EFFECT OF MONO-SPECTRAM RADIANT ON AUTONOMIC NERVOUS SYSTEM

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This study investigated the effects of certain specific wavelengths of lighting on the autonomic nervous system (ANS) using the heart rate variability (HRV) as an index. Six subjects with normal color vision participated in this study between 15:00 and 17:00 hr to neutralize any visual differences arising from circadian rhythm. The environmental conditions of the laboratory were maintained in complete darkness and the temperature was equilibrated at 24□ with a relative humidity of 60%. Subjects were only subjected to light stimulation when the pupil of eyes attained a minimum size of 2 mm by projecting illumination equalized with the same spectral radiance of 500-700 nm with 50-nm internal radiance. HRV was calculated from electrocardiogram (ECG) with systematic respiratory control at 0.35 Hz. The results suggest that illumination with certain wavelengths may induce ANS activation.

Introduction

Light or illumination is essential in our daily livelihood. If light ceased to illuminate the Earth, current living systems/forms would follow suit; all plants would perish and besides hunger, our visual system would not be able to perceive the world surrounding us. As such, light has to prevail to keep our body and soul/mind in tune with the world around us, and provide us with a livelihood with respect to achieving, in particular, visual functionality. In other words, light has to be consistently illuminating our environment to activate the functionality of our visual system. Despite the undeniable life-supporting existence of light, issues on the effects of illumination on the living system, including the nervous systems and other organic tissues/structures, have recently surfaced. On

showering our bodies with different kinds of light with various spectra and intensities, diverse influences with multivariate effects may be elicited and some of these outcomes may be more a problem than benefit. In this study, we focused on the effects of light with specific wavelengths on the ANS (autonomic nervous system) of humans.

Materials and Methods

Six university students with normal color vision, who volunteered and participated in the study, were exposed to light stimuli with constant spectral radiance at random while their heart rate variability (HRV) was monitored. Experiments were performed within the fixed period of 15:00-17:00 hr to nullify effects on visual gain due to circadian rhythm[5][6][9]. The laboratory was maintained in total darkness, and the temperature was equated at 24℃ with 60% relative humidity. Illumination with constant spectral radiance[4][5] of 5000/550/600/650/700 nm afforded by a W-type mono-spectrum filter (ASAHI SPECTRA CO.,LTD) via a defuser (A032-3M, Misholiday) was employed as light stimuli. Projection of light stimuli was only performed when the pupil size of eyes of subjects attained a minimum diameter of 2 mm. This was done to condition the eye and neutralize any experimental error before initiation of any experiment in a series, as variation of the pupil size would definitely occur if the eyes were subjected to previously different light stimuli prior to the experiment. A halogen fiber illumination device (PHL-150) was used as the light source. The time-schedule for the experiment (Table. 1) allowed 5 min for light adaptation[7] before illuminating 15-min light stimulation. The measurement index, HRV, was employed with respiratory control designated at 0.35 Hz. Measurement periods, each of 2-min interval, were designated during the 5-min light adaptation and 3 times during the 15-min light stimulation (i.e., 2 min x 3), accounting for a total of 6 min (x 3-time) measurement during light stimulation. The subjects were consistently seated in a resting position before and during the experiments.

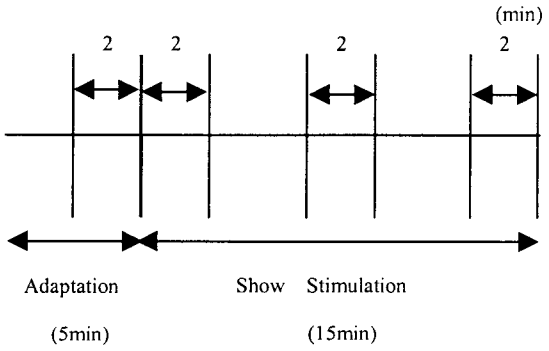

Table.1(Time Schedule)

The low-frequency (LF) and high-frequency (HF) components were calculated from the HRV[2], and quantitative analysis employed the values derived by subtracting the value during stimulation by the control. Three-way ANOVA was used to verify the relation: LF x HF x LF/HF, and the respective items were subjected to Student's t-test evaluation.

Results

LF, which is regulated by both the SNS(sympathetic nervous system) and PNS(parasympathetic nervous system), indicated major effects on the subjects with specific light wavelengths (Fig. 1). From the Student's t-test,

illumination with 650-nm wavelength elicited effects more significant than those observed with 550-, 650- and 700-nm wavelengths.

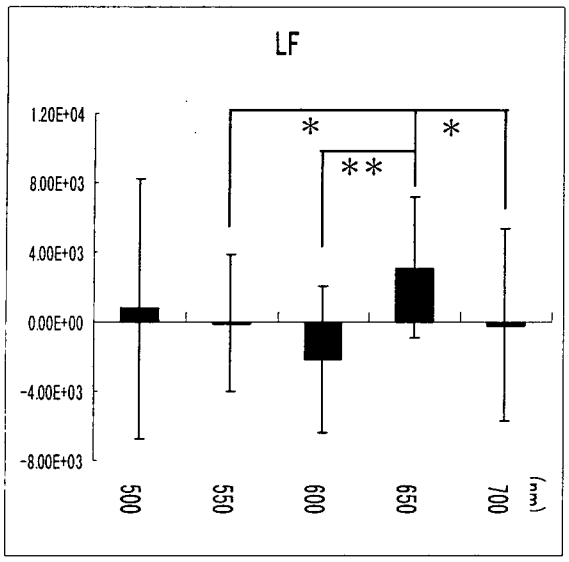

Fig.1(LF ＊:p<0.05 ＊＊:p<0.01)

HF, which is closely associated with the PNS, did not manifest either major or mutually interactive effects (Fig. 2). Light illumination with 650-nm wavelength induced a significantly more pronounced effect compared with that of 550-nm wavelength illumination.

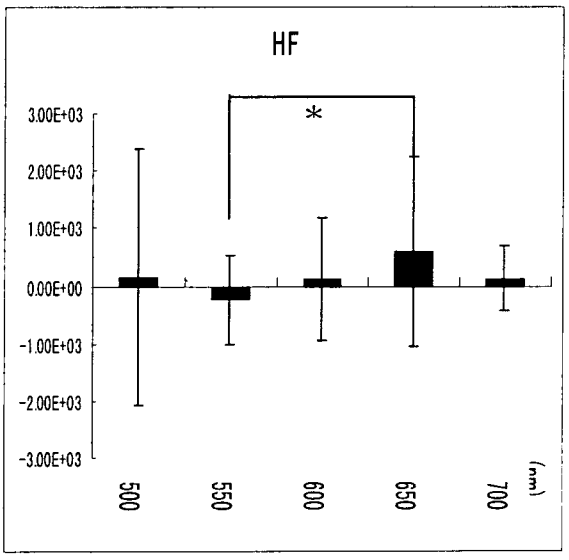

Fig2 (HF ＊p<0.05)

In the SNS-related LF/HF, major effects were observed in wavelength and subjects (Fig. 3).

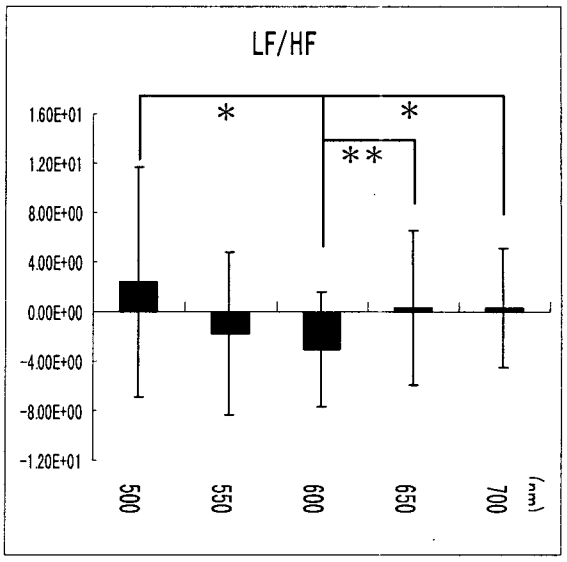

Fig.3(LF/HF ＊:p<0.05 ＊＊:p<0.01)

Analytical results based on Student's t-test demonstrated that illumination with 600-nm wavelength induced significantly lower effects compared with those of 500-, 650- and 700-nm wavelengths.

Discussion

The index, LF/HF, representing SNS decreased to 600 nm. In short, in the spectral luminous efficiency curve of visible range illumination, SNS activity decreased with light illumination where $V(\lambda)=0.7$. Two possible explanations may account for this phenomenon: effects could have been induced by either "colors" or "illuminance". In "color", orange color is illuminated at a wavelength of 600 nm, and this color might have elicited inhibitory effects on the SNS per se. In "illuminance", the effects might have induced by the illuminance of illumination. By employing an

index of the phase response (rhythm-phase changes in response to light pulses) of behavioral rhythm of hamsters to elucidate the light wavelength/illumination interval, Takahashi et al.[6] have revealed that a maximum phase forward shift is induced with 500- to 530-nm illumination when light pulses are irradiated for 15 min. However, as phase changes are dependent on light intensity, irradiation time and animal species, data obtained from hamsters may not be exactly adopted for humans. In any case, if projection with 600-nm illumination in the present study coincided with either forward or backward shift of circadian phase in humans, shifting of the phase to attenuate SNS activities during HRV measurement might have been induced.

From the plot of the HF component, it is clear that major effects on the wavelength in PNS were not established. Moreover, as for the difference among the various wavelengths, only the effect of illumination with 650-nm wavelength surpassed that of illumination with 550-nm wavelength. However, the LF/HF component was not significant when illuminated with these wavelengths, and where LF indicated significant effects, 650-nm illumination manifested the greater outcome. From these findings, activation of the HF component could have been induced by illumination at 650-nm wavelength. Similar to the LF component, which is affected by both SNS and PNS activities, LF/HF in this study portrayed comparable attenuation with 600-nm illumination. Either the color (orange) of 600-nm illumination attenuated the LF component, or a phase-response (see above) was induced. In addition, activation of the LF component was induced with 650-nm illumination. With regard to this, two possible explanations are conceivable: effects due to phase response and/or activation of LF component with the color, red, projected at 650-nm illumination. In either case, one issue remains to be answered. In the case of 700-nm illumination where a similar color ought to have projected, the LF component was not activated. This could be attributed to the difference in illuminance, rendering different perception of brightness/luminescence by the subjects. As our study was designed with projection of a constant spectral radiance on illumination with various wavelengths, brightness perceived by the subjects was dependent on the spectral luminescence efficiency. In other words, even with the same color by projecting lights of 650 and 700 nm, brightness perceived by the subjects was greatly dissimilar; perception of 700 nm was relatively dark compared with 650 nm. As such, the present experimental results were probably due to a discrepancy in the phase response generated by a difference in illumination intensity with light of two different wavelengths. In accommodation of illumination with light of 550-nm wavelength, the brightest luminescence, activation of the ANS was not established when the respective plots with this wavelength were focused. From this finding, higher luminescence does not always imply ANS activation.

With reference to the plots of LF/HF and LF at 600 and 650 nm, the effect with the latter was significantly greater. As statistical difference in effects was established with a mere narrow range of 50 nm, illumination between 600 and 650 nm connoted certain specific significance/implication for humans.

Although certain issues remain unanswered,

changes in the phase response of humans with lights of various illumination intensities and the effects of their respective colors on ANS activity are hence warranted in follow-up studies.

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