial low vision examination and introduction to the CCTV apparatus. They included, although not rigorously, such requirements as the ability to operate the device easily, the need to write, and the ability to read small grint with the apparatus. In terms of reading speed and endurance, the criteria included the ability to read 30 words per minite (or if better than 30 words per minute, to read 50% faster than with a comparable optical aid) and a similar criterion for reading duration. Visual acuity measurements, using special low vision techniques, ranged from 0. 5 to 0. 014 with a mean of 0. 07. There was no significant difference in the mean visual acuity for the recommended and not recommended groups. All the subjects were legally blind males, with ages ranging from 22 to 76 (median age 44).

Apart from the initial introductory session, the trial subjects were followed up continuously during their stay at the Center or visited at home if they were not resident. The results obtained both with optical aids and CCTV are thus more applicable to the degree of success obtained after a considerable period of familiarisation and training than in the case of Genensky's subjects.

The published results stress differences between the recommended and not recommended group. It is perhaps important to note that in allocating subjects between groups, individuals were only included in the recommended group if their initial performance showed that cheaper, more portable optical aids were insufficient for their needs. All subjects in both groups showed:

a) increased reading speeds with CCTV as compared with optical aids (up to 64%),
b) ability to read smaller print sizes with CCTV than with optical aids,
c) ability to read longer with CCTV than with optical aids,
d) writing ability with CCTV, while only 25 were able to write with optical aids, and
e) use of magnifications higher with CCTV than with optical aids when these were prescribed.

The authors report that it was not possible to obtain meaningful results from an attempt to analyse performance in terms of ocular pathology. In any case, even if this analysis had been possible, the nature of the sample makes it be unlikely that the results could be generalised in terms of the partially sighted population as a whole. Apparently, no attempt was made to analyse the results in terms of visual acuity measurements But the mean values were 0. 06 and 0. 088 for the recommended and not-recommended groups respectively, indicating perhaps a slight, expected bias towards including the lower visual acuity patients in the CCTV group. In addition to the numerical material presented in the report, the authors also concluded that the choice between CCTV and optical aids must include a number of qualitative factors. These range from subjects' motivation and expressed needs to particular features of CCTV not possessed by optical aids--e.g. contrast reversal, contrast enhancement, increased depth of focus, ability to vary magnification, use of higher magnification without distortion. The authors point out that as a writing aid, CCTV proves considerably better than alternative optical aids. Thus, for low vision subjects for whom the ability to write continuously is important, this is a particularly important indicator for its prescription.

CCTV Systems in an Operational Environment

The preceding paragraphs summarized certain CCTV trial results. Most of these trials were carried out under semi-clinical conditions. The questions now to be asked are 1) how far are these results substantiated in actual use of the systems, and 2) what effect do they have on the earning capacity and general life style of the partially sighted persons using them? No formal follow-up trials reports have been encountered in the literature, but Blankenagel and Jaeger [18] have surveyed in a general fashion the long term results achieved by a group of 41 patients of the Universitaetsaugenklinik Heidelberg who had used, at home or at their work, a CCTV system for six months to two years.

Out of the 41 patients, 3 had, unfortunately, become totally blind and could no longer use their CCTV apparatus. The general reaction of the remaining patients was strongly positive: they used their CCTV for reading between 4 to 6 hours daily, most of them without fatigue. Some, who had been using optical systems beforehand, were enthusiastic about the greater flexibility and ease with which they could now read. None had difficulty operating the equipment, although some commented adversely on control positions on older models of the equipment. Those who had been formerly restricted to Braille commented enthusiastically about the new possibilities for reading which the systems gave them. Half of the patients used their CCTV for writing as well as reading although this mainly was confined to essential tasks such as correcting typewritten drafts; use of a typewriter with the device proved unsatisfactory.

Although the report gives no detailed breakdown of use by professional groups, Blankenagel specifically refers to the use of CCTV systems for normal office work, for students, and for computer programmers. Among the patients were two scientists who used their equipment for two hours daily in consulting the literature in their field and in preparation of reports and papers. It is interesting to note that the subjects reported no particular maintenance problems.

For the purposes of the full study, it will be necessary to establish in more precise detail what is the experience of actual operation and use and of the subjective value to users of these devices. Since the literature is poor in this area, it was decided, as part of this feasibility study, to examine methods by which such information could be obtained. The two largest manufacturers of CCTV systems in the USA were willing in principle to collaborate in a questionnaire type approach to a sample of their clients. Approaches were also made to manufacturers in the Netherlands, the German Federal Republic, and Switzerland. In the case of the German manufacturer, he considered that the questionnaire could elicit no further useful information other than that recorded by Blankenagel (see above). Questionnaires have been circulated by the Swiss manufaturers, and initial response both from the USA and Switzerland indicates that useful data can be obtained by this technique.

VI. DISCUSSION

Data Requirements

In the cost-benefit analysis which is one of the aims of the study proper, it will be necessary to obtain fairly precise answers to such questions as:

a) the size of the severely visually handicapped population, i. e. those who cannot perform normal near-vision tasks such as reading and writing with spectacles, but who are not functionally blind;
b) the proportion of that population for which optical aids are better than, or equal to, CCTV in restoring ability to perform near-vision tasks;
c) the proportion whose needs can only be met by CCTV; and
d) the proportion who cannot be assisted to read or write by optical or CCTV aids, including unmotivated individuals.

If the study is to be useful in providing more than general guidance to health care planners, it should also seek to establish whether there are specific indicators for the sub-populations in (b), (c), and (d) above. For example, is visual acuity an indicator, or are particular pathologies also an important factor?

It will also be important to derive an age distribution for (b) and (c), if only to separate out the educational, economic, and purely social medicine aspects. Lastly, we should seek to determine what indicators exist from trial and follow-up results which have a bearing on the relation of CCTV systems design to real operational needs.

The issues for discussion here centre on the extent to which the incomplete data so far examined show the feasibility of answering these questions by a full study, and how the sample data presented might be extended to fill gaps. In this respect, it has already been shown that information incidence of partial sight and on how the disability is defined has been arbitrarily limited to the UK and USA. A culturally and geographically broader data base will obviously be necessary for the full study.

The Definition of the Population: Criteria

As shown in Section II of the report, methods of defining the blind or partially sighted population differ. The differences and the imperfections of the methods used make evaluation of the size of the problem more a matter of comparing approximate estimates based on different standards, than a comparison of exact measurements. Functional definitions--related to visual performance rather than to clinical measurements of remaining vision--have been suggested, not only to overcome the arbitrary nature of combinations of visual acuity and visual field measurements but also for social policy reasons. If partially sighted persons are to be regarded as a handicapped group deserving some kind of assistance from the community--whether this be tax privileges, free or assisted purchases of aids, or early state pension--a functional definition of who should benefit seems a preferred instrument of social policy as it could be directly related to the degree of economic and social disablement. Certainly, however, any redefinition--especially if associated with more accurate population surveys--would result in an increase in the number of recognised cases of blindness and partial sight: a function definition must be based on the ability to perform visual tasks (e.g. reading, in the case of near vision) and the numbers falling within such definitions are several times the number falling within current definitions of "legal blindness."

Depending on the policy adopted by individual health care and social security administrations, redefinition could cost the community extra money, but it could also result in economic and social gains. This feasibility study cannot give precise numerical expression to the possible effects of redefinition but it has at least indicated the order of magnitude of the problem. If we replace the concept of "blindness," as for example in the US definition of legal blindness, by a functional definition related to severe economic or social handicap, we are likely to find that the affected population is increased by a factor of about four.

In handling data about blindness and severe visual impairment, measurements--however inadequate or inexact--of visual acuity are important for the needs of the full study since a) such measurements appear in all current definitions so far examined and b) most trial records bear visual acuity numbers. In this feasibility study it has therefore been necessary to try to define the boundaries of severe visual impairment. A comparison of the recommended WHO standards with the conclusions of Genensky and Goldish (as has been done in Table II, Section II), shows a reasonable measure of agreement that the upper limit of what WHO defines as "partial impairment" is what equates, at a level of 0.3 visual acuity, with the upper boundary of what Goldish calls "severe visual impairment." The same figure is quoted, with reservations, by Genensky as the upper threshold of the "functionally visually impaired." It should be noted that field restrictions are not specifically taken into account in these visual acuity thresholds.

There is also agreement upon what constitutes the lower threshold of severe visual impairment, where it merges into virtual or absolute blindness. The WHO recommended standards suggest a lower limit of around 0.02 and Goldish suggests that it lies somewhere between 0.025 and light perception. It should be noted, however, that both the Genensky and Krieger trials included subjects of acuities below 0.02, some of whom were successful with either CCTV or optical aids.

In regulatory or legal definitions there is no correspondence between regulatory thresholds and those recommended by WHO or suggested by Genensky and Goldish. The USA definition of legal blindness at 0.1 obviously includes some partially sighted (severe visually impaired) persons. But the UK bandwidth of admission to the UK Partially Sighted Register (between 0.05 and 0.1)--except for determining whether children require special schooling--is itself within the definition of US legal blindness.

Size and Structure of the Severely Visually Impaired Population

On the functional basis suggested in the previous paragraphs, the data indicate that 0.77%, i.e. 8 per thousand, of the population of an industrialised country such as the USA have severe visual impairments. Until this data is extended to other countries, this statement must remain a working hypothesis.

Partial sightedness is to a large extent an age-dependent condition. One USA estimate indicates that 64% of persons with severe visual impairment are over 65 years old, 32% are between 25 and 64, and 4% are between 1 and 25 years. The UK statistics (see Table 3, Section III), while following the trend indicated by the US estimates for those over age 65, show a reversal in the two lower age groups (23% and 14% respectively). For the reasons discussed in Section III, it is difficult to know to what extent the statistics by age groups in the UK sample are biased by the way in which they are collected. From an inspection of the data, however, it would seem that the incidence in the infant group is likely to be severely under-reported compared with children aged between 5 and 10 years. The data for the middle-age groups is also suspect, since they actually show a substantial decrease in some age groups compared with the next junior group, a tendency that seems hardly likely in view of the generally irreversible nature of most of the eye conditions concerned, except cataract.

Moreover, insufficient information on the basis for the age breakdown of the US statistics is available from Ref. 7 to analyse it in detail. For a future cost/benefit analysis, we will need a finer structure for the severely visually handicapped population by age;

a more detailed breakdown is also required to verify the relation of trial samples in certain age groups to the overall population. Turning now to the trials reported in Section V, we find that in the Krieger sample, 20% of the subjects were 5 to 25 years old, 38% were aged 30 to 59 years, and 42% were 60 years or older. In Genensky's sample, 8% were between 7 and 14 years, 46% between 20 and 60, and 46% over 60 years. The Blankenagel and Jaeger sample of 50 patients was ranged as follows: 14% were under 25 years old, 50% were 26 to 64 years old, and 36% were 65 years old or older.

There is a clear disparity between the trial populations and the one estimate we have for the age breakdown of the severely visually impaired population as a whole. No generalised conclusions can be inferred, however, until the latter estimate has been analysed in detail and cross-checked with statistics for other countries. It is possible to infer that any trial will be likely to involve more subjects with a higher motivation to seek low vision aids than a general cross section of the severely visually impaired. A trial population thus is likely to include a smaller proportion of elderly persons who accept their partial sight as an invitable consequence of growing old. This might partially explain why the trial samples tend to have reversed proportions of elderly and middle-aged groups compared with the whole population estimate. It is interesting to note, however, that the percentages of subjects in trial samples by ages--ignoring the group over 75 years old--are not inconsistent with the recalculated percentages in the Golish estimates of the total severely visually impaired population.

Relative Effectiveness of Types of Aid

A casual inspection of the trial results reported in Section V of this report--without reference to the differences or similarities of the samples of subjects--suggests the following broad conclusions:

1) For optical aids, 48% of a population of 917 severely visually impaired patients were initially helped by the provision of aids. However, after use of the aids for a minimum period of six months, only 20% of the trial subjects found that the particular aid prescribed "met their needs."

2) For the Genensky sample of 81 low vision subjects initially exposed to CCTV systems for a half hour period, 83% were able to read in some fashion with the aid of the prototype RANDSIGHT system and 56% read over 30 words per minute. About 69% were able to write more or less legibly, on first exposure to the system.

In the Blankenagel and Jaeger trial of 45 patients, selected by reference to the degree of magnification required, 71% were able to read with CCTV on first initiation. In a follow-up study Blankenagel reported that all of the subjects (after a minimum of six months' use of the system) found that it met their needs (except for three patients whose condition had worsened to total blindness).

3) In the test of 40 subjects exposed to both optical and CCTV aids by Mehr et al., all subjects showed better reading performance with CCTV (reading speed and duration), and while all were able to write with CCTV, only 25 of the 40 were able to do so with optical aids.

This incomplete and highly compressed comparison of the trial results examined should not be interpreted as indicating that for all low vision subjects in all circumstances CCTV is the superior prosthetic. It does seem fair to conclude that a CCTV system is generally more likely to produce markedly better performance in reading, and especially in writing, than an optical aid.

Visual Acuity as an Indicator

For a more complete comparison we must look for possible determining factors which could indicate what type of aid might be prescribed in individual cases. The obvious starting point is whether measurements of remaining vision are such an indication. Krieger, Genensky, and Blankenagel give breakdowns of their samples by visual acuity. Mehr et al. indicate the spread of visual acuity measurements of their subjects, but do not give any details: however, they state that there was no significant difference in mean visual acuity between the parts of their sample recommended for CCTV and optical aids respectively. One cannot compare directly the Krieger and Genensky results, since the former are expressed in terms of uncorrected distant visual acuity and the latter as the best corrected visual acuity in the better eye. In Table 10, constructed from the data given in [10] and [11], the two series of results are contrasted; the Genensky series has, so far as possible, been aggregated in the same groups of visual acuities as those of Krieger.

Table 10

Visual Acuity as a Success Indicator for Low Vision Aids

A. Optical Aids (Krieger)

Distant Visual Acuity (Uncorrected)	Total in whole sample	Initial Success (Aids prescribed)	%[a]
less than 0.015	172	49	28%
0.015 - 0.025	298	153	51%
0.0275 - 0.05	347	170	49%
0.0666 - 0.2875	100	68	68%
	917	440	

B. CCTV (Genensky)

Distant Visual Acuity (best corrected)	Total in whole sample	Initial Success (Nos. able to read during 1/2 hour test)	%
less than 0.01	four cases[b]		
0.01 - 0 025	8	5	58%
0.025 - 0.05	19	14	74%
0.05 - 0.2	45[c]	42	93%
0.2 - 0.4	5[c]	4	80%
	81	65	

Notes:

a) The success of the Krieger sample is measured by the percentage of the sample to whom aids were prescribed. If one uses the sustained success ratio, i. e. those in the recall sample who had used aids successfully for a period of six months or more, the overall success ratio in the original sample is reduced to about 20%.

b) These four cases consisted of two within this visual acuity band and two whose visual acuities were unassessable. Although the latter two scored successes in reading, it is not reasonable to allocate a success ratio to this bracket of visual acuity, owing to the small size of the sample and its ambiguity.

c) One subject in each of these groups was a child who apparently had never been taught to read print.

Visual acuity, whether uncorrected or best corrected, is clearly not a reliable or precise indication for "success" with either optical or CCTV aids. There is, however, a rough indication that the chance of success begins to be appreciable at a lower level of visual acuity with CCTV than with optical aids: while the success percentages for the lowest range (0. 015 - 0. 025) do not differ much between optical (51%) and CCTV aids (58%), the latter is, however, based on a very small sample (8 cases in all).

It might be supposed that had uncorrected visual acuity measurements been used for the CCTV sample, these cases would have been moved to the group below 0. 015; and, therefore, they should more properly be compared with those with a success ratio of 28% in Section A of the table. Little can be inferred from the fact that success ratios rise more steeply with increasing visual acuity in the CCTV sample than in the optical aids sample, other than that over the trial populations as a whole, the probability of success with CCTV is likely to be greater than with optical aids. It is interesting to speculate that if 1) totally compatible data for CCTV and optical aid trials existed for an adequate number of cases in each visual acuity group, and if 2) these data were rigorously analysed, whether significant differences in the relative success ratios between groups as compared with the overall success ratio of each type of aid could be found*. On the evidence available, however, the real meaning of such a difference, if found, would be questionable. All the authors cited in Section V conclude that actual visual performance depends not so much on the extent of the visual damage (which might be thought to correlate approximately with visual acuity if a single standard of measurement were adopted), but on the location and nature of the damage

---

*Mehr et al. found no significant difference of visual acuities between the recommended and not recommended groups of their small sample, but since the two groups were chosen, in part, by performance criteria, it is difficult to generalise from this result.

Magnification Requirements

Another possible indicator might be the linear magnification required for a particular visual loss. It has been suggested by Blankenagel and Jaeger as an appropriate empirical measurement which they used in defining their trial population for CCTV (more than 6 - 8x). While they do not discuss the subject, linear magnification requirements in their view appear to define a practical lower threshold for CCTV, and therefore (presumably) an approximate upper threshold for optical aids. Genensky et al. also measured linear magnification used by their subjects; the results appear in Table 9, Section V. This shows that about half of the subjects used (for reading) linear magnifications below the arbitrary threshold of Blankenagel and Jaeger. There exists, however, substantial agreement between the two sets of trial results in the percentage of subjects scoring initial success. If linear magnification of 6 - 8x alone was an adequate threshold indicator for prescribing an optical aid rather than a CCTV system, one would expect--given the large number of Genensky's subjects using reading magnifications below this arbitrary threshold--the Genensky success ratios to be much above those of Blankenagel and Jaeger.

Nevertheless, for efficient operation with an optical aid, it is perfectly possible to imagine that an upper limit of magnification is a real threshold. Large magnifications are associated with small fields of view for normal-sized lenses, and reading speeds and duration are limited by restriction of the field of view to a single word or part of a word. Scanning, whether by precise head movements or by hand movement of the lens mounting, becomes more difficult and fatiguing as magnification requirements increase and useful field of view diminishes. A large plate lens of the Fresnel type can provide a larger undistored field of view than other types, but this, too, has operational limitations. Trial data to establish the operational thresholds in linear magnification by measurements of reading speed and duration have not so far been encountered in this study.

Functional and Ergonomic Indicators

From an empirical point of view, it is not surprising that physical measurements such as visual acuity or required magnification which are only indirect measurements of remaining vision, do not appear to be suitable indicators for low vision aids. An aid must not only restore vision; it must restore useful vision if it is to be functionally effective. How "useful," as to be defined in this context, depends on the individual's expressed or implied needs. How effectively an aid meets these needs depends in part on quantities which may be adequately represented by physical measurements. But "needs" vary widely, and the extent to which an aid will in practice "meet needs" depends also on the motivation of the subject and other psychological factors.

To illustrate the possible decisive role of such factors, let us consider two persons with the upper limits of severe visual impairment, i.e. with visual acuities between 0.1 and 0.2. The first is an elderly, financially secure retired person, accustomed to his disability, whose cultural and social needs are met by talking books, by the radio, and by having someone read from the newspaper each day. His more personal reading needs might be a regular check on his bank statements, and the use of his personal list of telephone numbers. His needs could therefore probably be met with a low power (2 - 3x) hand-held illuminated magnifier.

The second person is a middle-aged man, with identical pathology and the same visual acuity who needs to work at an occupation which is dependent on reading or writing for continuous periods. Although, by physical measurement standards, he could read with the same hand-held magnifier our first subject would use, such an aid is almost useless to him. The slow speed required to scan a paper using such a device and the fatigue resulting from a bent-over posture at a fixed distance from the paper being read, would effectively inhibit his ability to work. In order to operate in his work environment, he needs a CCTV, but could also use. less effectively and with more fatigue, a manoeuvreable illuminated stand magnifier, ideally with a Fresnel lens. But while both devices are transportable, both are non-portable: this person therefore will also need a small, hand-held illuminated magnifier if he is to be independent of others' vision outside his workplace (e.g. for reference to telephone lists, railway timetables)

From the point of view of writing need, the indications, particularly from Mehr et al., are that CCTV results in so much greater facility for substantial writing at length that its use is indicated at a rather higher threshold of remaining vision than for reading alone (All 40 of Mehr's subjects were able to write with CCTV, while only 25 were able to write with the optical aid recommended.) The same trial indicates a quantitative difference in reading performance with CCTV and with optical aids (types not stated): all subjects were able to read for longer periods and up to 64% faster with CCTV. The subjects recommended for CCTV could read for an average duration of 14.8 minutes with optical aids and 48.3 minutes with CCTV, but for the non-recommended group the increase in duration was less marked (19 minutes as compared with 35 minutes for CCTV)

Certain technical features of CCTV systems are probably an important factor in reading and writing performance. Examples are the need for contrast reversal (expressed by 30 - 50% of subjects in CCTV trials) and the possibility of electronically blanking out all but a selected portion of the screen (Blankenagel and Jaeger report the difficulty encountered by some glaucoma patients in focusing attention on one line). Probably, however, the most important single factor contributing to increased reading speed and duration and to greater facility in writing is the flexibility of CCTV in operation as compared with optical aids.

A major advantage is that the choice of working distance, and therefore of posture is at the user's discretion, rather than a function of the focal length of the lens system used. (Since the monitor screen may be moved, even those subjects who need a very short working distance may adapt the screen to their comfort.) The ability to enhance contrast is undoubtedly an important advantage of CCTV over optical aids, even those with sophisticated built-in illumination. (In the literature so far examined, however, there is almost no quantitative data on the relation of contrast to visual performance for the various eye conditions causing partial sight.)

While particular eye pathologies are not likely to be indicators for particular types of prosthetics, two striking points from the trial results discussed in this report should be mentioned here. First, a comparison of the Blankenagel and Jaeger cases who initially failed with CCTV shows that all these patients had multiple pathologies, with cataracts as the common factor. If these cases are compared with others of simular age and visual acuities having the same pathology uncomplicated by cataracts, who succeeded with CCTV, it might be inferred that cataract surgery together with a CCTV prosthetic might restore useful vision to a substantial proportion of the aged severely visually impaired population. The average age of failures with cataract complications was sixty-five years, but three cases included were in young or middle age groups. Secondly, the presence or absence of scotomas seems to be a determining factor in initial success with CCTV (all but one of Genensky's reading failures had scotomas).

The Overall Requirement for CCTV

Like any other form of treatment or prosthetic, CCTV systems could not be prescribed on an "off the shelf" basis, without taking into account the characteristics of individual patients, as interpreted by the skilled judgment of the low vision specialist. We must see, however, how far it is possible to answer the question posed earlier in this section in the general level of the requirement. For the present purpose, the question of relative cost is to be ignored, i. e. that every severely visually handicapped person is enabled to receive the prosthetic which yields the greatest benefit in terms of increased near vision performance. This assumption should however be qualified by a caveat: no one is likely to be prescribed an aid which he cannot use, nor will a complicated and expensive aid be prescribed when an individual's needs can be met by a simpler, cheaper one. Since the aim is to establish a target, rather than to make prediction, we need not, at this stage, discuss whether or how these assumptions could be validated in operational or financial terms.

All the trials discussed throw some light on the question of numbers of CCTV aids versus optical aids, but none provides a conclusive answer. The Mehr et al. results to some extent take into account relative need, based on clinical judgment, and show that for this sample 28 were recommended for CCTV and 12 for optical aids, i.e. 70% and 30% respectively. We do not know, for example, the relation between the age structure of this sample and the age structure of the severely visually impaired population as a whole; nor can we guess at the representativeness of the "needs" estimation which played an important part in this result. From Krieger's results, we can say that to the extent that his large sample of 917 is a cross section of the severely visually impaired population, some 20% (interpolated from possible limits of 14% and 26%) were supplied with optical aids which they said met their needs, after a minimum period of use of six months. One could perhaps conjecture that had CCTV been available, needs might have been met by about 80% of those requiring near vision aids (the approximate success ratios from Genensky et al. and from Blankenagel and Jaeger). This 80% would contain the 20% who succeeded with optical aids. Thus, while Mehr shows a three to one ratio in favour of CCTV, the other trial results combined might indicate a four to one ratio. While this is a pleasing coincidence, it is probably no more than that: the samples (other than Krieger's) are too small. Moreover, their divergence from the single estimate of the age breakdown which has been used in this feasibility study is so marked in the group over sixty-five that little confidence should be placed in such a simple calculation of relative requirements. The gaps in the data required for a more sophisticated calculation may be summarised as follows:

1) We have no fine structure for age in the estimate of the severely visually impaired population. By reference to the original data such a fine structure could probably be inferred. This would enable trial samples to be adjusted to the age distribution of the overall population itself.
2) The trial samples are small, particularly in the upper and lower age groups. However, we do not need extensive clinical data to assess success or failure and the degree to which needs are met, but rather we need field data on aids actually in use. Consequently, there is a prospect that, for CCTV, the necessary extension of the data could be obtained by survey methods which are likely to be feasible in principle, and for which practical arrangements could

be made.

3) It is clear that not enough information on needs has yet been gathered. To some extent, needs may be inferred from occupations for which Goldish gives data [7]. This question, which may be crucial in the full study, is discussed below.

Feasibility of Structuring "Need"

There is clearly a differential structure of need for functional near vision between age groups, occupations, and socio-economic circumstances. At the lower age of the age scale, the need of severely visually impaired children and young people of college age is of major social and economic importance. Muck has been written about the special educational problems of blind and partially sighted children, but this whole field has been left aside for subsequent study: the resources of the feasibility study did not permit a review of this area. However, the literature includes trials using CCTV as an educational tool, particularly in special classroom systems combining a number of different features to permit selection of the most useful systems design characteristics. In terms of absolute "need," one important aspect must be studied: the necessity of teaching children to use their remaining vision whenever possible, rather than to resort to non-visual methods. The training of visual memory is apparently of great importance, and its absence may affect subsequent development. While this feasibility study has no conclusions to offer on evaluation of need for optical aids or CCTV for school and college age groups, the literature is extensive and the data plentiful.

For workingage adults, an approximate need estimation from existing data seems possible once a firm basis for the numbers of severely visually impaired persons in this category can be established. Goldish gives occupational data [7] and recourse to the original survey data he uses in this respect should provide an adequate breakdown.

The main problem in establishing need lies in the retired (over sixty-five years) adult group, since the indicators are that the majority of severely visually impaired persons fall into this category. This needs to be checked by reference to national samples, but it will clearly be necessary in the full study to analyse the real near vision requirements of the elderly. The problem of motivation to read and write is probably most important in this age group. In the trial results so far examined, the apparent lack of motivation to use remaining vision to the best effect has been noted in some of elderly subjects. The general literature on elderly persons with severe visual handicaps may provide valuable clues to establish a need pattern in this group.

One would expect that more extensive field data on CCTV systems in actual use would provide information on what kind of elderly or retired people use such devices. It is unlikely, however, that great precision in establishing "need" in a quantitative sense could be expected. However, there is much experience of this problem in low-vision clinics and other institutions concerned with welfare of elderly handicapped persons, and aggregations of this experience should provide a general frame of reference for the problem. In any case, a cost/benefit analysis in respect of the retired population cannot be rigorous as it is unrealistic to suppose that social benefits could be exactly quantified. The structure of the analysis of the use of low-vision aids will therefore be more descriptive than numerical.

However, a quantification of benefit could perhaps be attempted in terms of the notion of dependency. A severely visually handicapped individual, particularly an older person, may need the services of someone else to replace his lack of near vision. The notional costs of providing this (either from community or family sources) might be calculated. The elderly person may, in any case, require such services because of his general infirmity, whether or not this is associated with severe visual impairment. The provision of visual aids could thus postpone the onset of dependency when the individual is severely visually impaired, but otherwise able to look after himself.

Means of Associating Data on Need and Other Factors

Let us assume that we can collect sufficient data to describe "need" with some degree of precision in the young and middle age groups, less so in the retired group. Remembering that in this context "need" is need for functional near vision, rather than need for a particular aid, its description might take the following form:

High Need--Need to read and write for continuous periods approaching the performance of the normally sighted;
Moderate Need--Need to read for short periods or at slow speeds, and occasional need to write short letters, notes;
Low Need--Only occasional need to read short items (e. g. telephone numbers, names, the calendar).

Obviously, the division into three groups is purely arbitrary, but it would seem to fit what can be inferred about need so far. Need is clearly related to occupation and age and may also, in a practical sense, embrace motivation. Residual visual ability is, however, a totally independent variable affecting the choice of prosthetics. While only approximately following visual acuity values, the trial results discussed suggest that visual performance with low vision aids could be approximately but adequately described by three groups whose boundaries roughly correspond to visual acuity as follows:

<u>High Remaining Vision</u>--best corrected visual acuity of better than 0.2: upper limit not precisely defined, but about 0.3 or slightly better;
<u>Moderate Remaining Vision</u>--best corrected visual acuity between 0.2 and 0.025;
<u>Low Remaining Vision</u>--best corrected visual acuity from 0.025 to 0.01, or lower, shading into the grey area where virtual blindness begins.

We have information on the relative incidence of low, medium, and high residual vision in the trial samples. These should be corrected to the distribution in terms of the whole population if data to be calculated in the full study permit. By combining "remaining vision" and "need" into a 3 x 3 matrix we could thus provide an initial framework for arithmetical analysis of the overall requirement. Totals in the "need" columns could probably be assessed from occupational statistics, but less precisely and with much greater uncertainty where the needs of the persons over age sixty-five are concerned.

Information from the feasibility study is, however, already sufficient to fill in some of the positions of the matrix without ambiguity:

	NEED		
Remaining Vision	Low	Medium	High
Low		CCTV	CCTV
Medium			CCTV
High	optical	optical	

The positions remaining blank are for the moment ambiguous as they would have to be filled by an intuitive estimation of the likely proportions of CCTV and optical aids in each. For example, one could estimate that the high need position would perhaps be occupied 75% by optical and 25% by CCTV aids. More precision could, however, be given as the need estimation become more precise with the additional data anticipated in the full study. To complete the matrix, and to calculate the numbers of aids allocated in each position, success rates could be introduced. Obviously this will be more important in the low and medium vision groups than in the high. But an application of possible success rates in the positions which contain a mixture of aids may also help to determine the most probable mix of aids in these positions.

VII. PLANS FOR A FULL STUDY

The method sketched out in Section VI of combining the data is a tentative suggestion which seems feasible as a starting point in a full study. In this section the various requirements for the full study which have emerged from the discussion in Section VI are summarised. They consist on the following broad areas.

Statistical and Cultural Basis

The first priority is to collect additional statistical information on the incidence of partial sight and on the structure of the partially sighted population in countries other than the USA and the UK. The main purpose is to provide a broader base for estimating the incidence per thousand in developed countries. The original US statistical data, which formed the basis for discussion in this report, will be studied in depth in order to determine the fine structure in terms of age and occupation. Comparison should be made, to the extent possible, with similar breakdowns for other countries. This is required not only to estimate more completely the magnitude of the problem facing health service planners in respect of the partially sighted/severely visually impaired/blind population, but also to make possible a more precise evaluation of need for functional vision this population. Additionally, further information will be sought to establish a linkage between visual function and measurements of remaining vision; there is ongoing research in this area.

Trials Data

While the four trials discussed have yielded much useful information, this needs to be supplemented particularly with field data relating to day-to-day performance with CCTV--if possible by occupation, age, and visual ability. There are several possible sources for such additional data, including sampling of existing CCTV users: possibilities for this exist for systems in use or under user trial in the USA, Switzerland, and Sweden. Ideally, if a clinical group could be motivated to carry out a randomized control trial, this would provide much needed basic data. Up to the present, no group planning such an activity has been identified.

The present limited study has not established positively that evaluation of CCTV systems has been undertaken in other countries, particularly the socialist countries. There are, however, centres of research activity in, for example, the GDR and in the USSR. It will be essential to include information on clinical or operational data on the effectiveness of visual aids from these centres.

Data on Educational Aspects

Educational aspects have not been covered in the feasibility study, but it will be necessary to research this area fully in the study proper. A large body of data on the subject exists, including trials of special CCTV systems in an educational environment.

Estimation of Need for Effective Near-Vision Performance

This has been shown to be an important area on which more data is required for a full study. The problem is particularly difficult in the case of the aged persons with severe visual handicaps, since these appear to constitute a majority of the severely visually impaired population. If the data from studies of partial sight prove inadequate, there is case study information on the requirements of the over sixty-five population group as a whole, particularly from the sociological point of view. This could provide a basis for estimating need for near-vision performance, by comparison with reading and writing needs for the "normal" population in this age group. Additionally, the postponement of dependency on others could be used as a means of quantifying the benefits to visually handicapped elderly persons.

Design Factors in CCTV Systems

This has not been explicitly discussed in this report, but is implicit in much of the inferences derived from the trial results. In general, the problem is the design of CCTV systems in relation to the width of the spectrum of user requirements. Existing good designs appear to cover the general needs well, but now that there has been sufficient experience with CCTV systems in an operational environment, the ergonomic system as a whole might well repay study.

Can a high persentage of <u>all</u> user requirements be met, for example, by one standard basic design, or are there special requirements for individual users which require special design design features. One might consider such topics as sharpness of the image in relation to flicker (which is perceptible at European frequencies of 50 cycles/second) and the need for "electronic windows" for certain pathologies. Another important ergonomic problem could be that of achieving the best contrast. Some systems use monitors derived from normal commercial television receivers. These tend to be less "hard" in contrast than some screens designed to operate in conditions of high ambient illumination, i. e. the balck/white contrast is really a grey/white contrast, even at the highest setting of the controls. Also there has been work on using color contrast as opposed to black/white contrast in an attempt to improve performance in the case of particular subjects for whom contrast is the main problem.

A further question might be the degree to which a modular concept for CCTV systems should be investigated. There are obviously special vocational requirements, e. g. for computer programmers and others, which might require special designs. If particular module packages could be developed, this might make it possible to meet special needs on a virtually off-the-shelf basis. A general problem of this kind is the question of cost-reduction. There has been a significant reduction in cost since the first commercially available equipment was placed on the market, but costs are still high in comparison with the most sophisticated optical aids. Are further reductions possible by series production methods?

It is not proposed that in a systems analysis study these problems should be examined from the point of view of actual hardware development. Nevertheless, a study of the interrelation of user needs and technical design factors might well provide useful information for those responsible for hardware development.

Outline of Possible Cost-Benefit Analyses

For the study proper, it will be necessary to try to bring together the various elements of cost and those benefits which can be quantified in economic terms. Such an analysis must describe the net effect on the GNP of a programme to correct severe visual impairment by CCTV and/or optical aids. On the cost side of the comparison, the costs for identifying the population potentially affected, and their ophtalmological inspection and treatment must be estimated. Probably, much of this data could be obtained from examining the procedures of low vision clinics. We already have considerable information on costs of CCTV and optical system: at present production levels a good quality CCTV system costs around $ 1500. Maintenance and depreciation can also be estimated. On the benefit side, the economic benefits to that part of the population at work could be estimated by making certain assumptions on the distribution of the population by socio-economic category. One could then calculate the changes in salaries and wages for each category attributable to various prosthetic devices. For that part of the population of school, etc. age, the economic benefit can be viewed as an investment problem in which it will be necessary to forecast probable life-time earnings with low-vision aids and without. For the elderly or non-working part of the population the concept of postponement of dependency discussed above could be used in computing economic benefits.

In the economic analysis as a whole, discounting procedures will have to be applied Social benefits are less easy to quantify, at least in any sense comparable with economic benefits, but it will be important to attempt a descriptive analysis in this area.

The "Blindness System"

For the feasibility study, no attempt has been made to collect data on the manner in which social security systems operate in the rehabilitation of the partially sighted population, and a systems insight into the operation of the "blindness system" in both market and non-market economics is in fact the main objective of the study proper. Organisational and institutional factors must also be considered, e. g. , how is the severely visually impaired population identified, and how is skilled low-vision care available to those who need it. Current policy for the rehabilitation of this part of the population, in different types of health-care systems must be examined. Finally, linkages must be established between the blindness system and the more general system of social and medical care for the handicapped as a whole.

REFERENCES

[1] "The Prevention of Blindness", Report of a WHO Study Group WHO techn. Rep. Ser., 1973, No. 518.

[2] Mehr, Edwin B., Alan B. Frost, and Loyal E. Apple: "Experience with Closed Circuit Television in the Blind Rehabilitation Program of the Veterans Administration", American Journal of Optometry and Archives of American Academy of Optometry, June 1973

[3] "Epidemiological and Vital Statistics Report", World Health Organization, 1966.

[4] "Prevention of Blindness", Report by the Director-General, World Health Organization, to the Twenty-Fifth World Health Assembly, A25/10, 30 March 1972.

[5] Genensky, S. M.: "Functional Classification System of Visually Impaired to Replace the Legal Definition of Blindness", Annals of Ophthalmology. vol. 3, No. 2, February 1971.

[6] Genensky, S. M.: "Binoculars: A Long-Ignored Aid for the Partially Sighted", The Rand Corporation R-1402-HEW, November 1973.

[7] Goldish, Louis H.: "The Severely Visually Impaired Population as a Market for Sensory Aids and Services", Part I, American Foundation for the Blind, New York, The New Outlook, June 1972.

[8] Goldish, Louis H: "The Visually Impaired as a Market for Sensory Aids and Services: Part Two - Aids and Services for Partially Sighted Persons", American Foundation for the Blind, New York, The New Outlook, September 1973.

[9] Sorsby, Arnold: "The Incidence and Causes of Blindness in England and Wales 1948 - 1962", Reports on Public Health and Medical Subjects No. 114, London, Her Majesty's Stationary Office, 1966.

[10] Krieger, A. A.: "The Partially Sighted Patient: A Study of 917 Cases", Tr. Am. Ophth. Soc., vol 65, 1967.

[11] Genensky S.M., H.E. Peterson, H.L. Moshin, R.W. Clewett, R.I. Yoshimura: "Advances Closed Circuit TV Systems for the Partially Sighted", The Rand Coporation R-1040-HEW/RC, April 1972.

[12] Sloan, Louise L.: "Recommended Aids for the Partially Sighted", (revised second edition), New York, National Society for the Prevention of Blindness, Inc., 1971.

[13] Jaeger W., G. zu Putlitz, A. Blankenagel: "Lesegerät für Sehbehinderte mit grosser Fresnel-Linse".

[14] Linvill, John G.: "Research and Development of Tactile Facsimile Reading Aid for the Blind (The Optacon), Electronics Laboratories Staford University, March 1973.

[15] Moffatt, P. McG.: "Visual Aids for the Partially Sighted", Acta. XVIII Conc. Ophth. 1958, Vol. 2, pp. 1567-74, Brussels, Imprimerie Medicale et scientifique, 1959.

[16] Braendstrup, P., and H. Skydsgaard: "Special Optical Aids for the Partially Sighted", Acta. Ophth., 42:287-94, 1964.

[17] Blankenagel, A. and W. Jaeger: "Erste Erfahrungen mit dem Fernseh-Lesegerät für hochgradige Sehbehinderte. (Bei welchen Patienten lohnt sich ein Versuch mit diesem Gerät?) Klinische Monatsblätter für Augenheilkunde, vol. 160, issue no. 6, 1972.

[18] Blankenagel, A. und W. Jaeger: "Das Fernsehlesegerät für hochgradige Sehbehinderte", Klinische Monatsblätter für Augenheilkunde, vol. 163, issue no. 3, 1973.

ANNEX

GENERAL DESIGN CHARACTERISTICS OF CCTV SYSTEMS

There are about ten systems which are commercially available at present, and they naturally differ in several respects. Further, there have been several versions of the prototype experimental equipment developed by the Rand Corporation (who made their work freely available without distinction to any individual or firm who wished to construct their own design). The following notes describe the main design features, and some of the differences, of the available systems.

Broadly, a CCTV system consists of:

1. A small TV camera, commercially available, similar to those used for initial surveillance in banks, stores, etc.
2. A monitor screen, again a commercially available product.
3. An X-Y platform on which the material to be read is placed.
4. A "cold light" to illuminate the X-Y platform.
5. A stand or stands on which the equipment is mounted.

Changing the magnification of the object being read is achieved by a simple control which raises or lowers the camera on the stand, or by a zoom lens on the camera itself, or by a combination of both. Magnification up to twenty-five times are perfectly practicable be these means, and the lens system is such that depth of focus is not a critical factor. The most usual size of monitor screen is seventeen inches, but some subjects prefer a smaller screen. Genensky's experimental and trial equipment has two eleven-inch monitors placed on either side on the equipment, so that it may be used with equal convenience by both left-handed and right-handed subjects without changing the relative position of the monitor and X-Y platform.

An essential feature of the electronics is the ability to reverse contrast--i. e. black letters on a white ground or white letters on a black ground--by a simple two position switch so that the subject may select the preferred combination. A feature found in some CCTV systems is the ability to blank out all of the screen except the centre portion, or intensify the centre of the field of view; some subjects find such features helpful as a means of concentrating their visual attention.

An effective X-Y platform is a vital part of the system and earlier models, which did not possess this feature, gave disappointing results.

The best X-Y platform now developed permits the reading or writing surface to be easily controlled by the subject. The lateral movement (i.e. in the X direction) may thus be smooth and naturally adjusted to the subject's reading or writing speed, and the line to line movement (i.e. the Y direction) may be effected precisely and rapidly. This is accomplished by a combination of weight, built-in friction, and precise bearings. The friction setting in some platforms may be adjustable to suit the subject, and margin stops are a simple but useful additional device. A further development by the Rand team is a split X-Y platform in which the right-hand half is independently moveable in the Y direction, but moves with the left-hand half in the lateral direction. Its purpose is to facilitate such operations as note-taking while reading a text, comparison of texts, and correction of proofs against an original draft.

The mounting of CCTV systems, i.e. the stand or stands is an important factor in their operation. For sustained working the subject must be comfortable: the screen position must be adjustable within limits, so that he can find the optimum working height and distance without adopting an awkward, tiring posture. The camera may either be mounted horizontally (a more compact arrangement, but one requiring a reflector system) or vertically. Some manufacturers offer the possibility of swivelling the camera so that a blackboard or wallchart may be viewed; in one horizontally mounted system the same effect may be achieved by inserting an additional reflector.

CCTV systems have hitherto not been readily portable: apart from their weight, the components must be disconnected and assembled, if, for example, a user wishes to move his apparatus from his work place to home. This may not be easy for many partially sighted persons without assistance. Some manufacturers have therefore thought about miniaturization. At least two portable systems exist, in which the equipment is assembled in a compact mounting in the form of a carrying case and require little or no effort to reassemble. To keep these portable equipments within reasonable size, only small (eleven-inch) monitors are supplied, which limits their usefulness somewhat. However, it is possible to attach such equipment to a second larger monitor if required.