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Abstract

The apparatus to measure multi-point critical flicker fusion frequency (MCFF) was devised for more precise determination of the critical flicker fusion frequency (CFF). Using this apparatus, the variations in flicker value after the work load of the television (TV) game, the Kraepelin using the video display terminal (VDT-Kraepelin) and the paper-Kraepelin were examined in order to test its practical applicability. The following results were obtained. The degree of decrease in the CFF values of some peripheral eye fields was larger than that on the central field of both eyes (ordinary CFF) after work load. The variation rates of the central and the peripheral flicker values were measured before and after loading in each work, and the correlations of variation rates between two CFF values among them were calculated. The numbers of peripheral eye fields showing significant correlation of variation rates between two eye fields in the TV game and the VDT-Kraepelin, were greater than those in the paper-Kraepelin.

KEYWORDS: VDT work load, multi-point critical flicker fusion frequency(MCFF), work fatigue

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Multi-Point Flicker Recognition Apparatus and Its Application for Video Display Terminal Work

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The apparatus to measure multi-point critical flicker fusion frequency (MCFF) was devised for more precise determination of the critical flicker fusion frequency (CFF). Using this apparatus, the variations in flicker value after the work load of the television (TV) game, the Kraepelin using the video display terminal (VDT-Kraepelin) and the paper-Kraepelin were examined in order to test its practical applicability. The following results were obtained. 1) The degree of decrease in the CFF values of some peripheral eye fields was larger than that on the central field of both eyes (ordinary CFF) after work load. 2) The variation rates of the central and the peripheral flicker values were measured before and after loading in each work, and the correlations of variation rates between two CFF values among them were calculated. The numbers of peripheral eye fields showing significant correlation of variation rates between two eye fields in the TV game and the VDT-Kraepelin, were greater than those in the paper-Kraepelin.

Key words : VDT work load, multi-point critical flicker fusion frequency (MCFF), work fatigue

Persons using video display terminals (VDT) are increasing, as various business or game machines are being introduced into offices or homes widely. Studies on the fatigue of people using VDTs have been done from many fields and the flicker fusion frequency (CFF) value was used as the index of mental fatigue (1-9). On the other hand, authors developed the equipment for measuring the multi-point critical flicker frequency (MCFF), which was advanced CFF (10, 11). As the assay is controlled by the microcomputer in this equipment, the measured value is expected to be exact. Moreover, as the CFF values can be printed out to the printer, misrecord can be protected and the period of examination can be saved. For the application of the MCFF apparatus, comparison between the peripheral CFF values and the central CFF value was needed and the work load of two types of the VDT work and one type of the Non-VDT work were studied by the MCFF. In addition, the near-point accomodation and the pulse rate were measured as the other indices of the degree of fatigue for work (12).

Materials and Methods

Examinees. Three women, from 21 to 23 years old, who did not use a VDT in their usual business, were employed in this study. Each person did each work six times on different days.

Works. The loaded works were a television (TV) game using a VDT and keyboard of a microcomputer (TV game), the Kraepelin test using a

VDT and the keyboard of the same micro-computer (VDT-Kraepelin). The controlled work was the Kraepelin test given on paper, that is, the usual Kraepelin test, (paper-Kraepelin). Even inexperienced subjects could easily understand these works and do them at the same level as experienced subjects. Therefore, the work load could be evaluated correctly. The work load of the paper-Kraepelin was done for comparison between under VDT and non-VDT. The micro-computer used had a 10-inch green Cathode Ray Tube (CRT). In the TV game, the picture was displayed on CRT by using 320×200 dots per image and the displayed picture was drawn only by the simple lines. In the VDT-Kraepelin, the numeric character was displayed on CRT by using 8×8 dots per character, 40 characters per line and 25 lines per image. Twenty characters per line and 5 lines per image were displayed on one screen in the VDT-Kraepelin. Each work session was taken 30 min.

Measures of work load. The MCFF was measured according to the method reported by Osaki *et al.* (10, 11), with a micro-computer at the central retina of both eyes (Both eyes CFF :

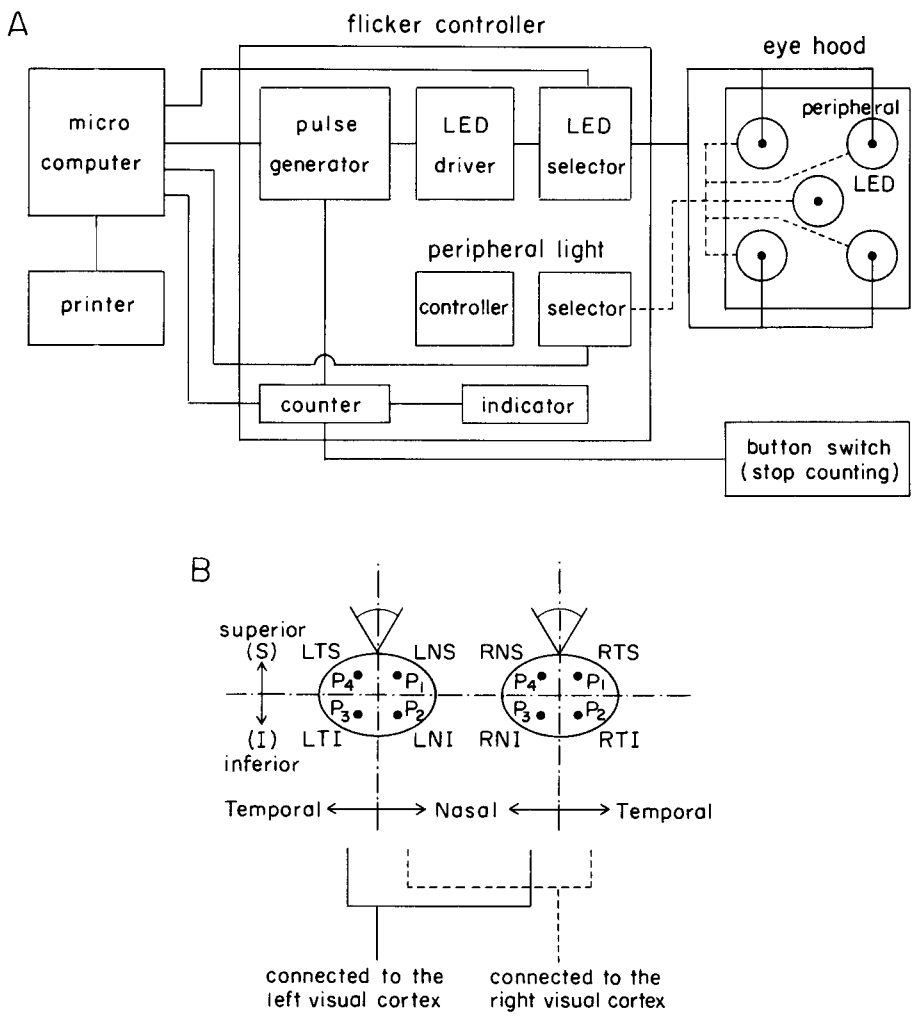

Fig. 1 (A) The block diagram of the equipment of the MCFF measurement and (B) the parts of the examinee's retina which could be measured in the MCFF and the parts of the visual cortex connected to them. Abbreviations : See Table 1.

BCF), the central retina of the right eye (Right eye CFF : RCF), the temporal and superior quadrant of the peripheral retina of the right eye (Right eye, Temporal and Superior CFF : RTS-CF), the temporal and inferior quadrant of the peripheral retina of the right eye (Right eye, Temporal and Inferior CFF : RTI-CF), the nasal and superior quadrant of the peripheral retina of the right eye (Right eye, Nasal and Superior CFF : RNS-CF), the nasal and inferior quadrant of the peripheral retina of the right eye (Right eye, Nasal and Inferior CFF : RNI-CF), and the corresponding regions of the left eye (LCF, LTS-CF, LTI-CF, LNS-CF and LNI-CF) (Fig. 1). The pulse rate was measured with a pulse meter and the near-point accommodation with a near-point accommodation meter of the Yamaji type. These tests were given before and after work.

Analysis of data. The rate of variation was used for analysis in this report. It was calculated by:

$$\text{Rate of variation (\%)} = \frac{\text{Value at finish} - \text{Value at beginning}}{\text{Value at beginning}} \times 100.$$

The mean values of the above-mentioned measures were calculated for each type of work and tested for significance under the hypothesis H_0: the rates of variation are 0, that is, the values before and after works are equal (13). About MCFF, correlation coefficient between CFFs on each part of the retina were calculated and its significance test was done, too (14, 15).

Results

Changes in MCFF. In order to examine the MCFF, two methods were used. The one was the t-test of degree of the change in the MCFF values after work load and the one was the correlation between two MCFF values (13).

Degree of the change in MCFF values. Fig. 2 shows the average rate of variation of the MCFF with all the subjects after each type of work. As shown in Table 1, CFFs on all eye fields significantly decreased in three types of work. The eye fields showing the most decreasing rate of CFF values

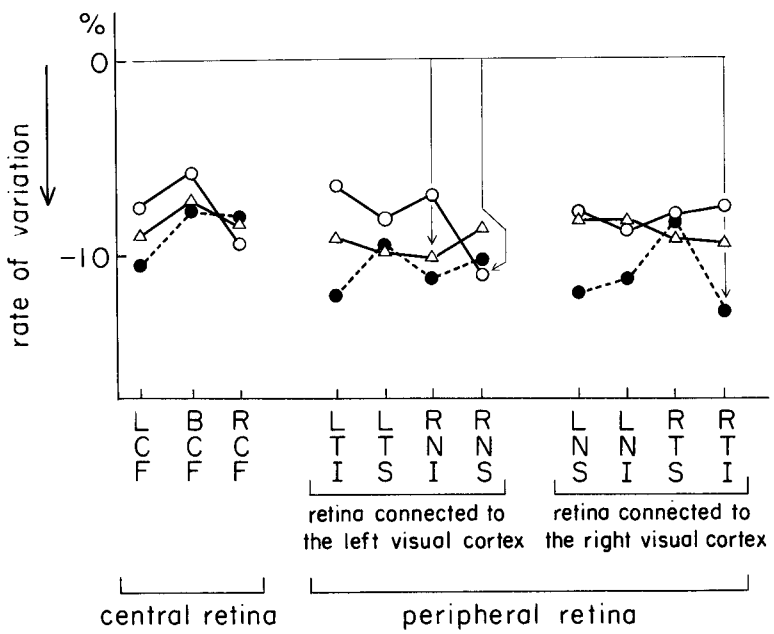

Fig. 2 The rate of variation of the MCFF in each type of work (mean for all subjects). TV-game (△), VDT-Kraepelin (○) and paper-Kraepelin (●). Abbreviations: See Table 1.

Table 1 The rate of variation[a] in the television (TV) game, video display terminal (VDT) Kraepelin and paper-Kraepelin.

Items	Fields[c]	The rate of variation or increment (M±SD)[b]		
		VDT-work		Non-VDT-work
		TV game	VDT-Kraepelin	Paper-Kraepelin
Multi-point critical flicker fusion frequency (MCFF)	BCF	−7.19**±4.25	−6.03**±4.51	−7.84**±3.01
	RCF	−8.37**±4.59	−9.51**±5.08	−8.30**±4.40
	RTS	−9.07**±5.66	−8.03**±4.68	−8.26**±4.16
	RTI	−9.34**±4.70	−7.50**±5.30	−12.73**±5.53
	RNI	−9.98**±6.43	−7.04**±6.13	−11.15**±4.60
	RNS	−8.59**±5.60	−10.78**±7.07	−10.22**±5.51
	LCF	−9.17**±3.46	−7.75**±4.81	−10.66**±4.02
	LNS	−8.07**±3.74	−7.94**±5.88	−11.84**±6.89
	LNI	−8.37**±4.53	−8.67**±5.07	−11.22**±6.46
	LTI	−9.17**±4.52	−6.63**±4.33	−12.04**±5.21
	LTS	−9.82**±5.99	−8.19**±5.16	−9.75**±7.66
Near-point accommodation	Right	—	5.85±10.62	−3.09±12.22
	Left	—	7.50±15.73	2.28± 8.27
Pulse rate		−1.18±13.46	−9.82**±12.49	−7.67*±11.62

a: Rate of variation (%) $= \frac{\text{value at finish} - \text{value at beginning}}{\text{value at beginning}} \times 100$.

b: The value was tested for the significance under the hypotheses H_0: the rates of variation are 0, that is, the values before and after works are equal (*: significant at 5% level. **: significant at 1% level).

c: BCF (the central retina of both eyes); RCF (the central retina of the right eye); RTS (the temporal and superior quadrant of the peripheral retina of the right eye); RTI (the temporal and inferior quadrant of the peripheral retina of the right eye); RNI (the nasal and inferior quadrant of the peripheral retina of the right eye); RNS (the nasal and superior quadrant of the peripheral retina of the right eye); LCF, LNS, LNI, LTS, LTI (corresponding regions of the left eye).

were RNI in the TV-game, RNS in the VDT-Kraepelin and RTI in the paper-Kraepelin.

For the evaluation on significance of the changes in peripheral CFF values due to the work load, *t*-test was employed. As the results, *t*-values, which were obtained from the variation of the flicker values in the central retina of each eye or in some peripheral retina, were larger than that in BCF (ordinary CFF). Especially in the VDT-Kraepelin, *t*-value obtained from variation rate in the eye fields of 9 parts out of 10 parts was larger than on BCF.

Correlation of the variation rates of flicker values after work between CFFs on each retina. The correlation of the rate of variation between two CFFs selected from the peripheral CFFs and the central CFFs was calculated respectively. The typical scatter diagram of the relation of BCF and RCF or LCF is shown in Fig. 3. The results were summarized in Fig. 4.

In the TV game

Correlation of variation rates in three combinations among three central CFFs. The statistically significant correlations were recognized in all three combinations between BCF and RCF, between BCF and LCF, and between RCF and LCF.

Correlation of variation rates in four combinations between the central CFF (RCF or LCF) and one of four peripheral CFFs on each eye. The significant correlations were recognized between RCF and RTS on the right eye, between LCF and LTI on the left eye, and between LCF and LNS on the left

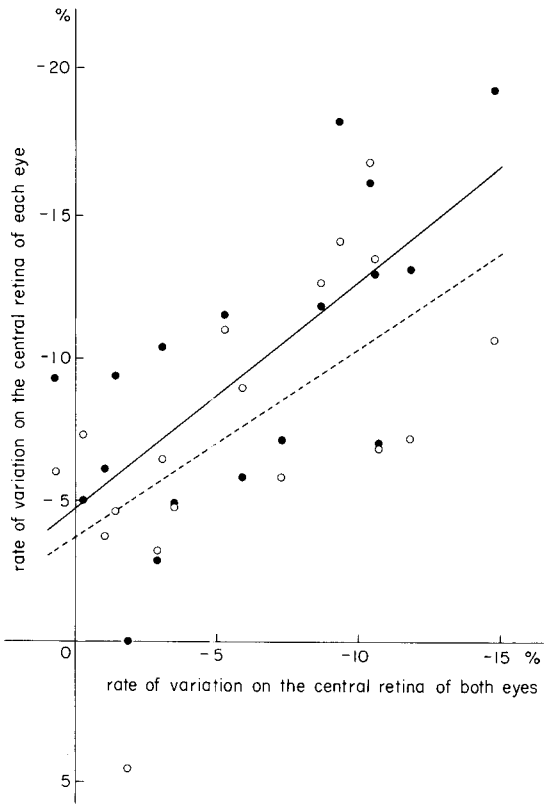

Fig. 3 The scatter diagrams and regression lines between BCF and RCF (●, ——) and between BCF and LCF (○, ·····) in the VDT-Kraepelin.

eye. Thus the significant correlations were recognized in three cases out of 8 cases.

Correlation of variation rates in six combinations among four peripheral CFFs on each eye. The significant correlations were recognized in five combinations on the right eye and in two combinations on the left eye. Thus, the difference of the combination numbers showing correlation was recognized between the right and the left eye.

In the VDT-Kraepelin

Correlation of variation rates in three combinations among three central CFFs. The correlations were recognized in three combinations, similar to the result of the TV game.

Correlation of variation rates in four combinations between the central CFF and one of four peripheral CFFs on each eye. The significant correlations were recognized in three combinations on the right eye and in two combinations on the left eye.

Correlation of variation rates in six combinations among four peripheral CFFs on each eye. The significant correlations were recognized in five combinations on the right eye and in three combinations on the left eye. The tendency has appeared similar in the TV game.

In the paper-Kraepelin

Correlation of variation rates in three combinations among three central CFFs. The significant correlation was recognized in only one combination, that is, BCF and RCF. This result of paper-Kraepelin was different from that of two types of VDT work.

Correlation of variation rates in four combinations between the central CFF and one of four peripheral CFFs on each eye. The significant correlation was recognized in none of combination on the right eye and in one combination between LCF and LNS on the left eye. Thus the significant correlations were recognized scarcely.

Correlation of variation rates in six combinations among four peripheral CFFs on each eye. The significant correlations were recognized in none of combinations on the right eye and in all six combinations on the left eye. The difference between the right and left eye was clear and this tendency was reverse in the VDT works.

The near-point accommodation and the pulse rate. Though the distance for the near-point accommodation became a little longer in the VDT-Kraepelin, its increase was not significant.

The pulse rate significantly decreased after the VDT-Kraepelin and paper-Kraepelin, but did not after the TV game. There was no clear difference between VDT works and Non-VDT work.

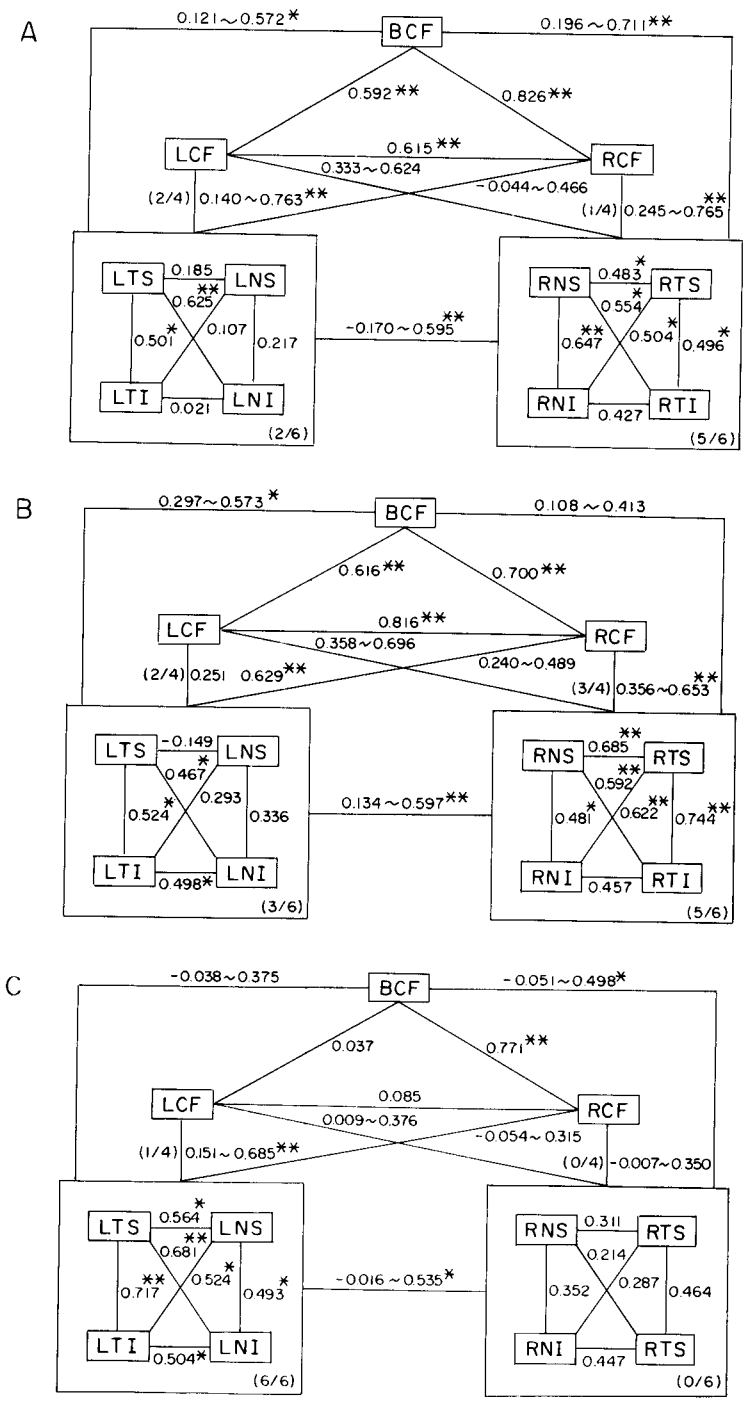

Fig. 4 The correlation coefficients between each part of the retina in the MCFF (*; significant at 5% level. **; significant at 1% level). Parentheses; (number of combinations showing significant correlations/total number of combinations), significant level is 5%.

The near-point accommodation and the pulse rate were not so efficient to evaluate the VDT work load, at least in this study in which the work was continued for a short time.

Discussion

MCFF apparatus allows to determine flicker value at each quarter part of the retina of right or left eye. Present experiment confirmed following points for the application of this MCFF apparatus for fatigue examination.

Decreasing rates of CFF caused by work load and significance of those calculated by statistical t-test. In the VDT work, t-values calculated by the significance test from the difference of the mean and the variation of decreasing rate were larger on many peripheral CFF than on BCF used commonly. Similar fact was also observed on right and left central CFFs, *viz.* RCF and LCF. These facts were considered to be available for examining flicker test. In the peripheral CFFs, the parts of retina, having larger decrease rate and/or larger t-value than BCF, were found and, also recognized that the part was different in the types of work. Even though the case of decrease in BCF (usual CFF) is not statistically significant, the possibility remained that the significant decrease could be observed in these peripheral CFFs.

Analysis by correlation about independency of CFFs on each part. In case that the correlations recognize between two peripheral CFFs among the four peripheral CFFs, these peripheral CFFs are thought to be dependent and the significance of measurement of CFFs on each part of retina is weakened. From this point of view, the correlation of the variation rates of CFF values after work between two preipheral CFFs was examined. In two types of VDT work, *viz.* the TV game and the VDT-Kraepelin, the significant correlations were recognized in all three combinations among three central CFFs (BCF, RCF and LCF). So the changes caused by the work load seemed to be parallel to each other in these cases.

Between the right or left central CFF and one of four peripheral CFFs on each eye, the numbers showing correlations were fairly larger in the VDT-Kraepelin (5/8), but smaller in TV game (3/8) and in paper-Kraepelin (1/8). Data indicated the changes in the peripheral CFFs seemed to be independent with that in the central CFF, and the measurement of both central and peripheral CFFs is necessary.

Among four peripheral CFFs on each eye, the numbers of peripheral CFF showing good correlation were larger in right eye but they were smaller in left eye in VDT works, and these numbers were larger in left eye and smaller in right eye in paper-Kraepelin. As there found some parts of peripheral CFFs which changed independently by work load, the measurement of these peripheral CFFs is necessary.

Further study about the physiological significance involving right or left visual cortex of the change on each part of CFFs is necessary.

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