OPTIMIZATION OF COMPUTER-ASSISTED PERIMETRY

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Key words. Automated perimetry, examinations strategies

ABSTRACT

The overall features of optimal examination strategies applied to computer-assisted perimetry are described. Emphasis is placed on the concepts of specificity and adaptivity which result from the necessity to obtain the greatest information gain within the amount of time available to the clinical examination. Implications for computer hardware and software are derived, including the programmability and interactive control of examination protocols.

INTRODUCTION

Computer-assisted perimetry has now proved its capability in providing useful information in the ophthalmologist's everyday's practice and is expected to give a new impetus to an examination which is often regarded as cumbersome and unreliable. The present automated perimeters can be considered as an alternative to conventional manual equipment with such interesting features as the standardization and reproducibility of examination procedures as well as the decrease of the results dependence upon the perimetrist's skill. However, the first clinical reports on automated perimeters outlined their lack of flexibility as an important limitation to the assessment and quantitative evaluation of visual field defects (13, 17, 18).

Much is expected from future developments of automated perimetry and it is widely believed that the optimization of examination procedures will improve the present state of affairs (6, 7, 15).

The aim of the present study is to give a rigorous statement of the goals and constraints of visual field examination and to analyze their consequences for computer hardware and software involved in computer-assisted perimetry.

VISUAL FIELD EXAMINATION – GOALS AND CONSTRAINTS

The visual field examination consists of a series of psychophysical measurements of light perception. Its goal is to obtain new reliable information which,

Greve, E. L , Heijl, A (eds.) Fifth International Visual Field Symposium.

ISBN 90 6193 731 0. Printed in the Netherlands.

correlated with other signs and symptoms of disease, allow the formulation of a diagnosis. We would like to point out that this does not imply an accurate and detailed mapping of the luminance difference threshold. Simple characteristic features of alterations such as a stepped nasal margin or an enlarged blind spot provide important clues for a diagnosis and in many circumstances, a complete mapping of visual field defects does not supply further information.

Variability and fluctuation of responses

One first problem in visual field examination is the variation or fluctuation of responses with parameters difficult to measure or to keep under control. Each individual response involves three major elements.

First is the visual stimulation. The light distribution over the retina is determined by the stimulus generation system as well as the optical status of the eye. Nowadays, most instruments rely upon the projection onto a screen of stimuli of controlled luminance, size, position, velocity, duration, color, etc. However, the optics of the eye introduce many variations to what is received by the retina. The pupillary size and the opacity of the ocular media affect the intensity and sharpness of the retinal image. The morphology of the orbit and the eyelids limit the extent of the peripheral visual field. The eye orientation controls the stimulus position and the eye refraction its sharpness.

The second element involved in the responses is the processing of the visual stimuli through normal or pathological structures of the visual system.

Third are functions irrelevant to the visual system but which are still implied in the responses. These functions include central decision processes which are affected by the psychological status of the patient: his ability to concentrate on the task, his degree of suggestibility, his understanding of the test, his general fatigue, etc. Effector functions are also involved which can be affected by age or disease.

Time limitations

A second problem in visual field examination is time limitation. Due to the increase of fatigue, threshold responses and discrepancies augment with examination duration. Otherwise, equipment and clinical staff availability does not allow for time-consuming examinations. 10 to 12 minutes is generally considered as a reasonable limit (11) but this value will vary depending on the psychological status of the patient, his age, etc.

OPTIMIZATION OF EXAMINATION PROCEDURES

Examination strategies aim at the greatest gain of reliable information with a minimum amount of tests. The repertoire of available stimulations should include the tests most suitable for the detection and analysis of deficits (10). Consequently, a perimeter should permit the exploration of the visual functions under a variety of different techniques. Suprathreshold, static and kinetic perimetry are now recognized standards. However, other approaches such as combined scotopic, mesopic and photopic evaluation (12), multivariable perimetry (4) and even objective perimetry might be worthwhile to develop.

The proper choice of tests should take into account all sources of information made available prior and during the examination. Flexibility and adaptation are the keys to optimal examination strategies. These features are compatible with the standardization and reproducibility required in daily office practice (14). This is true as far as we are not interested in obtaining a precise mapping of the visual field but rather in identifying characteristic features of alterations.

The initial knowledge of the patient's disease will direct the choice of a specific protocol. This protocol will be adapted to the patient's age, refraction and pupil size, i.e. information which is collected during the clinical investigation.

During the examination process, further adaptation will be introduced from the findings made from the analysis of responses. This adaptation will be based on two different criteria: one is to validate the responses, the other to identify specific features of the alterations.

Validation of responses

Each individual response is weighed according to its reliability.

External monitoring systems allow the rejection of unreliable responses. Such systems have already been developed for monitoring fixation steadiness from optical properties of the eye. Similar developments might be thought of for controlling other parameters which affect the results such as the patient's vigilance.

Another complementary approach is to test the responses according to specific properties of the visual field (9). The likelihood control consists of comparing the responses to normal values. It allows the detection of fixation unsteadiness by the presentation of stimuli within the blind spot area. It permits an evaluation of the patient's level of cooperation by testing his reaction to unseen stimuli. The control of adjacency is based upon the spatial continuity of the 'island of vision'. The sensitivity variation between neighbouring responses should be within a given interval depending upon the type of pathology involved. The control of coherence consists in comparing measurements obtained with different techniques as, for instance, static and kinetic perimetry.

Finally, averaging techniques can be applied in order to improve the 'signal to noise ratio' of responses (1).

Analysis of visual field defects

This analysis aims at the classification of visual field defects through the identification of specific features of the alterations. The degree of evidence of a given defect can be used to determine the orientation of the examination protocol. It necessitates a precise knowledge of the action of diseases as well as a model for the resulting alterations and their evolution. Such work has already been carried out for the macular alterations (8), allowing the identification of foveolar, perifoveolar or macular impairments. Similar approaches could be made for other types of deficits. The diagnostic process would terminate when the likelihood of identity between one of the models and the collected responses would exceed a given threshold.

IMPLEMENTATION ON COMPUTERIZED SYSTEMS

The optimization rules which have been described previously can easily be applied on manual perimeters. Ther implementation on a computerized system is subjected to two major requirements: programmability and interactivity.

Programmability

Medicine is essentially an art and this is specifically true of visual field examinations (10). It is difficult to realize an agreement on the best decisions to be made at each examination step as long as a precise, mathematical statement of the problem is not available. The present situation will undoubtedly remain the same for quite a long time.

Another approach is to allow skilled perimetrists who have gained extensive clinical experience to program their own examination protocols. A major barrier to this development is programming. Programmability is not only the possibility to develop automated sequences of stimulations. It should allow the practician to cope easily with a repertoire of actions, storage facilities and computational capabilities which are not familiar to the clinical world. A serious difficulty is to express clinical concepts in terms of numerical data that can be processed by a computer. Specific programming functions are needed for the generation of visual stimuli and recording of responses. Other programming functions should be provided for the analysis of responses and the detection of such features as an enlarged blind spot or an arcuate defect. Such programming functions can be combined with linear programming techniques to develop examination protocols. They make up a 'language of perimetry' which allows a precise formalization of examination protocols and could benefit the exchange of methodologies between practicians dealing with the optimization of examination protocols.

Interactivity

Interactivity is needed to supply the examination protocol with data not directly accessible to the computer. This task might be reduced in future developments with the integration of the different examination tools within one computer network (2). Another purpose of interactivity is to cope with situations not expected in examination protocols. The operator must be provided with a direct, real time control of the examination including information on the ongoing procedure, on the acquired responses and on the present interpretation of the results performed by the computer.

He must also be able to act rapidly and accurately on the examination process. These features are made possible by the recent technological developments in display devices, light pens and time-sharing processing. The use of graphic displays seems to be an absolute necessity given the large amount of information to be transmitted. Combining color and graphics would further enhance data comprehension, reduce the operator's fatigue and allow higher data throughout. The operator should be able to select the mode of display most suitable for the interpretation of data (5). topographic representations of the 'island of vision' such as equisensitivity curves (isopters), grey density and color maps, profile displays and numerical tables.

A difficult problem to solve is the allocation of tasks between the computer and the operator. Different solutions can be proposed (16), depending upon the operator's expertise. One option is to give the operator no role except for surveying the examination and entering requested data. The other extreme option would give the operator a leading part and let the computer execute commands. In clinical situations, a compromise has to be found between these two extremes. Some tasks may be entirely automated and others left to the operator.

CONCLUSION

The rules described in this paper have been implemented or are under development on the automated perimeter 'perimatic' which is presently used in routine clinical work at Lille medical center.

A surprising fact is that the examination strategies which have been implemented are not quite different from those applied by skilled and experienced perimetrists on manual instruments. This can be explained by the use of inference and deductive rules. Future developments might include probabilistic deicison-making schemes which, combined with categorical reasoning, would exhibit medical expertise (19).

ACKNOWLEDGEMENT

This work was supported by grants from the French DGRST, INSERM and Fondation pour la recherche médicale.

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