Reports

Pattern Electroretinogram Threshold Does Not Show Contrast Adaptation

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Pattern electroretinogram (PERG) thresholds were examined using a swept contrast stimulus method. Stimulus contrast was either continuously changed (swept) from high to low (descending sweep), or from low to high (ascending sweep). Visual evoked potential (VEP) contrast threshold was higher when measured using descending sweeps than when using ascending sweeps. This VEP threshold difference has been attributed to cortical adaptation. Although previous work has reported changes in the PERG amplitude as a function of pre-exposure, we have found no analogous effect on the PERG threshold. Invest Ophthalmol Vis Sci 28:1614–1616, 1987

Prior exposure to a high contrast grating decreases psychophysical sensitivity to a subsequently presented grating.[1] This effect has been considered to be of cortical origin since it is both orientation- and spatial frequency-selective. Indeed, cells in cat striate cortex show reduced firing rates following exposure to a high contrast grating.[2] Cortical adaptation in human also has been shown electrophysiologically using visual evoked potential (VEP) measures. VEP amplitude to a suprathreshold stimulus is reduced following prior exposure to a high contrast grating of similar spatial frequency and orientation.[1,3,4] Similarly, VEP contrast threshold is elevated under stimulus conditions which are reported to cause cortical adaptation.[5]

The existence of pre-cortical contrast adaptation is controversial. Psychophysically, dichoptic presentation of adapting and test gratings results in threshold elevation 60–70% of that obtained from monocular conditions,[1,6] suggesting that a majority of the adaptation is cortical in nature. In addition, recordings from single cells in cat lateral geniculate nucleus (LGN) have not shown an effect of grating pre-exposure.[7] However, in the human electrophysiological literature, Odom and Norcia[4] have reported that the pattern electroretinogram (PERG) to a suprathreshold grating is reduced in amplitude following exposure to a high contrast grating.

The purpose of the present study is to determine whether PERG contrast threshold is elevated by prior exposure conditions. We have employed a swept stimulus, lock-in amplifier method to measure PERG thresholds in real-time. Thresholds are compared between descending sweep trials, in which contrast is decreased from suprathreshold levels, and ascending sweep trials, in which contrast is increased from below threshold and in which there is no pre-exposure to the stimulus prior to threshold determination. Threshold of the VEP response to a descending sweep has been found to be elevated by 0.6 log units when compared to an ascending sweep condition, an effect attributed to contrast adaptation.[5]

Materials and Methods. Three adult males (the authors) with normal vision served as subjects. Prior to the study, informed consent was obtained from all subjects.

Sine-wave grating stimuli were presented on a video monitor (Conrac, Covina, CA, Model QQA 14) which subtended 16° by 22° of visual angle at the viewing distance of 71 cm. Contrast was reversed in a square waveform over time at a rate of 7 or 16 reversals/second (rev/sec). The mean luminance of the stimulus was 50 cd/m^2 and was independent of stimulus contrast. Background luminance was 12 cd/m^2. An external control voltage, applied to the pattern generator (Institute of London), allowed stimulus contrast to be continuously changed (swept) over the course of a 20 sec trial while mean luminance remained constant. The course of the contrast sweep was approximately logarithmic and was either from 0.1% to 20% (ascending sweep) or from 20% to 0.1% (descending sweep). In any one session, ascending sweep trials were run before descending sweep trials to avoid any possible cumulative effect on thresholds of repeated high contrast presentations.

The PERG was recorded from the right eye with a gold foil electrode referenced to the right earlobe. An electrode on the left earlobe served as ground. The left eye was patched. In order to ensure that we could replicate previous results of VEP contrast adaptation,[5] we also measured the VEP for ascending sweep and descending sweep conditions. The active electrode for the VEP was placed 2 cm above the inion. Reference and ground electrodes were identical to those used for the PERG.

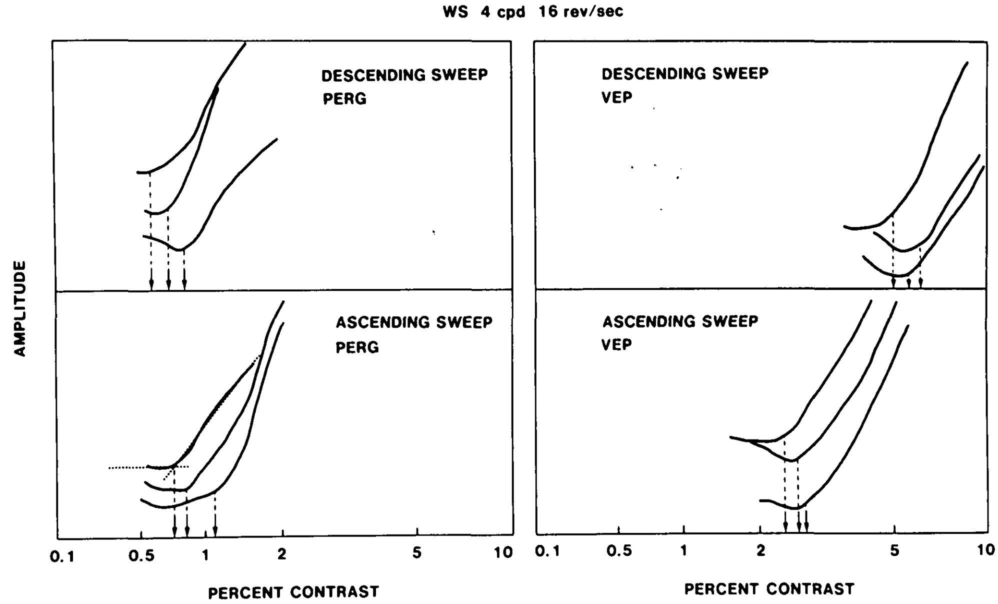

Fig. 1. Examples of PERG (left panels) and VEP (right panels) trials for one subject. The 4 cpd sine wave grating reversed contrast 16 times per sec. The top panels represent descending sweep (20% to 0.1% contrast) trials and the bottom panels represent ascending sweep (0.1% to 20% contrast) trials. Arrows denote contrast thresholds, determined by extrapolating the amplitude slope back to baseline, as shown for one trial in lower left panel (dotted lines). Only the threshold determining portion of the responses are presented. Traces have been vertically displaced for clarity of illustration.

The technique of using lock-in amplifiers in phase-sensitive detection mode for retrieval of electrophysiological threshold has been extensively described.[8,9] In the present study, this technique was applied to PERG contrast threshold.[10] Following initial amplification (Grass, Quincy, MA, Model P511J, gain = 10 k, 1–100 Hz), the bioelectric signal was input to a pair of lock-in amplifiers (EG&G/PAR, Princeton, NJ, 9505-SC). As contrast was continuously changed, the response was synchronously demodulated at the second harmonic of the stimulus frequency. This analysis was simultaneously performed at four phases relative to the reversal of the stimulus (0°, 45°, 90°, 135°). The result of each demodulation was integrated (time constant = 3 sec) and stored on separate channels of the signal averager (Nicolet, Madison, WI, 1170B). The channel containing the signal was identified by examination of the response phase, calculated from the orthogonal (quadrature) output of one lock-in amplifier.

Results. Figure 1 presents examples of PERG and VEP trials recorded under ascending sweep and descending sweep conditions. The output of the lock-in amplifier is plotted as a function of swept contrast. DC level of the output reflects total waveform information at the second harmonic of stimulation frequency. As response strength increases the amplitude of the lock-in output grows. The arrows point to obtained contrast thresholds, which were determined by extrapolating amplitude slope back to the point where it first increased.[5,8–10]

Using a 4 cpd sine wave stimulus reversing contrast at 16 rev/sec, VEP contrast thresholds (Fig. 1, right) for descending sweeps were significantly higher than for ascending sweeps ($t[4] = 6.06$; $P < 0.01$), whereas PERG contrast thresholds (Fig. 1, left) were not statistically different for descending or ascending sweeps ($t[9] < 1$).

Values in Table 1 represent the difference between the mean contrast threshold obtained from descending sweep and ascending sweep PERG trials for a variety of stimulation conditions. A positive value indicates that the threshold obtained from the descending sweep condition was higher than that obtained from the ascending sweep condition, a result consistent with an adaptation effect. The overall mean (0.046%) was not significantly different from zero ($t[6] < 1$). Thus, the contrast threshold of the PERG was not affected by direction of the sweep.

Discussion. We have found that contrast threshold of the PERG is not affected using a paradigm which

Table 1. Mean difference between PERG contrast threshold for descending sweep and ascending sweep trials

Stimulus condition	*Subject*	*Mean threshold difference (% contrast) descending sweep − ascending sweep trials*
1 cpd	MB	−0.003
7 rev/sec	NP	−0.095
4 cpd	MB	−0.01
7 rev/sec	NP	+0.299
	WS	+0.06
4 cpd	MB	−0.106
16 rev/sec	WS	+0.176
Overall mean difference (SD)		+0.046 (0.147)

yields large adaptation effects for the VEP. This result is in apparent disagreement with those of Odom and Norcia,[4] who have reported reduction of PERG amplitude as a result of contrast adaptation. Odom and Norcia[4] measured changes in PERG amplitude in response to suprathreshold stimuli, whereas we have measured PERG threshold responses. Thus, the two measures may not be directly comparable. If it is assumed that under adapted and unadapted conditions PERG amplitude versus contrast functions have similar slopes, then adaptation either should or should not be found at both threshold and suprathreshold levels and our results would be at odds with the Odom and Norcia study. However the results of the two studies would be consistent with one another if the slope of this function decreases as a result of adaptation. In this latter case, the same threshold could be obtained under descending and ascending sweep conditions whereas a large effect of pre-exposure would be obtained with high amplitude responses. A study of the changes in response amplitude slope under purported adapted and nonadapted stimulus conditions would be useful in distinguishing between these alternatives.

Finally, it is possible that the adaptation effect on suprathreshold response amplitude has a retinal as well as a cortical locus, whereas threshold elevation produced by a descending sweep is the result of cortical adaptation alone. Shapley and Victor[11] have demonstrated contrast gain control in cat retinal ganglion cells. They showed that amplitude and phase of the contrast response can be perturbed by the presence of a high contrast grating. However, sequential effects on the contrast response function were never tested, and no specific prediction regarding the presence of contrast adaptation at threshold or suprathreshold levels can be made based on their data. In a direct test of sequential contrast effects on firing rate of cat LGN cells, Ohzawa et al[7] failed to find contrast adaptation. This result, if analogous to human gross electrophysiological measures, would suggest that contrast adaptation does not take place prior to the LGN, since any modification of the response at a more peripheral level should be reflected at subsequent stages of visual processing.

Key words: electroretinogram, PERG, contrast threshold, contrast adaptation

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