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Steady-state visual evoked potentials to computer monitor flicker

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Abstract

In the present study, steady-state visual evoked potentials (S-VEP) in response to amplitude-modulated light from a computer monitor (colour sVGA, 15-inch tube) have been examined. S-VEPs to computer monitors with different refresh rates (60 Hz or 72 Hz) and screen brightness (65 cd/m^2 or 6 cd/m^2) were recorded in 13 subjects with normal or corrected-to-normal vision. EEG samples were amplified, averaged and stored using Cadwell Excel EMG-EP recorder and a regression model was applied for the amplitude analysis. The mean values of S-VEP amplitude at 60 Hz were found to be significantly higher at 60 Hz refresh rate vs. 72 Hz ($F_{1,12} = 14.1$; $P = 0.003$). Effect of screen brightness ($F_{2,24} = 6.5$; $e = 0.62$; $P = 0.00075$) as well as the interaction effect of refresh rate and screen brightness ($F_{2,24} = 11.6$; $P = 0.0003$) were also found to be significant. Data obtained show that the characteristics of amplitude-modulated light from a computer monitor (frequency, brightness, waveform) are sufficient to elicit S-VEP, and the influence is not only restricted to the peripheral divisions of the visual system as it was shown earlier, but also extends to the central brain structures. © 1998 Elsevier Science B.V.

Keywords: Video display terminals (VDTs); Refresh rate; Amplitude-modulated light

1. Introduction

Interrelations between the dynamics of subjective perception of flickering light and brain cortical responses, steady-state visual evoked potentials (S-VEP), have been widely investigated using different kinds of visual stimulation. Van der Tweel and Lunel (1965) found S-VEPs to sinusoidally (100%) modulated light with luminance of approx. 6000 trolands and at temporal frequencies of approx. 60 Hz. Regan (1968) recorded distinctive evoked responses to sinusoidally modu-

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lated light at a depth of 33%, with frequencies of 45–60 Hz. Furthermore, S-VEP amplitude increased as stimulus frequency was increased near and beyond the CFF. Some other studies indicated that S-VEPs amplitude declined for frequencies above 50 Hz, but lower brightness and modulation depth were used in those cases (Sokol and Riggs, 1971; Sternheim and Cavonius, 1972).

The highest brightness can be reached by using stroboscope flashes or light emission diode (LED) stimulation. Stroboscope stimulation provides S-VEP records at temporal frequencies higher than 70 Hz (Brundrett, 1974). In normal subjects, mean values of critical frequency of photic driving were found at 72 flashes per second at ages 20–30 years and 69 flashes per second at ages 30–60 years (Celesia, 1982). Although the amplitude of S-VEPs varies significantly between subjects, the intrasubject variability (run-to-run variation) of the amplitude is relatively small (Tobimatsu et al., 1996).

S-VEPs are usually described by several parameters: amplitude and phase of individual harmonic components. However, at frequencies above 50 Hz, evoked potential is predominantly a pure fundamental response at the stimulus frequency (Regan, 1989).

Steady-state protocol is used in clinical practice for diagnosis of optic neuritis, multiple sclerosis and other neurological disorders (Celesia, 1984; Regan, 1989; Tobimatsu et al., 1994; Falsini and Porciatti, 1996). Abnormalities of S-VEP have also been observed in persons with subjective neurological symptoms and/or autonomic disorders. A slower decline of S-VEP amplitude with increasing flash frequency is found in persons complaining of headache and eyestrain in association with fluorescent tube light, as compared with normal subjects (Brundrett, 1974). Sandström et al. (1997) found that persons with subjective symptoms associated with computer work or TV watching had a higher amplitude of S-VEP at frequencies above CFF in comparison with a control group. Stroboscope stimulation was used in both studies.

These data show that S-VEP can be recorded at frequencies close to refresh rates commonly used in modern computer monitors. The cathode ray tube based monitor refreshes the screen at a rate of 60–75 Hz. Any particular letter or symbol on the screen could be considered as a periodic light stimulation with 16.7 ms (60 Hz) or smaller interstimulus intervals at 100% of modulation depth. The aim of the present study was to examine the steady-state visual evoked potentials to computer monitor ('video display terminal', VDT) flickers at different screen refresh rates and luminance values.

2. Methods and materials

Thirteen healthy volunteers (eight male and five female, 19–41 years old) with normal or corrected-to-normal vision participated in the study. Subjects were seated in a dimly illuminated, sound attenuated room facing a colour sVGA videomonitor (Dell, USA) with a 15-inch tube at a distance 70 cm. Shorter distances led to a rapid increase of artefact contamination due to electrical fields from the monitor. To keep the subject in a relaxed condition, the natural pupil was used.

During the experimental session, each subject received four 'screen exposures' with different refresh rates and luminance (colours) as well as a control exposure (see below). Screen exposures I and II: white background with only a black centre cross (thin lines 4×4 cm) for eye fixation; refresh rates 60 Hz or 72 Hz. The space- and time-averaged luminance of the display area was 65 cd/m^2. Screen exposures III and IV: deep-blue background and white centre cross with refresh rates either 60 Hz or 72 Hz. The averaged luminance of the display area was 6 cd/m^2.

Residual electric fields originating from the monitor might lead to artificial oscillations with the fundamental frequency equal to monitor refresh rate. To exclude such artefacts, control records (monitor screen was covered with a lightproof paper sheet, but with all other conditions unchanged) were used. Furthermore, S-VEP to standard Cadwell LED matrix at frequency 60 Hz served as 'positive' control, since this type of stimulus action evoked the highest individual re-