Evaluation of High Quality LCDs Displaying Moving Pictures, on the Basis of the Form Obtained from Statokinesigrams

Kazuhiro FUJIKAKE[1], Masaru MIYAO[1,2] Ryumon HONDA[3], Masako OMORI[2], Yasuyuki MATSUURA[4] and Hiroki TAKADA[5]*

[1]*Graduate School of Information Science, Nagoya University, Chikusa-ku, Nagoya 464-8601, Japan*
[2]*Information Technology Center, Nagoya University, Chikusa-ku, Nagoya 464-8601, Japan*
[3]*Department of Hygiene, Kanazawa Medical University, Daigaku, 1-1, Uchinada, Ishikawa 920-02, Japan*
[4]*Graduate School of Natural Science, Nagoya City University, Mizuho-ku, Nagoya 467-8501, Japan*
[5]*Gifu University of Medical Science, 795-1 Nagamine, Ichihiraga, Seki 501-3892, Japan*
**E-mail address: takada@u-gifu-ms.ac.jp*

(Received May 24, 2007; Accepted November 4, 2007)

Keywords: Liquid Crystal Displays (LCDs), Optically Compensated Bend (OCB) Display, Moving Pictures, Statokinesigram (SKG), Sparse Density (SPD)

Abstract. Optically compensated bend (OCB) mode liquid crystal display (LCD) panels are newly developed displays that have excellent moving picture quality, which is almost equivalent to that of a cathode ray tube (CRT). A high performance, with a brightness of 600 cd/m^2 and a contrast ratio of 600:1, was obtained by using the pseudo-impulse driving method to insert a black period between two continuous frames; further, the blinking backlight method was used. By measuring the centre of gravity of the human body, we compared statokinesigrams obtained from subjects viewing moving maps on OCBs and on conventional model displays. The results suggest that OCBs are better than conventional displays for scrolling map images such as those in car-navigation systems.

1. Introduction

Today, liquid crystal displays (LCDs) are extensively used as general visual display terminals. They have several features such as large display, reduction in weight and size because of miniaturization, and low power consumption. However, users viewing movies on LCDs often complain of blurring and bleeding of the images.

Many researches have been conducted previously for obtaining legible character displays on the screen. The optimal brightness ratios required for displaying characters as well as the background were obtained from ergonomic experiments (KIMURA *et al.*, 1990; SCHARFF and AHUMADA, 2002). SCHARFF *et al.* (2000) also examined the legibility of the colors in the characters. In comparison with backlit LCDs, it has been observed that non-backlit LCDs reduce the focusing speed among young subjects and reading performance among middle-aged subjects (MIYAO *et al.*, 1993). For the readability of sufficiently large characters, no significant difference between the high- and standard-resolution video

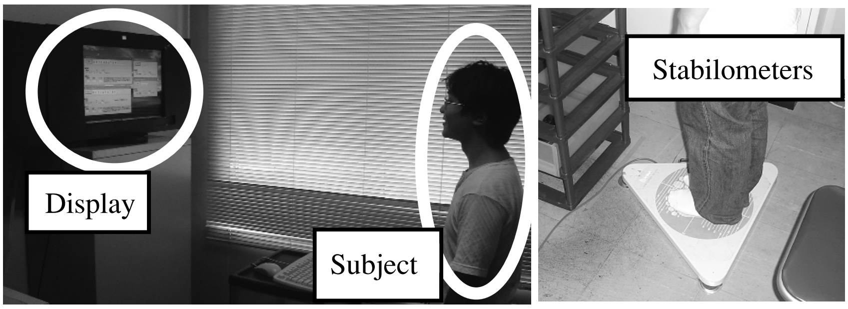

Fig. 1. Experiment setup.

display terminals (VDTs) could be detected. However, for very small characters, a higher resolution improved readability (MIYAO *et al.*, 1989). OMORI *et al.* (2002) and HASEGAWA *et al.* (2005) stochastically discussed the aspect ratio involved in the readability of characters on the LCDs of mobile phones. On the other hand, optokinetic stimulation (OKS) is known to trigger motion sickness (LESTIENNE *et al.*, 1977). Anterior displacement of the center of pressure on the force plate was observed during human body sway. In particular, the displacement increased when random dots were rotated vertically at a speed of 40–60 deg/s as an OKS to the subjects. However, there has been no study to evaluate the LCDs viewed by the subjects using the data obtained from statokinesigrams (SKGs).

When users viewed moving pictures on LCDs, they experienced visually induced motion sickness that was caused by a disagreement between visual stimulation and stimulation of the inner ear (REASON and BRAND, 1975). The blurred images on the LCDs sometimes induced "image sickness" in viewers, which is an unpleasant feeling similar to that of motion sickness. Significant increases in the postural sway were observed during the image sickness induced by simulators (STOFFREGEN and SMART, 1998).

In this study, a newly developed LCD was compared with a previous model. By using stabilometers, we compared the sway of the centre of gravity in the case of the abovementioned two displays. The centre of gravity when the subjects were viewing moving maps was compared.

2. Method

We adjusted the temperature in the experiment room, which was kept dark, to 25°C. The photograph shows the experimental setting.

The subjects stood without moving on the detection stand of a stabilometer (G5500, Anima Co., Ltd) in the Romberg posture with their feet together for 1 minute before the recording of the sway. Each sway of the centre of gravity was then recorded with a sampling frequency of 20 Hz.

Subsequently, the subjects first stood with their eyes open for 1 minute (resting state); they then viewed each display with a moving map task for the following 1 minute (testing state). Subsequently, they closed their eyes for 1 minute. The visual distance was 1 m (Fig. 1).

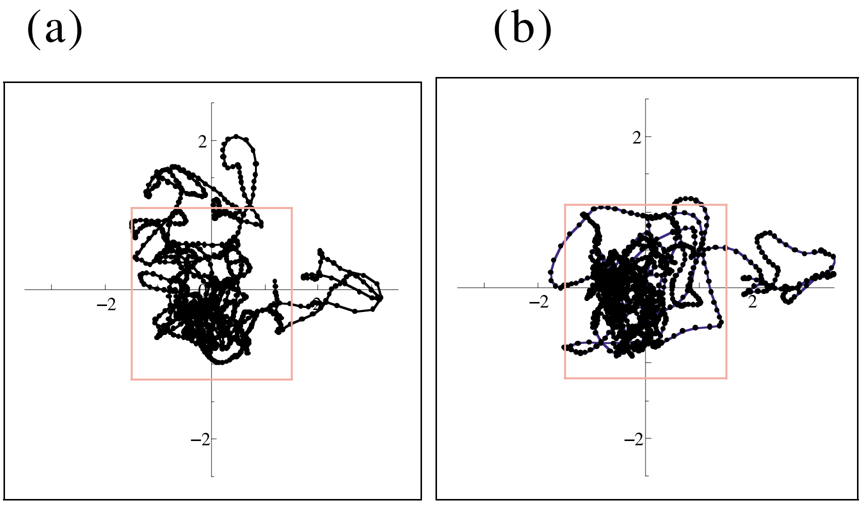

Fig. 2. Typical examples of SKGs extracted from a subject (a) viewing the display of a previous LCD model (the previous model display), (b) viewing the OCB display.

Display device

We used two types of displays-the display of a previous LCD model and an optically compensated bend (OCB) display. The former was a hold-type display of a typical LCD model, while the OCB display was a newly developed pseudo-impulse drive type.

Subjects

The subjects were six persons from 20 to 27 years old with no history of equilibrium function problems.

Moving map task

The map of a fictitious city was scrolled from left to right. The subjects had to read the name of a place from the moving map as a moving map task. The scroll speed of the moving map was 20 dots/s.

Evaluation

We calculated several indices that are commonly used in the clinical field (SUZUKI *et al*., 1996) for the SKGs, such as 'area of sway', 'total locus length', and 'total locus length per unit area'. In addition, new quantification indices termed 'sparse density (SPD)', 'total locus length of chain 1', and 'total locus length of chain 2' were also estimated (Appendix).

3. Results

Typical SKGs, which represent examples of the results from stabilometry, are shown in Fig. 2.

Table 1. Results from stabilometry (mean ± standard deviation).

Index	Resting state	Previous model display	OCB display
Area of sway	2.3 ± 1.0	6.8 ± 3.4	4.9 ± 2.7
Total locus length	53.8 ± 16.4	96.5 ± 21.4	96.3 ± 22.0
Total locus length per unit area	38.8 ± 9.1	52.2 ± 10.4	56.3 ± 11.6
Sparse density S_2	1.3 ± 0.1	1.9 ± 0.2	1.7 ± 0.3
Sparse density S_3	2.0 ± 0.4	3.3 ± 0.4	2.7 ± 0.7
Total locus length of chain 1	1.9 ± 1.4	3.3 ± 1.6	3.0 ± 1.5
Total locus length of chain 2	1.7 ± 1.4	2.9 ± 1.5	2.4 ± 1.5

The left and right figures show the results when a subject viewed the display of a previous model and when a subject viewed the OCB display, respectively. In these figures, the vertical axis shows the anterior and posterior movements of the centre of gravity, and the horizontal axis shows the right and left movement of the centre of pressure. The red squares in the two figures indicate the range recorded in the resting state. The amplitudes of the sway as well as the right-left movement were larger when the subjects viewed the display of the previous model than when they were in the resting state.

The measured values are shown in Table 1. In most cases, the values for the display of the previous model were higher than those for the OCB display.

4. Discussion and Conclusion

Moving pictures were rotated horizontally at a speed of 25 deg/s or less, which was considered to be a sufficiently small OKS; therefore, the standing posture could be controlled by a mechanism regardless of whether the subjects viewed the moving pictures.

We statistically compared the resting state among the testing states using the values of the indices that evaluated the SKGs (Fig. 3). Among these states, the results of one-way analysis of variance (ANOVA) showed a significant difference in all the indices except for the total locus of chains ($p < 0.01$). From multiple comparisons, it was found that the values of indices, other than the total locus length per unit area, were significantly larger when the subjects viewed the display of the previous model than when the subjects were in the resting state ($p < 0.05$). These statistical results indicated that visually induced motion sickness was affected by the display of the previous model. In contrast, there was no significant difference between the resting and testing states for the OCB display although the values of the indices tended to be larger when the subjects viewed the OCB display than when they were in the resting state. This result indicated that the use of the OCB display suppressed visually induced motion sickness, which was an effect of the display of the previous model.

When the testing states for the display of the previous model was compared with the OCB display, no significant difference was found in the indices other than the SPD S_3 (see Appendix). This index S_3 may be convenient for the evaluation of displays. According to the previous researches, aging does not produce an effect on the SPD but it has an effect on the chains (TAKADA *et al*., 2003a). However, the SPD of the stabilometry indicates

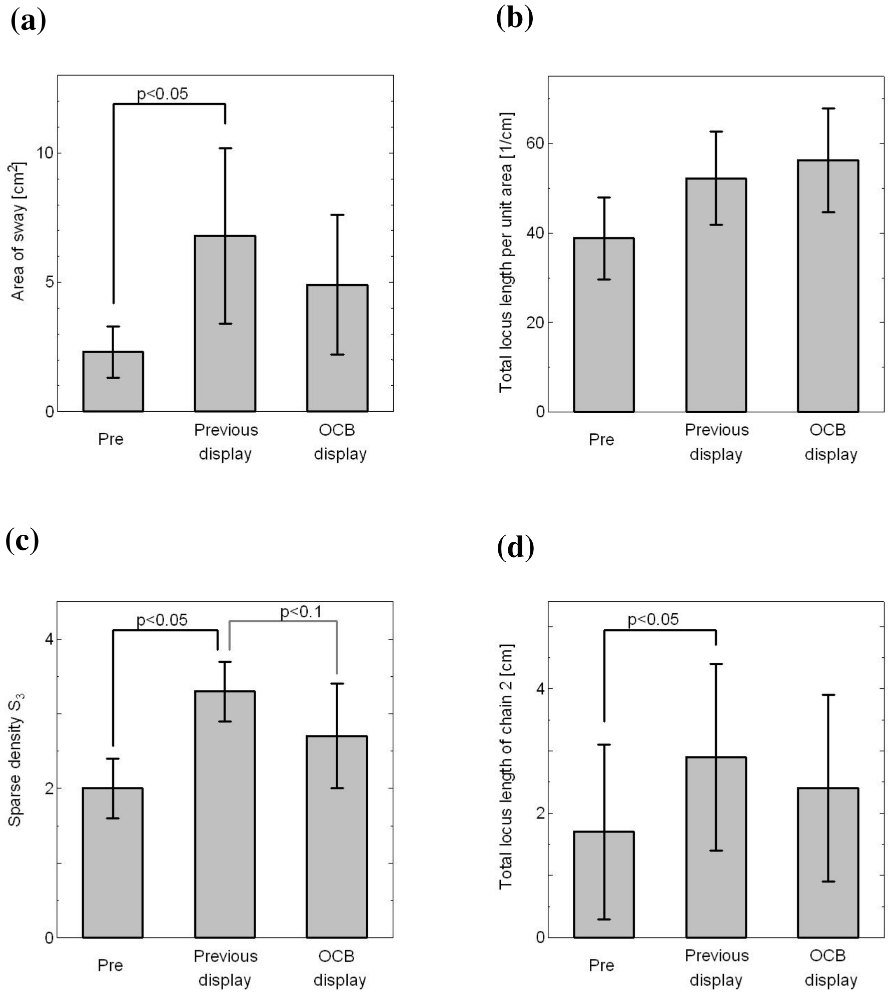

Fig. 3. We statistically compared the resting state among the testing states using the values of the indices that evaluated the SKGs; (a) area of sway, (b) total locus length per unit area, (c) sparse density S_3, (d) total locus length of chain 2.

whether the subjects had consumed alcohol an hour before the test (TAKADA *et al.*, 2003b). It is well known that the equilibrium function of a vestibule-cerebellum system is deteriorated by the ingestion of alcohol as a medical action (KAGA, 1992). Therefore, the image sickness induced by the blurred images on the LCDs might exert an influence on the vestibule-cerebellum system.

OCB displays have excellent moving picture quality. The present results suggest that for many applications, OCB displays are better than conventional displays.

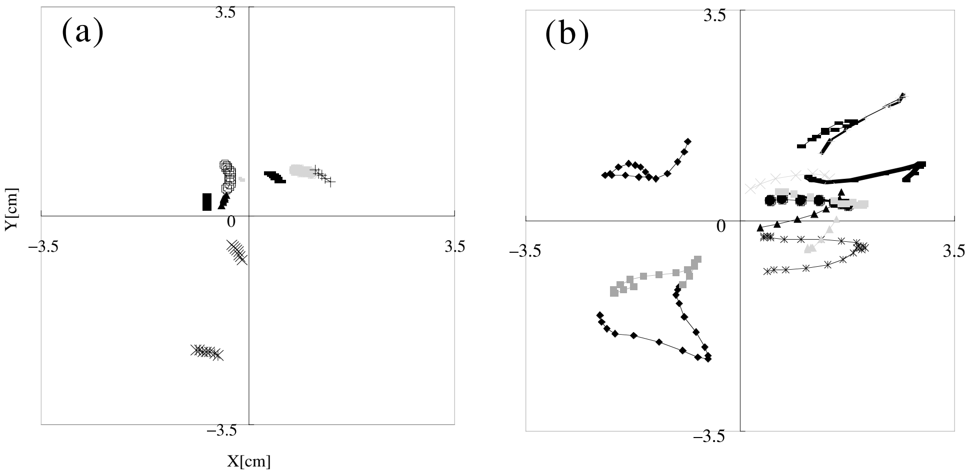

Fig. A1. Chains were extracted from an SKG. (a) Chain 1 and (b) chain 2 These figures have already shown to define the chains by TAKADA *et al*. (2003b).

Appendix

New quantification indices—'sparse density: S_2', 'sparse density: S_3', 'total locus length of chain 1', and 'total locus length of chain 2'—were proposed by TAKADA *et al.* (2003b). We herein review the definitions of the SPDs and chains.

Sparse density (SPD)

SPD was defined by a scaling average of the ratio as $G_j(l)/G_j(k)$. An SKG was divided into quadrates of which the latus is j times longer than the resolution, and $G_j(k)$ expressed the amount of divisions including more than k measured points. If the centre of gravity does not move, the SPD value becomes 1. If there are variations in the SKGs, it becomes greater than 1. In this manner, the SPD depends on the characteristic of the SKG and the motion process of the centre of gravity (TAKADA *et al.*, 2003b).

The anterior-posterior direction y was considered to be independent of the medial-lateral direction x (GOLDIE *et al.*, 1989). Stochastic differential equations (SDEs) on the Euclid space $\mathbf{E}^2 \in (x, y)$

$$\frac{dx}{dt} = -\frac{\partial}{\partial x} U_x(x) + w_x(t)$$

$$\frac{dy}{dt} = -\frac{\partial}{\partial x} U_y(x) + w_y(t)$$

have been proposed as a mathematical model that generates the SKGs (COLLINS and DE

LUCA, 1993; EMMERIK *et al*., 1993; NEWELL *et al*., 1997; TAKADA *et al*., 2001). Pseudo-random numbers were generated by the terms of the white noises $w_x(t)$ and $w_y(t)$. Due to non-linear SDEs constructed from SKGs, their temporally averaged potential functions U_x, U_y have plural minimal points, and fluctuations could be observed in the neighborhood of the minimal points (TAKADA *et al*., 2001). The variance of the SKG depends on the form of the potential function in the SDE; therefore, the SPD is regarded as an index for its measurement.

Chain

The force acting on the centre of gravity of the body was defined in terms of the difference in the displacement vectors. In particular, we focused on the singular points where statistically tiny or large forces were exerted. On the basis of the forces, the chains were eliminated from the SKG as a consecutive time series. If the times measured at these points were temporally vicinal, these points were connected by segments (sequences). The figures formed by these sequences are known as teamed chains because of the shape of the connections. 'Chain 1' and 'chain 2' were defined by the figures of the sequences of the points where small and large forces were exerted, respectively; the former has local fluctuations or straight lines while the latter is a cusp pattern (Fig. A1).

REFERENCES

COLLINS, J. J. and DE LUCA, C. J. (1993) Open-loop and closed-loop control of posture: A random-walk analysis of center of pressure trajectories, *Exp. Brain Res*., **95**, 308–318.

EMMERIK, R. E. A., VAN SPRAGUE, R. L. and NEWELL, K. M. (1993) Assessment of sway dynamics in tardive dyskinesia and developmental disability: sway profile orientation and stereotypy, *Moving Disorders*, **8**, 305–314.

GOLDIE, P. A., BACH, T. M. and EVANS, O. M. (1989) Force platform measures for evaluating postural control: reliability and validity, *Arch. Phys. Med. Rehabil*., **70**, 510–517.

HASEGAWA, S., SATO, K., MATSUNUMA, S., MIYAO, M. and OKAMOTO, K. (2005) Multilingual disaster information system: Information delivery using graphic text for mobile phones, *AI & Society*, **19**(3), 265–278.

KAGA, K. (1992). *Memaino Kouzo: Structure of Vertigo*, pp. 23–26, 95–100, Kanehara, Tokyo (in Japanese).

KIMURA, K., OSUMI, Y. and NAGAI, Y. (1990) CRT display visibility in automobiles, *Ergonomics*, **33**(6), 707–718.

LESTIENNE , F., SOECHTING, J. and BERTHOZ, A. (1977) Postural readjustments induced by linear motion of visual scenes. *Exp. Brain Res*., **28**, 363–384.

MIYAO, M., HACISALIHZADE, S. S., ALLEN, J. S. and STARK, L. W. (1989) Effects of VDT resolution on visual fatigue and readability: An eye movement approach, *Ergonomics*, **32**(6), 603–614.

MIYAO, M., ISHIHARA, S., FURUTA, M., KONDO, T., SAKAKIBARA, H., KASHIWAMATA, M. and YAMADA, S. (1993) Do liquid crystal displays assure better readability than cathode-ray tubes?, *Nippon Eiseigaku Zasshi*, **48**(3), 746–751.

NEWELL, K. M., SLOBOUNOV, S. M. and SLOBOUNOVA, E. S. (1997) Stochastic processes in postural center-of-pressure profiles, *Expaerimental Brain Research*, **133**, 158–164.

OMORI, M., WATANABE, T., TAKADA, H. and MIYAO, M. (2002) Readability and characteristics of the mobile phones for elderly people, *Behav. Inf. Technol*., **21**, 313–316.

REASON, J. T .and BRAND, J. J. (1975) *Motion Sickness*, Academic Press, London.

SCHARFF, L. F. V. and AHUMADA, A. J., Jr. (2002) Predicting the readability of transparent text, *Journal of Vision*, **2**(9), 653–666.

SCHARFF, L. F. V., HILL, A. L. and AHUMADA, A. J., Jr. (2000) Discriminability measures for predicting readability of text on textured backgrounds, *Optics Express*, **6**(4), 81–91.

STOFFREGEN, T. A. and SMART, L. J., Jr. (1998) Postural instability precedes motion sickness, *Brain Research Bulletin*, **47**, 437–448.

SUZUKI, J., MATSUNAGA, T., TOKUMASU, K., TAGUCHI, K. and WATANABE, Y. (1996) Q&A and a manual in Ssilometry, *Equilibrium Res*., **55**(1), 64–77.

TAKADA, H., KITAOKA, Y. and SHIMIZU, Y. (2001) Mathematical index and model in stabirometly, *FORMA*, **16**(1),17–46.

TAKADA, H., KITAOKA, Y., IWASE, S., SHIMIZU, Y., WATANABE, T., NAKAYAMA, M., MIYAO, M. and MIHASHI, K. (2003a) Characteristic changes of sway of center of gravity with advancing age, *Env. Med*., **47**, 85–89.

TAKADA, H., KITAOKA, Y., ICHIKAWA, S. and MIYAO, M. (2003b) Physical meaning on geometrical index for stabilometry, *Equilibrium Res*., **62**(3), 168–180.