# AUTOMATIC DETECTION OF VISUAL EVOKED POTENTIALS - AN URGENT NECESSITY FOR OBJECTIVE PERIMETRIC INVESTIGATIONS

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Abstract

Objective perimetry uses VEP elicited by localised stimuli as the criterion of perception. Automatic signal detection in this case is a difficult task because of the unfavourable signal properties of VEP and EEG. In this study the decision strategy is based on signal-adequate, on-line applicable statistical algorithms. The presence of the signal is detected by implementation of a rank dispersion test analysing significant differences of variance. The method has been evaluated using an extensive patient database.

## Introduction

Automatic perimetry is a modern non-invasive diagnostic method, which applies to ophthalmologic, neurologic and neurosurgical problems. Perimetry is the determination of the monocular visual field, i.e. of the space visible for a fixing eye. The decision strategy of subjective perimetry is based upon the statement of the patient about the psychophysiologic perception of localised light stimuli. Hence this method is highly dependent on the ability and willingness of the patient to cooperate making it error-prone to subjective influences. Following this as an alternative to subjective perimetry there is a need for an objective method not requiring the immediate cooperation of the patient. A methodical basis is the evaluation of VEP signals elicited by localised light stimuli. The initially by Copenhaver and Beinhocker (1963) [1] proposed idea of objective visual field testing has been picked up by numerous research teams. Nevertheless there is up to now no feasible method for clinical routine use.

## Methods

The generation of VEP for perimetric investigations is possible using both Xenon flashlights and LED at different stimulus locations within the visual field. In this investigation peristimulated data sets of 64 sweeps for every stimulus location, 1024ms per sweep (both 512ms pre- and poststimulus), were derived occipitally in three electrically independent unipolar channels.

Methods for process-specific detection of VEP require the adequate consideration of the physiological and pathophysiological signal properties of spontaneous and evoked electrical brain activity. VEP emerge in certain temporal correlation to the stimulus application. They are hidden by the spontaneous EEG (SNR<0dB down to -20dB). Furthermore they are characterised by a high intra- and interindividual variability of the signal shape, esp. under pathological conditions. The properties of both signal and noise are not exactly known a priori and time-variant. According to this characteristic the task is to detect an unknown quasi-deterministic signal in noise.

Derived from the characteristics of the signals there are the following requirements to the methods to be developed: signal shape-independency, robustness regarding signal variability, no demand for a priori information. In order to minimise the examination time signal detection with a variable number of sweeps and break-off with a positive result is necessary. This requires an on-line coupling of the detection algorithm with the process, where on-line stands for the detector processing the data during derivation of the data.

Because the mechanism of generation and the assignment of VEP components to anatomical structures of the visual system are not reliably known [2] the following (physiologically not adequate but for this purpose sufficient) additive model is taken as a base:

$x = n_{pre}$ - prestimulus time (EEG) (1),
$x = n_{post} + s$ - poststimulus time (EEG + VEP) (2),

where s is an unknown deterministic signal and $n_{pre}$ and $n_{post}$ are realisations of the same stochastic process.

Detection methods were applied both on samples of single responses (Hotellings-$T^2$, Friedman-Test) and averages (Levene-Test according to Brown-Forsythe).

According to the signal model an increased variance can be observed in the poststimulus interval in the presence of VEP. Therefore a method was implemented which detects differences in variance between samples of the pre- and poststimulus intervals (after averaging). Because of the presence of the transient signal significant deviations from the normal

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distribution can be observed (Shapiro-Wilk-Test). Since the F-Test is quite sensitive to these deviations a non-parametric test (Siegel and Tukey 1960) [3] has been chosen which merely requires homomere distributed samples. This rank dispersion test allows the null hypothesis to be tested, ie if two samples (pre-, poststimulus) belong to one population regarding their variability, mean variation or dispersion. The alternative hypothesis is : both samples stem from different populations with the poststimulus interval having the greater variance (in presence of VEP). The interpretation of the null hypothesis leads to the detection of a blind point and the interpretation of the alternative hypothesis to the detection of a healthy point in the visual field. The combined samples are ranked that way that low ranks are assigned to extreme values and high ranks to the centre values. For the sake of test efficiency and validity both samples are centered before combination. Significant differences of dispersion can be recognised evaluating the normal-distributed variable z [4], where

$$z = \frac{2R_1 - n_1(n_1+n_2+1) + a}{\sqrt{n_1(n_1+n_2+1)(n_2/3)}} \qquad (3),$$

with $R_1$ - sum of the ranks of the smaller samples; $n_1,n_2$ - dimension of the samples; if $2R_1>n_1(n_1+n_2+1)$ then a=-1, otherwise a=1.

Samples of 200ms (25 values) taken from the end of the prestimulus interval and from the interval of primary VEP response have been compared. Generally the detection is based upon the 5% significance level. A positive decision is made on exceeding an empirically fixed threshold of 15 successive significance differences.

## Results

For the assessment of the detection methods an extensive patient and healthy subject database has been created. The patient data contain cases with established hemianopsia and concentric or irregular visual field defects. A first validation of the rank dispersion test with 298 data sets showed an average detection certainty of 69% with patients and 88% with healthy subjects, where reliable subjective perimetric results were used as a reference. On the basis of the patient data sensitivity of 0.74 and a specifity of 0.65 have been determined with a prevalence of 0.46. But considering the whole data material the sensitivity is 0.74 and the specifity is 0.72 at a prevalence of 0.34. While some of the methods tested (e.g. $T^2$-Test) were too pessimistic and others (e.g. Levene-Test) were too optimistic these results show an almost equal probability to detect correctly a blind or healthy point, respectively. The predictive values yield a test efficiency of 1.44. Since the tests have been realised predominantly with patient data (80%) these results are very encouraging (Fig. 1).

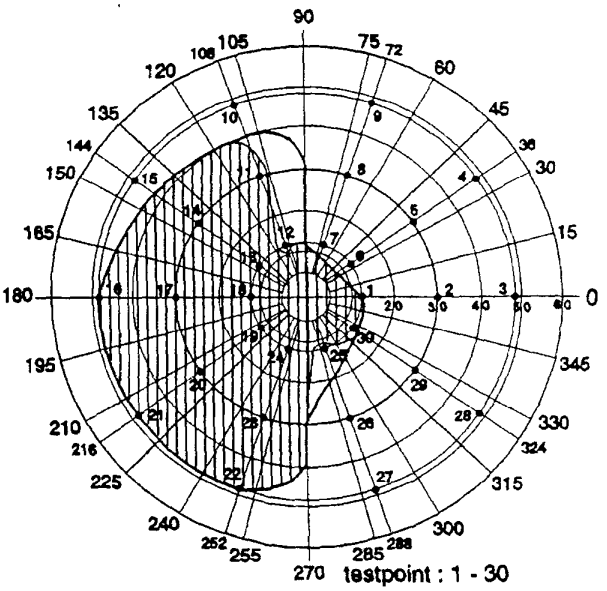


Fig. 1: Visual field of a patient with established hemianopsia of the left eye; subjective method (solid line), objective method (shaded area).

## Conclusions

The results proove that the test described above is a feasible approach for VEP detection in objective perimetry. A further improvement of detection certainty is expected by an optimised stimulation and sample selection and decision strategy as well as the integration of multiple stimulation modalities and VEP mapping.

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