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Preferred viewing distance of liquid crystal high-definition television

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ABSTRACT

This study explored the effect of TV size, illumination, and viewing angle on preferred viewing distance in high-definition liquid crystal display televisions (HDTV). Results showed that the mean preferred viewing distance was 2856 mm. TV size and illumination significantly affected preferred viewing distance. The larger the screen size, the greater the preferred viewing distance, at around 3–4 times the width of the screen (W). The greater the illumination, the greater the preferred viewing distance. Viewing angle also correlated significantly with preferred viewing distance. The more deflected from direct frontal view, the shorter the preferred viewing distance seemed to be.

1. Introduction

Watching TV is an indispensible part of modern daily life. Cathode ray tube television, or CRT-TV, had been the mainstream in the past. During the past few years, due to technological development, global environmental awareness, and the requirement for smaller product design, the flat panel display television, or FPD-TV, featuring energy-saving, lighter and thinner design with no radiation, has gradually replaced the giant and high-energy consuming CRT-TV. Also a factor is the transition to digital broadcasting all over the world. FPD-TV technology, with its advantages over the CRT-TV, which is analog-interfaced with no compatibility with digital broadcasting, is expected to provide great business opportunities in the future. Among all FPD-TVs, the liquid crystal display television, or LCD-TV, with its technological maturity and lower price, has taken the lead to become the main stream in the market. iSuppli (2009) estimated the global production of LCD-TV at 112.5 million sets in 2009 and 200 million sets in 2010.

Viewing distance is one critical factor affecting viewing performance and viewing fatigue. A longer viewing distance makes images of visual stimuli on the retina smaller and less clear. However, it is generally accepted that shorter viewing distances increase the tension of the ciliary and extraocular muscles and produce greater visual strain (Weston, 1949; Fisher, 1977). Some studies (Jaschinski-Kruza, 1991; Shieh and Chen, 1997; Shieh and Lee, 2007) showed VDT viewing distance to be correlated with visual strain; there were fewer reports of visual fatigue at a longer viewing distance. Research for proper viewing distance has been an important topic in Human Factors Engineering. Until now, studies mostly focused on computer displays.

There are not many studies available regarding optimal TV viewing distance and the results are inconclusive. Enoch (1959) found 6.25*W (W = width of screen) to be the best viewing distance. University (Wisconsin) Facilities Research Center (1963) suggested 5 W and 14 W would be the minimum and maximum viewing distance. Wadsworth (1968) suggested 2 W and 6 W would be the minimum and maximum viewing distance. McVey (1970) found the minimum viewing distance to be 4 W. When watching high resolution TV (800 or more pixel scanning lines), the minimum viewing distance could be dropped to as low as 2 W; while the maximum viewing distance was 8 W.

Ardito et al. (1996) found in their research that the preferred viewing distance (PVD) was 3 W or 5.2 H (H = Height of screen) in general. Narita et al. (2001) pointed out the recommended viewing distance was 2 H or 3 H for HDTV. Sakamoto et al. (2008) revealed that viewing fatigue was lowest when viewing distance was between 3 H and 4 H. In addition to the aforementioned experimental studies of TV viewing distance, there were some field surveys about television viewing distance at home. Nathan et al. (1985) found an average of 3368 mm for adult viewers. Kubota et al. (2006) obtained an average viewing distance of 2660 mm, similar to 2700 mm found in the Great Britain (Tanton, 2004). Kubota et al. suggested living room size to be an influential factor. The size of living room in the U.S.A is bigger than in Japan or the Great Britain and hence resulting in a longer TV viewing distance in the U.S.A. If this conjecture is true, one may hypothesize that

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average viewing distance at home may be confined by the limited room size and thus be less than the preferred viewing distance. This conjecture deserves investigation.

Among all these earlier studies, the viewing medium was the CRT-TV. During the past few years, the studies were based on FPD-TV, but most of them measured viewing fatigue or viewing preference at fixed viewing distances. Rarely did the subjects have their choice of PVD. For example, in the study by Sakamoto et al. (2008), subjective visual fatigue, heart rate variability, and eye blinking rate of 10 participants were recorded and compared at fixed viewing distances of 2 H, 3 H, 4 H, and 6 H of TV screen. From a practical point of view, it is necessary to pinpoint the now mainstream LCD-TV as the target viewing medium and to allow viewers to choose the PVD.

All the above literature reveals that the size of the display panel plays an important role on viewing distance. In addition to that, the characteristics of the viewing person and viewing environment have to be taken into consideration. Among these factors, illumination and viewing angles were explored in this study. In general, the illumination of a living room where the TV located is around 500 lx–700 lx. It is worth exploring the effect of higher or lower illumination on viewing distance. While watching TV in a group, there are only a few who directly face the screen - the rest face the screen at an angle. Field surveys about family television viewing show that the average viewing angle was about 20 deg horizontally with a maximum to 60 deg (Nathan et al., 1985; Kubota et al., 2006). There needs to be further analysis on the relationship between viewing angle and viewing distance.

In summary, there were very few human factor evaluations of PVD of LCD-HDTV available. Many factors have effects on viewing distance, including TV characteristics such as size, environmental factors such as ambient illumination, as well as operational factors such as viewing angle. Therefore, it is necessary to have more practical analyses to understand the PVD in watching television, and at the same time, to provide users and manufacturers with guidance and suggestions. This study explored the effect of TV size, illumination, and viewing angle on PVD of watching HDTV.

2. Method

2.1. Experimental design

This study evaluated three independent variables:

(1) TV size: at three levels, 32 in, 37 in, and 42 in. measured diagonally in inches. That is, TV size $= \sqrt{((\text{TV Height})^2 + (\text{TV Width})^2)}$.
(2) Illumination: at three levels, 250 lx, 650 lx, and 1050 lx. The illumination was measured at 750 mm from the floor of the laboratory room, and the illumination levels were altered using rheostats on fluorescent lamps. Illumination was consistent throughout the room.
(3) Viewing angle: at five levels: 0° (perpendicular to the screen center), left 15° facing the screen (+15°), left 30° (+30°), right 15° (−15°), and right 30° (−30°) to the perpendicular axis.

TV size and illumination were between-subject factors. Each participant was randomly assigned to one of the 3 (TV size) × 3 (illumination) = 9 conditions; and there were ten subjects for each condition. Viewing angle was a within-subject factor. Each participant completed 5 different viewing angles.

2.2. Participants

Ninety participants took part in this experiment. All were college students between ages 18 and 23 ($M = 20.4$, SD = 1.2). All had corrected 0.8 or better visual acuity with normal color vision. They were recruited by an announcement posted on the school Internet website and bulletin board. There was an institutional review board (IRB) approved by Oriental Institute of Technology and all the participants gave written informed consent in the study. Each participant was paid NT $300 (about 9 USD).

2.3. Apparatus

The three high resolution liquid crystal display TVs (Sampo Corporation, Taiwan) were SAMPO 32 LCD Unit LM-32H512 (Display Size: 697.60 mm (W) × 392.20 mm (H), Resolution: 1366 × 768 dots); SAMPO 37 LCD Unit LM-32V513 (Display Size: 819.60 mm (W) × 460.80 mm (H), Resolution: 1366 × 768 dots); SAMPO 42 LCD Unit LM-42H512 (Display Size: 930.24 mm (W) × 523.26 mm (H), Resolution: 1920 × 1080 dots). A Topcon screenscope (Topcon, Japan) and standard pseudo-isochromatic charts (Ishihara, Japan) were used to examine participants' visual acuity and color vision. Fluorescent lamps were used for lighting and illumination levels were measured with illumination meter LT Lutron Lx-103.

2.4. VDT conditions of workplace

The experiment was conducted in Human Factor Laboratory of Department of Industry Management, Oriental Institute of Technology. The TV set was placed on a normal TV cabinet 535 mm above the ground. The participants sat on a chair 460 mm high with a chin-supporter to fix their head. The laboratory room temperature was controlled at 26 °C. The audio volume of TV program was set at 55–60 db (measured 3600 mm away from TV set). The illuminations were measured within ±5% of the designated levels. The laboratory room was illuminated by fluorescent lamps. Neither glare nor reflection appeared on the TV screen. The screen luminances for the 3 TVs were set at scale 50 during the experiment. The scale range was from 0 to 100 with greater value indicating greater image brightness. The maximum luminances for the 3 TVs were the same at 450 cd/m^2 (scale 100). Thus, the brightest image was 225 cd/m^2 for brightness scale 50. The luminance contrasts were also set at scale 50. That is, the luminance ratio of the darkest and brightest images was 50 in this study. Lines for the viewing angles were drawn on the floor of the laboratory to help the data collection process.

2.5. Task and procedure

The TV program (stimuli material) presented during the experiment was a DVD film titled "What Just Happened". The movie display format is Blu-Ray H264 1080p, the screen resolution was set to 1280 × 768/32 bit color. The movie was played by the shooter video player (SPlayer). Each participant was required to proceed with the following:

(1) Randomly assigned one out of the five viewing angles by the experimenter;
(2) Sit on a plastic, movable chair 460 mm high and watch the program on the TV;
(3) Adjust the PVD and then allow the experimenter to measure and record the data. The participants were instructed to adjust the PVD to their best visual comfort and legibility after watching TV for 3 min. They adjusted PVD by moving the chair