Principles and Practice of Clinical Electrophysiology of Vision

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PART IV

Retinal Physiological Mechanisms

19

Visual Evoked Cortical Potential With Chromatic Stimuli

Thomas Berninger
Geoffrey B. Arden

In primate retina about 90% of all retinal ganglion cells are color coded and can be recognized as smaller "beta" cells. They almost all project to the parvocellular layers of the lateral geniculate nucleus (LGN). The larger "alpha" cells project to the magnocellular layers, respond poorly to colored objects present on an equiluminant background of different color, but are sensitive to motion, flicker, and luminance spatial contrast.[4, 7, 8, 11] The smaller ganglion cells are better represented in the fovea, and nearly all are color coded, about 90% being of the red-green opponent type.[3, 6, 9] This subdivision is preserved in the cerebrum. The two subsystems project to different layers of striate cortex, and cytochemical techniques show that subsequent information processing occurs in segregated portions of the visual cortex.[9, 10]

The foregoing differentiation was established by single-cell recordings in subhuman species.[3, 4, 6–8, 9, 10, 16] Psychophysical studies, however, showed that selective stimulation of the two pathways also gives rise to differing sensations in human subjects.[11] Formerly human visual evoked potentials showed little difference in waveform when elicited by alternation using either achromatic or chromatic stimuli.[13, 15, 17] However, visual evoked cortical potentials (VECPs) are tested with combinations of patterns in which appearance and reversal are combined with luminance contrast or isoluminance color contrast, the waveforms, and other properties of the evoked potentials change in ways that strongly suggest that the functional division of the visual system can also be demonstrated by these noninvasive electrophysiological procedures.

COLOR VISUAL EVOKED CORTICAL POTENTIAL TO APPEARANCE

In the cortex, VECPs evoked by isoluminant colored gratings produce quite different responses to patterns in which there is luminance but no color contrast (Fig 19–1). Isoluminant colors produce simple surface-negative waves. Murray et al.[12] reported that for red-green gratings strict isoluminance is required for the negativity to be uncontaminated by positive components. The same is true for blue-yellow.[1] In addition, responses to blue-yellow stimuli vanish for higher spatial frequencies at which blue modulation is diminished since only the fovea can resolve higher spatial frequencies (Fig 19–2). This may be an electrical demonstration of foveal tritanopia. Thus it appears that there are specific cortical responses to color contrast patterns of low and

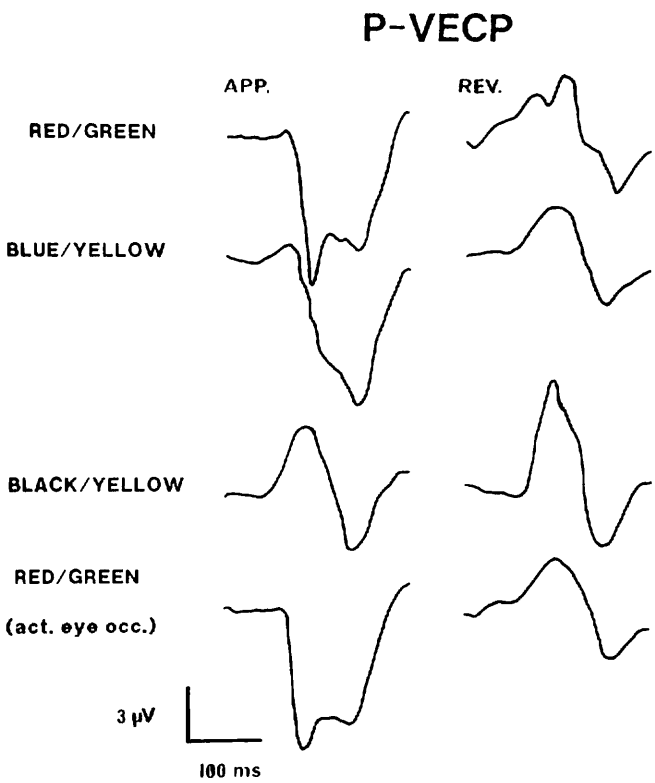

FIG 19–1.
VECPs are shown (stripe sizes, 1.5 cycles per degree; surface positivity gives an upward deflection). For isoluminant gratings a significant difference between appearance and reversal mode can be seen. For both red-green and blue-yellow gratings *(rows 1 and 2)* a large negative response is found, with an early maximum for red-green and a late maximum for blue-yellow. Note that reversal of a colored pattern produces a VECP with an early positive component. Similar responses are also found for black-yellow stimuli (row 3). (From Berninger TA, Arden GB, Hogg CR, Frumkes TE: *Br J Ophthmol* 1989; 73:502–511. Used by permission.)

midrange spatial frequency color contrast. The responses to blue-yellow and red-green are also easily distinguishable by their timing, by the relative scalp location of the maximum voltage, and by their spatial tuning (see Fig 19–2). It is interesting that there are also perceptual differences in reaction time that correspond to the different peak times of the evoked potentials.[2]

COLOR VISUAL EVOKED CORTICAL POTENTIAL TO REVERSAL AND MOTION

When color contrast gratings have low spatial frequency and are used in the pattern reversal mode, they produce the sensation of motion, like monochromatic patterns, and the VECPs evoked resemble the VECPs produced by monochromatic patterns (see Fig 19–1). It is known that the amplitude of responses to luminance contrast varies with spatial frequency, but a calculated spatial frequency for zero amplitude does not correspond to visual acuity. A much closer correlation is obtained with pattern appearance. Hence it is often suggested that the pattern reversal VECP evoked by coarse patterns is related to motion detection. This strongly suggests that the specific negative responses produced by the isoluminous colored patterns, in the appearance mode, may correspond to the operation of the parvocellular system. Consistent with this view is the finding that achromatic patterns with high spatial frequencies (10 cycles per degree and more) may also evoke surface-negative evoked potentials.[5, 14]

CLINICAL DATA

Regan[15] as well as Murray et al.[12] examined a deuteranopic patient with red-green gratings and did not record any response when the gratings were isoluminant. Berninger et al.[1] examined a subject with mild red-green deficiency and observed that the VECP response to red-green gratings has a completely different configuration when compared with normal individuals, while the response to blue-yellow gratings was in the normal range (1 SD). The demonstration of the different response configuration, however, was only possible because transient recording conditions were used. Only the response configuration was altered and not the "power" of the response.

The color VECP is able to detect hereditary color vision defects. Detection of acquired color vision deficiency, however, is of more clinical importance. The ability of the color VECP for this purpose has to be shown in future research.

CONCLUSIONS

Using equiluminous color contrast stimuli simplifies the responses, a finding that is of practical interest. The use of patterns containing color or luminance contrast may distinguish between the two parallel visual systems. This raises the further possibility that the structural organization of parvocellular and magnocellular pathways, or the different neurotransmitters, account for the polarity differences in the evoked potentials; the evoked potentials pro-

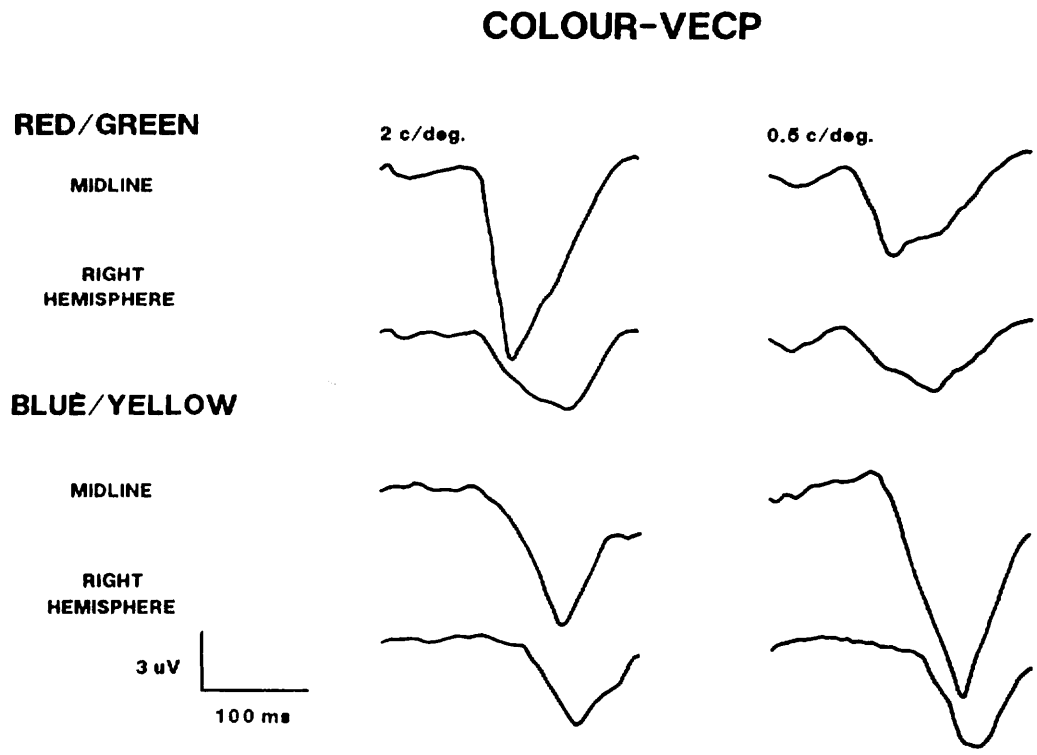

FIG 19–2.
Midline and right hemisphere responses for two spatial frequencies are shown. For red-green and for higher spatial frequencies the maximal response is found in the midline, while for blue-yellow there is no significant amplitude difference between the midline and periphery. Further, the red-green response in the midline peaks early at about 135 ms. The maximum amplitude for the red-green response in the hemisphere peaks later (about 190 ms). For blue-yellow in the maximum response peaks significantly later, both in the midline and the hemisphere. (From Berninger TA, Arden GB, Hogg CR, Frumkes TE: *Br J Ophthalmol* 1989; 73:502–511. Used by permission.)

duced by color may assist in understanding a variety of ophthalmological and neurological conditions.

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