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ORIGINAL ARTICLE

Comparison of Visual Evoked Potential Components between Laser and Cathod-Ray Tubes Stimulation in Healthy Human Subjects

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Abstract

We studied the differences in latency and amplitude between the laser stimulated visual evoked potentials (VEPs) and the cathode-ray tubes (CRTs) stimulated VEPs to estimate the risk of inducing photosensitive epilepsy by laser displays. Twenty healthy subjects were recruited for the study. Red and blue light stimulations were flashed in 1, 7.5 and 15Hz. The latency of P1, N1, P2 and N2 in 1 Hz stimulation revealed no significant difference by a paired t test between laser and CRT stimulation. The peak-to-peak amplitude was significantly smaller with red or blue laser stimulation than with red or blue CRT stimulation, for P1-N1 and N1-P2 at 7.5Hz stimulation, and for N1-P2 and P2-N2 at 15Hz stimulation. We therefore postulate that laser does not produce more excitability to occipital cerebral cortex than CRT does. There was no evidence to say that laser stimulation is more dangerous as the risk of inducing photosensitive epilepsy than conventional CRT stimulation.

Key words: Amplitude, Cathod-Ray Tubes, Environmental Hazards, Laser, Latency, Visual Evoked Potentials.

INTRODUCTION

Laser is useful for a color display and may widespread as an evolutionary tool in future. Laser display produces a clearer presentation than the ordinary cathode-ray tubes (CRTs), because the wave-length of color display stimulation is different between laser and CRTs. However, the risk of photosensitive epilepsy (PSE) by laser display is unknown, although the risk for the eyes and the skin by laser has been well known. Some reports suggest that patients with PSE show high amplitude visual evoked potentials (VEPs) by flash-light stimulation[1-5] or pattern-reversal stimulation by CRTs[5,6]. Generally speaking, increased VEP amplitude and shortened VEP latency may reflect increased excitation of visual cortex neurons and facilitated conduction of visual information processes[7-10]. There have been no studies on VEPs induced by laser stimulation. Therefore, we studied the differences in latency and amplitude between the laser-beam stimulated VEPs and the CRTs stimulated VEPs in healthy adults to estimate the risk of inducing PSE by laser displays.

MATERIALS AND METHODS

Twenty right handed subjects (8 women, 12 men) aged 22－40 years (mean 28.3 ± 5.37 years) were recruited for the study after their informed consent had been obtained. We explained the risk of PSE to every volunteer and prepared the life saving kits for unexpected convulsions. This study was approved by the ethics committee of Yokohama City University in September 2002. All the subjects were healthy and had normal or corrected normal visual acuity. The subjects were seated in a dimly lit and electrically shielded

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room. The subjects were instructed to fixate on a center of the target placed at a distance of 57 cm from the eyes.

The target was a round circle 10cm in diameter. The entire stimulating field subtended an angle of 10 degree of arc measured to the subject's eye. Binocular stimulation was used with the natural pupil. To assess electrophysiological aspects of visual cortex excitability by laser and CRT stimulation, VEP latency and amplitude were measured. We used laser and CRTs for visual stimulation to measure VEP latency and amplitude. Red and blue light stimulations were flashed in 1, 7.5 and 15Hz. The stimulation and non-stimulation ratio was 1: 1. The wave-length of laser was 642 nm in red and 457nm in blue. The wave length of CRTs is shown in Fig. 1. The mean brightness of both laser and CRTs were 90cd/m2 in red and 44 cd/m2 in blue. Transient VEPs to red and blue light stimulations were obtained by a stimulation frequency of 1 Hz. Steady-state VEPs were defined as potentials evoked by stimulus of sufficiently high repetition frequency to result in an overlap of responses, so that no individual response cycle could be related to any particular stimulus cycle[11-13]. Steady-state VEPs to red and blue light stimulations were produced by a stimulation frequency of 7.5 and 15Hz.

Electroencephalogram (EEG) was recorded with Ag/Ag-Cl scalp electrodes applied to the scalp with collodion. The electrodes were placed with impedances below 5,000 ohms at Oz and Fz in the International 10－20 system. The Oz electrode was referred to the Fz electrode, while the right mastoid scalp was grounded. The filter bandwidth of the preamplifiers ranged from 0.3 to 100 Hz (-6dB per octave). The raw signal was digitized with a sampling rate of 2000 Hz (12-bit resolution). The output from main amplifiers was fed into a computer (amplified, 50,000-fold). Positivity of the VEPs was shown as a downward deflection. Each evoked potential was the result of the summation of 100 responses. If the amplitude of electroencephalogram (EEG) exceeded a threshold voltage (± 125 μV), the waves were automatically rejected. EEG was analyzed 300 ms before and 700 ms after each visual presentation at 1 Hz. EEG was analyzed 60 ms before and 140 ms after each visual presentation at 7.5 Hz and at 15 Hz. Two repetitions of 100 trials for each stimulus type were performed to confirm the reliability of the VEP recording.

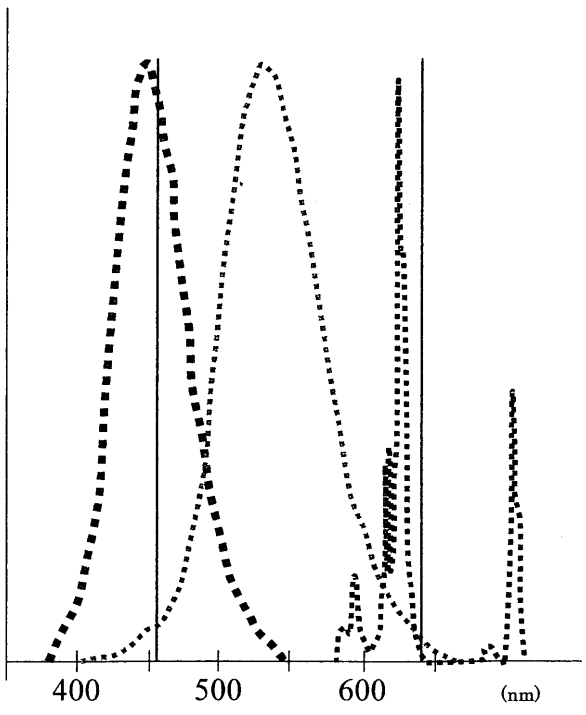


Fig. 1

The wave-length of laser and cathode-ray tubes (CRTs) stimulation. The dotted lines indicate blue light of CRTs (370－550 nm), green light of CRTs (400－660 nm), and red light of CRTs (570－650nm). Blue light of laser (a bar at 457 nm) and red light of laser (a red bar at 657 nm) are also shown.

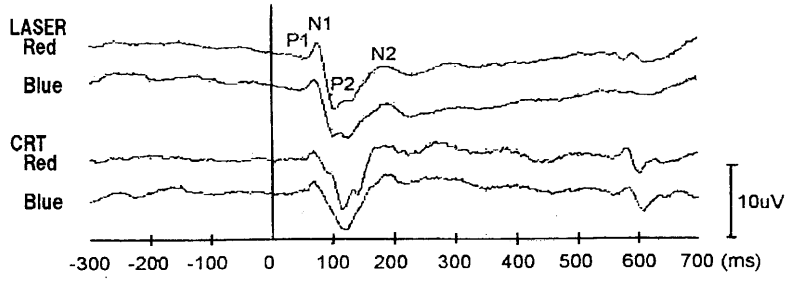
RESULTS

Fig. 2 shows averaged VEP waveforms to laser and CRT stimulation at three different stimulus frequency. The VEP waveforms varied considerably from one subject to another. However, VEPs on repeated trials in the same subject showed high reproducibility with little variation. The latency of peaks (P1, N1, P2, N2) in 1Hz stimulation and the inter-peak amplitudes (P1-N1, N1-P2, P2-N2) in 1Hz, 7.5 Hz and 15 Hz stimulations were evaluated using the paired t test to determine if the values differed significantly between laser and CRT stimulation.

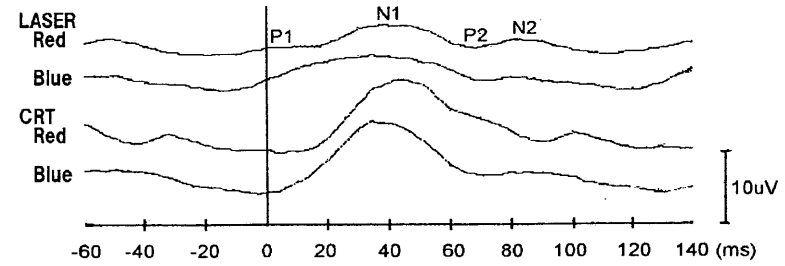
The latency of P1, N1, P2 and N2 in 1 Hz stimulation revealed no significant difference by a paired t test between laser and CRT stimulation (Fig. 3A and 3B). We found that the P2-N2 amplitude (μV) of VEP in 1 Hz red light stimulation was significantly smaller with laser stimulation than with CRT stimulation (8.89 ± 3.108 vs 11.51 ± 4.333, $p=0.028$). The N1-P2 amplitude (μV) of VEP in 1 Hz blue light stimulation was significantly larger with laser stimulation than with CRT stimulation (10.26 ± 4.941 vs 8.07 ± 3.975, $p=0.0428$) (Fig. 4A and 4B).

A paired t test revealed that the P1-N1 and N1-P2 amplitudes (μV) of VEP in 7.5Hz red light stimulation were significantly smaller with laser stimulation than with CRT stimulation (P1-N1; 6.90 ± 3.951 vs 13.26 ± 4.818, $p<0.001$, N1-P2; 5.21 ± 2.612 vs 14.14 ± 7.367, $p=0.016$). The P1-N1 and N1-P2 amplitudes (μV) of VEP in 7.5Hz blue light stimulation were significantly smaller with laser stimulation than with CRT stimulation (P1-N1; 5.59

a. 1Hz stimulation



b. 7.5Hz stimulation



c. 15Hz stimulation

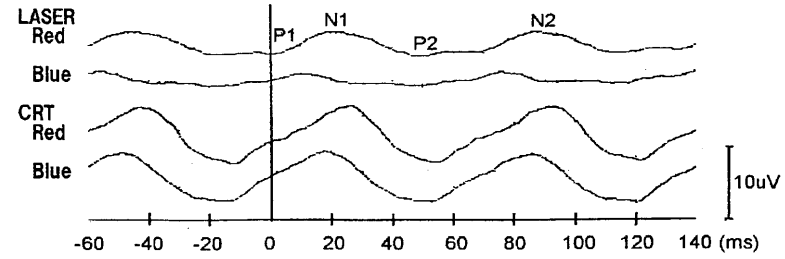


Fig. 2

Averaged waveforms of visual evoked potentials (VEPs) to laser and cathode-ray tubes (CRTs) stimulation at three different stimulus frequency; a. 1Hz stimulation, b. 7.5 Hz stimulation, and c. 15 Hz stimulation. Positivity of the VEPs was shown as a downward deflection. Electroencephalogram (EEG) was analyzed 300 ms before and 700 ms after each visual presentation at 1 Hz. EEG was analyzed 60 ms before and 140 ms after each visual presentation at 7.5 Hz and at 15 Hz.

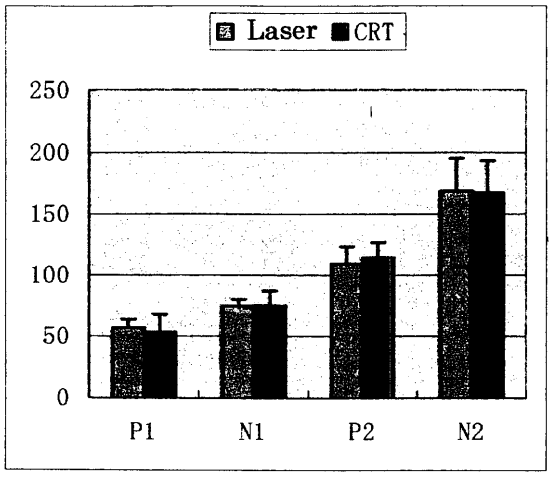


Fig. 3A

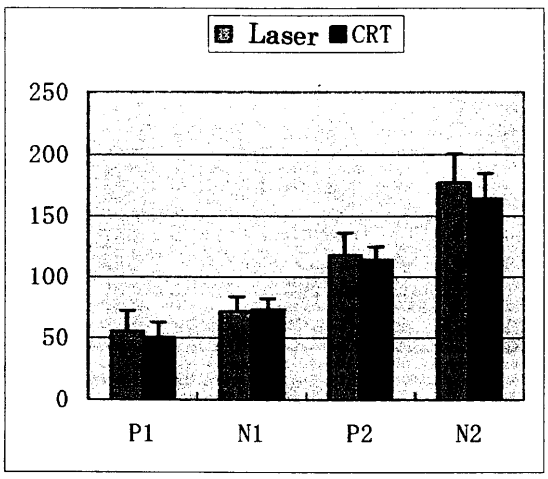


Fig. 3B

Mean and standard deviation of peak latencies (ms) in 1 Hz stimulation; A. red light stimulation (P1; n=11, N1; n=19, P2; n=19, N2; n=19), B. blue light stimulation (P1; n=8, N1; n=20, P2; n=20, N2; n=19).

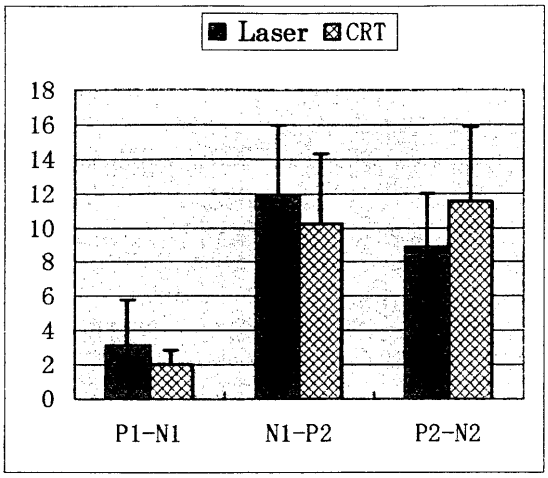


Fig. 4A

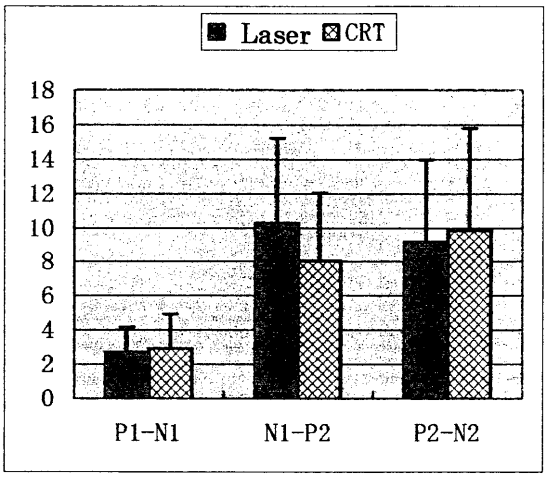


Fig. 4B

Mean and standard deviation of inter-peak amplitudes (μV) in 1 Hz stimulation; A. red light stimulation (P1-N1; n = 12, N1-P2; n = 19, P 2-N2; n = 19), B. blue light stimulation (P1-N1; n = 8, N1-P2; n = 20, P2-N2; n = 19).

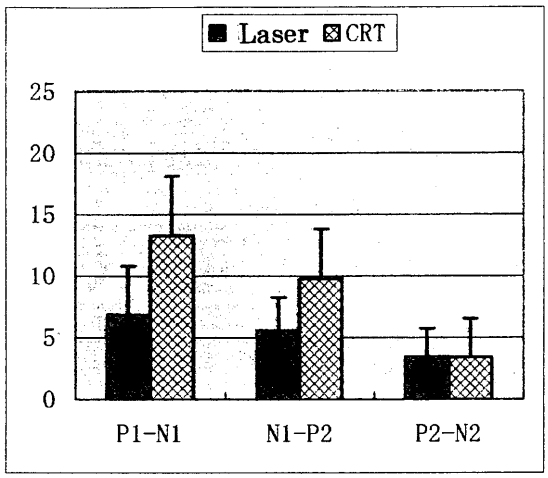


Fig. 5A

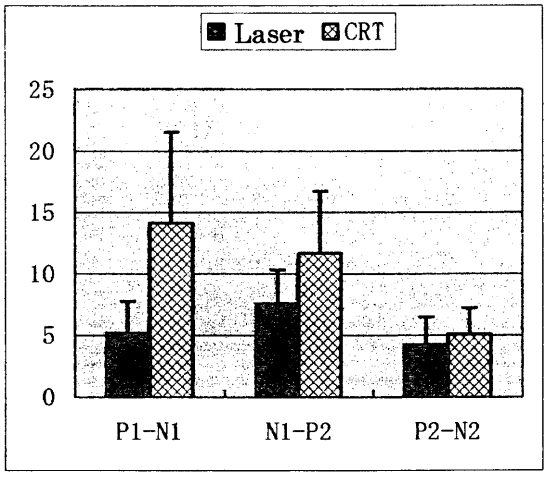


Fig. 5B

Mean and standard deviation of inter-peak amplitudes (μV) in 7.5 Hz stimulation; A. red light stimulation (P1-N1; n = 14, N1-P2; n = 20, P2-N2; n = 19), B. blue light stimulation (P1-N1; n = 7, N1-P2; n = 18, P2-N2; n = 16).

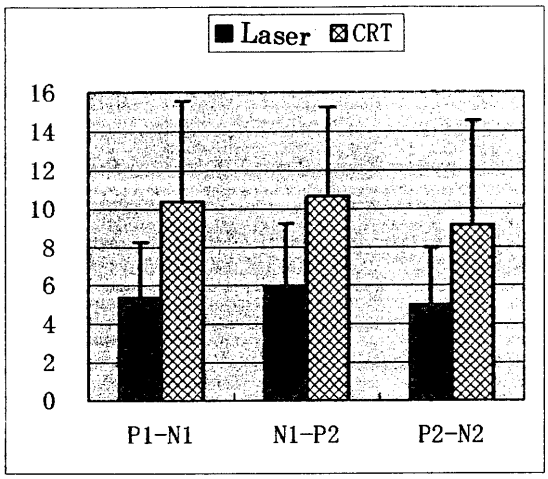


Fig. 6A

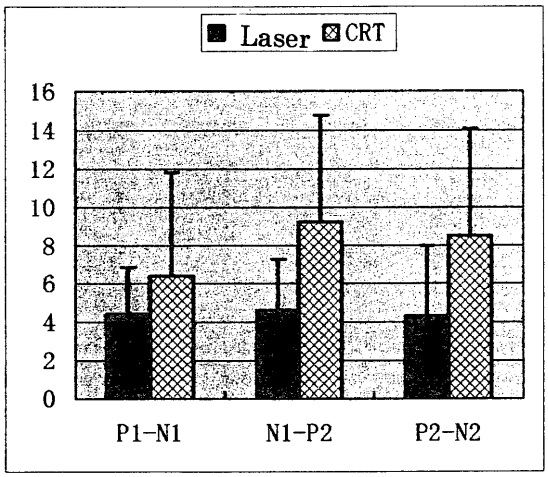


Fig. 6B

Mean and standard deviation of inter-peak amplitudes (μV) in 15 Hz stimulation; A. red light stimulation (P1-N1; n = 8, N1-P2; n = 20, P 2-N2; n = 20), B. blue light stimulation (P1-N1; n = 9, N1-P2; n = 18, P2-N2; n = 19).

± 2.695 vs 9.78 ± 4.036, $p<0.001$, N1-P2; 7.59 ± 2.750 vs 11.67 ± 5.049, $p=0.005$) (Fig. 5A and 5B).

The N1-P2 and P2-N2 amplitudes (μV) of VEP in 15Hz red light stimulation were significantly smaller with laser stimulation than with CRT stimulation (N1-P2; 5.96 ± 3.252 vs 10.63 ± 4.616, $p<0.001$, P2-N2; 4.65 ± 2.616 vs 9.21 ± 5.565, $p<0.001$). The N1-P2 and P2-N2 amplitudes (μV) of VEP in 15Hz blue light stimulation were significantly smaller with laser stimulation than with CRT stimulation (N1-P2; 5.00 ± 2.980 vs 9.12 ± 5.428, $p=0.001$, P2-N2; 4.33 ± 3.668 vs 8.50 ± 5.570, $p=0.001$). (Fig. 6A and 6B).

DISCUSSION

The wave-length curve of laser-beam light shows a very sharp peak either in red or blue stimulation, being quite different from wave-length curve of conventional CRT light in red or blue stimulation. The present study is the first which measured VEPs induced by laser stimulation. If high amplitude VEPs are induced by laser light stimulation to the eyes, a new laser display needs to be assessed for possible heath hazards such as PSE, since the risk of PSE by laser display is unknown and increased VEP amplitude may reflect increased excitation of visual cortex neurons. The differences between laser VEPs and CRT VEPs were assessed by using a paired t test to estimate the risk of inducing PSE by laser displays. It has been known that stimulation frequency greater than 3 Hz has potentially higher risk for PSE, the results on VEPs to 7.5 Hz and 15 Hz stimulations are more important than those to 1 Hz stimulation. We found that the peak-to-peak amplitude was significantly smaller with red and blue laser stimulation than with red and blue CRT stimulation, for P1-N1 and N1-P2 at 7.5Hz stimulation, and for N1-P2 and P2-N2 at 15Hz stimulation. We therefore postulate that laser does not produce more excitability to occipital cerebral cortex than CRT does. In our study, there were no statistical difference of VEP components between red laser and bluelaser stimulation, and between red CRT and blue CRT stimulation, although Takahashi et al. reported wave-length dependent photoparoxysmal response in photosensitive generalized epilepsies[14]. Our results proved that there was no evidence to say that laser stimulation is more dangerous than conventional CRT stimulation, although we couldn't conduct this examination in PSE patients and children in ethical reasons.

Acknowledgements

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