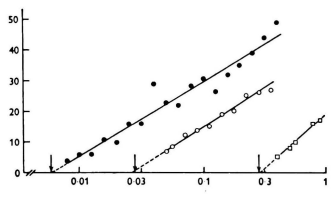
Visual evoked potentials and contrast perception

H. Strasburger, W. Scheidler & I. Rentschler

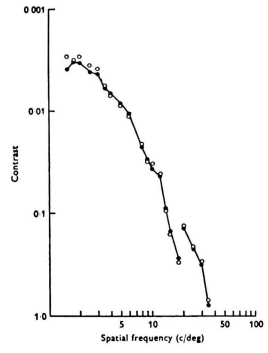
Institut f. Medizinische Psychologie, 8000 München 2, FRG

INTRODUCTION - In 1970, Campbell & Maffei have shown a direct relationship between thresholds of steady state visual evoked potentials (VEP) and (subjective) grating detection thresholds (i.e., the inverse of the contrast sensitivity). It would be of obvious clinical interest if a similar relationship could be established for suprathreshold contrast levels. We investigated this possibility by using a newly developed digital sweep technique for recording and analysing the steady-state VEP. Here we present typical results from a study based on 20 normally sighted subjects (contact author for individual differences).

Campbell & Maffei (1970) obtained a linear relationship between steady-state VEP amplitude and log contrast. This enabled them to determine VEP grating contrast thresholds by extrapolating to zero VEP amplitude the regression lines fitted to their data.

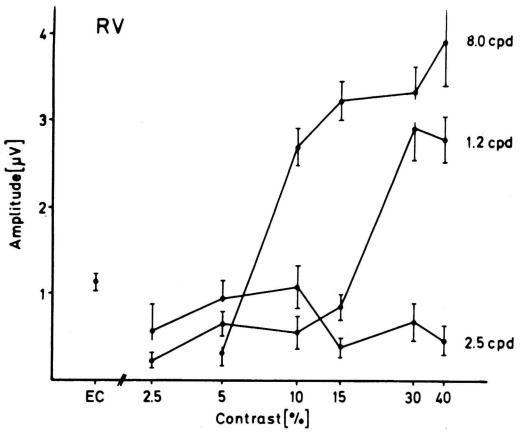


Campbell and Maffei's VEP grating contrast thresholds coincided remarkably well with the psychophysical grating detection thresholds. (Note that the plot shows grating contrast sensitivities, i.e., inverse threshold values.)

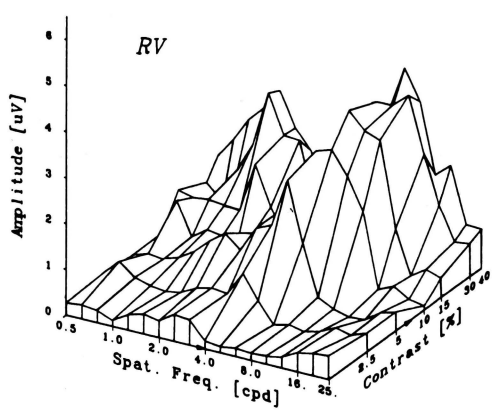


METHOD - Steady-state visual evoked potentials elicited by phase-alternating sine-wave gratings of variable contrast and spatial frequency. 8 Hz (16 reversals per sec) sinusoidal temporal contrast modulation. Recording by a computer controlled digital sweep technique (Strasburger 1986, J Electrophys Tech). The sweep variable was spatial frequency. A Fourier analysis of the averaged VEP was performed. Amplitude and temporal phase results for the 16 Hz components are shown (for a discussion of the employed techniques see Strasburger et al 1986, Clin Vision Res).

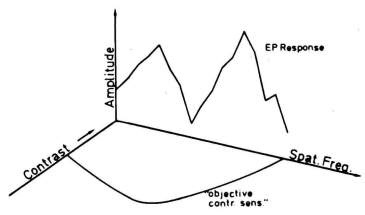
VEP AMPLITUDE



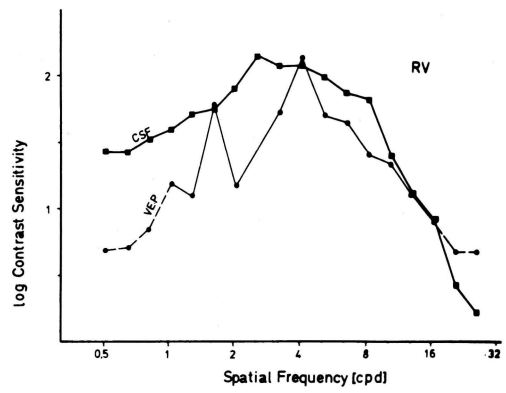
VEP AMPLITUDE - Campbell and Maffei reported a linear increase of VEP amplitude with log contrast with the slope being independent of spatial frequency. We found this true only for some values of spatial frequency. More generally, the slope and also the occurance of VEP saturation depended clearly on spatial frequency. Moreover, for certain medium spatial frequency values (3.2 +- 0.3 cpd), amplitude shows an unpredictable variation with contrast displaying little or no increase with increasing contrast, or, after an initial increase, decreasing to noise level above ca. 5% contrast and eventually increasing again for higher contrast values.



In a 2D-plot of amplitude vs. spatial frequency and contrast these peculiarities show as a bisection of the surface shape, with maxima for low (1.6 +- 0.18 cpd) and high (7.2 +- 0.75 cpd) spatial frequencies and a pronounced notch in between. There is considerable variation between subjects in the shape of this surface, with one of the peaks being smaller or absent for some subjects. Repeated measurements for the same subject show remarkable reliability of the individual response, however.

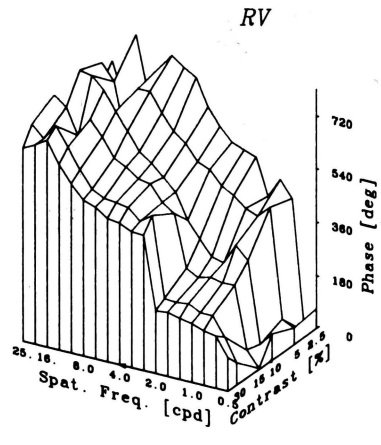


Applying the regression technique described above to the low-contrast part of the amplitude/log-contrast interrelations results in an intersection line in the (horizontal) contrast/spatial-frequency plane as schematically illustrated. These extrapolated VEP thresholds are replotted together with a (psychophysical) CSF (static sine-wave gratings, obtained with the method of adjustment). As can be seen, VEP thresholds and psychophysical results agree well.

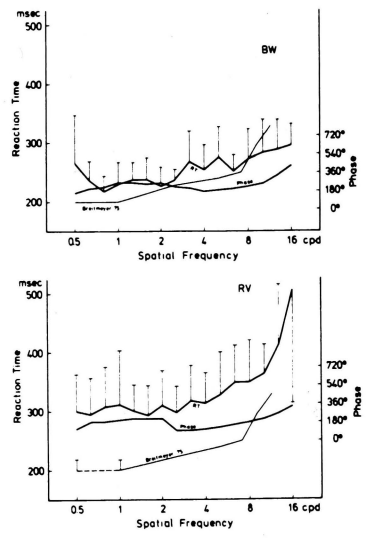


VEP PHASE

VEP PHASE- Temporal phase increases with increasing spatial frequency and decreases with increasing contrast. (Note that the horizontal plane has been rotated relatively to the 3D-illustration above for sake of clarity.) For intermediate spatial frequency there is a discontinuity of the phase surface at medium to high contrast levels. This discontinuity occurs at the same spatial frequency value where the amplitude response of the individual subject is notched.



Changes in temporal phase can be interpreted as changes in neuronal information processing delay of the visual input. Thus we compared our phase results with reaction times (RT) to the detection of sine-wave gratings obtained in the same subject. In their basic trend - increase with increasing spatial frequency and decrease with increasing contrast - temporal phase results and RT results agree. The changes in phase are smaller than those of RT, however, amounting to ca 50% of the latter. As in the case of VEP amplitude and contrast perception, the discontinuities of phase at intermediate spatial frequency do not have a subjective counterpart in reaction time results.



CONCLUSION - Steady state evoked responses to temporally modulated gratings allow the prediction of grating detection thresholds but do not provide information about suprathreshold contrast perception. One aspect of this is the occurance at intermediate spatial frequencies of a sharp notch in the VEP amplitude response that has no subjective counterpart. Moreover, there is a moderately good correspondence between VEP phase and reaction times to grating onset with the phase discontinuity at the spatial frequency of the notch in the amplitude response having no perceptual correlate. The discrepancy between objective and subjective data, however, does not necessarily mean that the analysis of the electrophysiological response cannot provide information of diagnostic value. A careful analysis of both the amplitude and the phase-lag of steady-state evoked potentials is needed to decide about such a possibility.

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