[Environmental Health and Preventive Medicine 6, 109–112, July 2001]

Original Article

Accommodative Load from Handheld Game Consoles in Kindergarten Children

Toshihiro SAKATA[1], Masaru MIYAO[2], Hisao ISHIGAKI[3], Yoshio SHIRAIWA[3], Shin'ya ISHIHARA[1], Masashi FURUTA[1], Takaaki KONDO[4] and Hideaki TOYOSHIMA[4]

[1]*Aichi University of Education, Igaya-cho, Kariya*
[2]*Graduate School of Mathematics, Nagoya University, Chikusa-ku, Nagoya*
[3]*Aichi Institute of Technology, Yagusa-cho, Toyota*
[4]*Department of Public Health/Health Information Dynamics, Nagoya University Graduate School of Medicine, Showa-ku, Nagoya*

Abstract

We analyzed and compared the visual accommodation of kindergarten children who were gazing fixedly at images from three different sources: Nintendo Game Boy DMG-01™ (non-backlit type game console: NBGC), NEC PC EnginePI-TG6™ (color backlit-type game console: CBGC) and a cartoon drawing (drawing). Subjects for the experiment were 13 4- to 5-year-old kindergarten children. The contrast ratios were, in the order, 1.1 (NBGC), 3.1 (drawing), and 3.4 (CBGC). These values show that the contrast of the NBGC screen was considerably lower than the others. The mean accommodative power incresed when looking at all three types of image: a drawing (1.75±0.52 D; mean±S.D.), CBGC (1.82±0.61 D), and NBGC (2.26±0.50 D). Compared with the other 2 targets, NBGC required stronger accommodation, indicating that the legibility of the NBGC was poor. Repeated measures ANOVA was used for the values of accommodation for each type of target. There were significant differences among the 3 targets ($p<0.01$). Significant differences were seen between NBGC and drawings ($p<0.01$) and NBGC and CBGC ($p<0.05$) using paired Scheffe test, but not between CBGC and drawings. This supports the finding that the legibility of NBGC is low due to dark and low contrast screens with poor resolution.

Key words: handheld game console, accommodation, legibility, contrast, children, mobile phone

Introduction

In the USA and European countries, negative health effects on children have already been reported following the rapid spread of TV games that began in 1983. One major physical problem caused by TV games is video game epilepsy[1–4] while negative mental effects include increased aggressiveness from violent games[5] and changes in visual function and symptoms of fatigue[6,7].

In addition to TV video games, handheld game consoles have also appeared on the market. Since these game consoles are portable and can be played anywhere, they have become popular with players ranging from kindergarten children to adults. These consoles differ from conventional TV video games in that they have small, liquid crystal displays (LCD) with poor contrast and are played at short visual distances, all of which are thought to cause a heavy visual load. In the present study, we analyzed and compared the visual accommodation of kindergarten children who were gazing fixedly at images from three different sources: a non-backlit type game console (Nintendo Game Boy DMG-01™; NBGC), a color backlit type game console (NEC PC Engine PI-TG6™; CBGC), and cartoon drawings (color paper; drawings).

Materials and Methods

Subjects for the experiment were 13 4- to 5-year-old kindergarten children (9 boys and 4 girls, all were emmetropic (visual acuity: 1.0 or more) without spectacles, and had standard height and weight.

The three types of screen used were NBGC, CBGC, and drawings. Around the center of these screens, there were famous characters' faces, Super Mario, Momotaro and Crayon-Shinchan, respectively. All target screens were a nearly uniform 65 mm (2.5 inches), 50 (horizontal)×40 (vertical) mm, in size (Table 1). These were presented in random order to the subjects at a distance (the eye to the target through the half mirror and the upper small mirror) of 40 cm (2.5 D) for 30 sec each (Fig. 1).

The luminance and the contrast of the two consoles were adjusted to the appropriate levels by the testers in advance. Glare or

Received Sep. 12 2000/Accepted Feb. 13 2001
Reprint requests to: Masaru MIYAO
Graduate School of Mathematics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464–8602, Japan
TEL/FAX: +81-52-789-5572,
E-mail: mmiyao@med.nagoya-u.ac.jp

Table 1 Three types of display used in this experiment

Target	NBGC	CBGC	Drawing
	Non-backlit type	Color backlit-type	Cartoon drawing
	Nintendo Game Boy	NEC PC Engine	
	DMG-01	PI-TG6	Paper
Screen resolution	160×144 dots	320×224 dots	–
Color usage	Monochrome	Maximum 512	Color paper
Size	63.5 mm (2.5 inch)	66.0 mm (2.6 inch)	63.5 mm (2.5 inch)
	45.9 (H)×41.9 (W) mm	51.1 (H)×39.7 (W) mm	50 (H)×40 (W) mm
LCD type	STN dot-matrix	Active matrix	

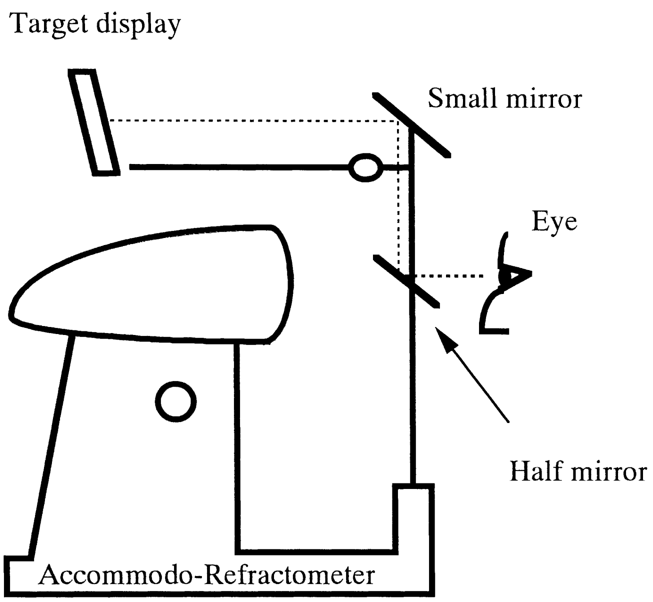

Fig. 1 A schematic view of the device developed for the present experiment. The distance from the eye to the target through the half mirror and the small upper mirror is 40 cm.

discomfort light were prevented by window blinds and curtains.

The subjects were instructed to focus on a human face (Super Mario, Momotaro and Crayon-Shinchan) in the center of each display.

The children were asked to give the name of the character's face which they saw while looking at each of the displays, and during this time accommodative stability was measured. Since all of the children were able to state the name of the characters in each of the displays after 15–20 sec, measurements of the average changes in accommodation were made in the last 10 sec of the 30-sec period (20–30 sec from start) one time each.

Visual function was tested using a custom-made apparatus (Fig. 1). This combined an automated infrared accommodo-refractometer (Nidek AR-1100™) and an original binocular half-mirror system[8]. The display images were placed in front of the small mirror for the tests. Subjects gazed at each type of image through a half (dichroic) mirror and an ordinary small mirror. The instrument measured visual accommodative changes of the right eye at a 12.5 Hz sampling rate objectively in both binocular and natural viewing conditions.

A repeated measures ANOVA was used to determine whether there was a difference in visual accommodation among the subjects depending on which of the 3 types of target they were looking at. The factors were type of target.

Table 2 Mean luminance (cd/m^2) in dark and light areas in each target

	NBGC	CBGC	Drawing
Dark	11.7	37.9	8.8
Light	13.2	130.5	26.9
Contrast ratio (Light/Dark)	1.1	3.4	3.1

Measured by Minolta Luminance Meter LS-100.
NBGC: non-backlit type game console.
CBGC: color backlit type game console.

Results

Table 2 shows the luminance in the dark and light locations on each screen and drawing, and the contrast ratio using the Minolta Luminance Meter LS-100. Among the three types of image, the luminance in both the light and dark areas was brightest on CBGC. The contrast ratios were, in the order, NBGC (1.1), drawings (3.1), and CBGC (3.4).

These values show that the contrast of the NBGC was considerably lower than the contrast standard for a television of 3.0[9], indicating that NBGC has low legibility.

The target display position was set at 40 cm from the subjects' eyes, which corresponds to 1.00/0.40=2.50 diopters (D).

Figure 2 shows the mean accommodative amplitude with the standard deviation for the target displayed. The amount of accommodation grew when looking at the Game Boy (2.26±0.50 D; mean±S.D), CBGC (1.82±0.61 D), and drawings (1.75±0.52 D), in that order. Thus, compared with the other 2 targets, NBGC required stronger visual accommodation.

Next, repeated measures ANOVA was used for the values of visual accommodation for each type of target to clarify whether there was a difference in accommodative power depending on the type of target. There were significant differences among the 3 targets ($p<0.01$).

Furthermore, significant differences were seen between NBGC and drawings ($p<0.01$) and NBGC and CBGC ($p<0.05$) using the paired Scheffe test, but not between CBGC and drawings.

This supports the finding that the legibility of NBGC (non-backlit type liquid crystal display) is low due to dark and low contrast screens with poor resolution.

Discussion

The present study used three different types of visual image. NBGC has a dark, non-backlit type LCD with poor resolution (160×144 dots) that is exceedingly difficult to view, while CBGC

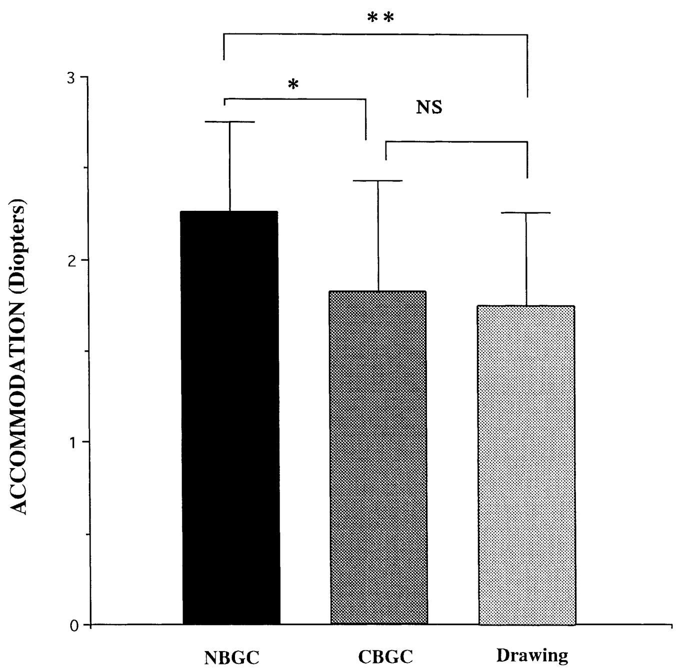

Fig. 2 Mean accommodative amplitude with standard deviation for the targets.
(*: p<0.05; **: p<0.01; NS: not significant).
NBGC: non-backlit type game console.
CBGC: color backlit type game console.

has a very bright backlit type color LCD with fine resolution (320×224 dots) that is relatively clear. The colored cartoon drawings were prints on paper, so it had none of the blurring of the electronic displays, and were the clearest of the 3 images. Thus, visual problems related to handheld game consoles were likely to be associated with brightness and darkness, the sharpness and blurriness of the contour (fine and poor resolution), and their relatively small in size.

The contrast ratio is also an important factor for legibility of the screens. Grandjean[10] reported that a display with characters should have a screen background that is neither too dark nor too bright. A luminance contrast ratio between characters and the background of 6:1 is sufficient for good readability. With a character luminance of 40–50 cd/m^2, a background luminance of 6–8 cd/m^2 would, thus, be appropriate. In another study, Grandjean[11] conducted a review of the contrast ratio as follows. Mourant et al.[12] studied the effect of reducing the character contrast on both a visual display terminal (VDT) screen and printed text using two subjects. Contrast ratios of 20:1 were found to be good for the display and 5:1 for the printed text. Shurtleff[13] determined the legibility of character contrasts and concluded that the minimum contrast ratio acceptable for general display conditions was between 10:1 and 18:1. Furthermore, he stated that the luminance of characters per se should not be lower than 35 cd/m^2. Kokoschka and Bodmann[14] carried out two adjustment experiments and one performance test on 10 subjects to find limits and optimal values for lighting variables at VDT workstations. They concluded that character contrast ratios of 10:1 are optimal, while a ratio of 2.5:1 should be considered minimal and a ratio of 15:1 maximal.

Based on the above-mentioned research, the German Industrial Standards[9] (DIN 50535; formerly West Germany) called for a luminance contrast ratio of greater than 3:1 for visual objects. With the exception of NBGC, the luminance contrast ratios in the present study were in the acceptable range.

Snyder and Maddox[15] and Snyder[16] drew attention to the important reciprocal relationship between sharpness and contrast of characters: poor sharpness requires higher character contrast if good legibility is to be maintained. This applies in particular when the contrast ratio between bar luminance and interspace luminance (space between two characters) is considered. CRTs with an insufficiently focused electron beam produce increased interspace luminance and the corresponding contrast ratio might be as low as 2:1.

The relationships between dark screens and visual accommodative load have previously been studied. Miyao et al.[17] measured and calculated the focusing speed (the 90 percent maximum amplitude of accommodation from a distant poster to the computer monitor, divided by time spent). They found that even young subjects had lower focusing speeds when they looked at non-backlit dark LCDs than at other bright displays such as cathode ray tubes (CRTs) or backlit LCDs ($p<0.05$, Kruskal-Wallis test). When the pupil expands, the depth of field becomes shallower. In that case, visual accommodation must be more rigorous. For the above-mentioned reasons, pupil size increases while viewing non-backlit dark LCDs, and the depth of focus obviously becomes shallower. It has been suggested that it is not easy to focus on non-backlit LCDs.

The visual distance in the present experiment was 40 cm, meaning that the visual accommodative load was fairly high. When using these three types of display, It is suggested that the greatest difficulty in visual acquisition of images would be with the poorer quality NBGC, followed by the CBGC and animated drawings.

It is known that blurring induces more rigorous visual accommodation. Gwiazda et al.[18,19] found that myopic children accommodate significantly less than emmetropic children for real targets at near distances, and that myopic children are used to blurred images. They visually accommodated insufficiently for blurred targets. In the present study, none of the subjects were myopic, so they all had to accommodate rigorously.

The resolution of CBGC is approximately three fold greater than that of NBGC. Blurring is closely related to the poor resolution of the display. In the present study, it appeared that the blurrier the target, the greater the accommodation. It is suggested that blurry, near images such as NBGC cause a greater visual accommodative load in children and may lead to the development of tonic accommodation.

Recently, the use of mobile phones has grown rapidly worldwide. Small message services (SMS), and personal digital assistants (PDA) with small displays and characters have also become popular. Mobile, on-line videogames have been developed, and it is likely that children will use them more frequently in the near future.

In contrast to most legibility studies for visual displays using adult subjects, the subjects in the present study were kindergarten children aged 4 to 5 years. The present findings may, therefore, reflect, to a certain extent, difference between legibility in adults and children. Furthermore, the present study investigated the short-term effects of video game playing on visual function. To determine the longer-term effects will require a follow-up study monitoring changes over a number of years.

References

1) Rushton DN. “Space invader” epilepsy. Lancet 1981; 1(8218): 501.
2) Jeavons PM, Barton ME, Bishop A. Seizures and hand-held space invaders. Lancet 1981; 2(8249): 758.
3) Maeda Y, Kurokawa T, Sakamoto K, Kitamoto I, Ueda K, Takasima S. Electroclinical study of video-game epilepsy. Dev. Med. Child Neurol. 1990; 32: 493–500.
4) Graham F, Harding, A. TV can be bad for your health, Nature Medicine 1998; 4: 265–267.
5) Griffiths M. Amusement machine playing in childhood and adolescence. J. Adolesc. 1991; 14: 53–73.
6) Knave B. IT in schools. Proceedings of WWDU ’97 Tokyo. 1997; pp. 107.
7) Miyao M, Sugiura S, Sakata T, Ishigaki H. The visual effect of video game on school children. Proceedings of WWDU ’97 Tokyo. 1997; 111.
8) Miyao M, Otake Y, Ishihara S. A newly developed device to measure objective amplitude of accommodation and papillary response in both binocular and natural viewing conditions. Jpn. J. Ind. Health 1992; 34: 148–149.
9) Deutches Institut fur Normung, DIN 5035, Innenraumbeleuchtung mit Kunstlichen Licht, DIN Berlin, 1978.
10) Gandjean E. Fitting the Task to the Man. London: Taylor and Francis, Ltd. 1988.
11) Gandjean E. Ergonomics in Computerized Offices. London: Taylor and Francis, Ltd. 1987.
12) Mourant RR, Lakshmanan R, Chantadisai R. Visual fatigue and cathode ray tube display terminals. Hum. Factors 1981; 23: 529–540.
13) Shurtleff D. How to Make Displays Legible. La Mirada, CA: Human Interface Design, 1980.
14) Kokoschka S, Bodmann HW. Untersuchungen zum Beleuchtungs-niveau und Zeichenkontrast am Bildschirmarbeitsplaz. Lichttechnik 1978; 30: 395–399.
15) Snyder HL, Maddox ME. On the image quality of dotmatrix display. Proceedings of the SID 1980; 21: 3–7.
16) Snyder HL. Lighting, glare measurement and legibility of VDT In: E. Grandjean, editor Ergonomics and Health in Modern Offices. London; Taylor & Francis, 1984: 295–304.
17) Miyao M, Ishihara S, Furuta M, Kondo T, Sakakibara H, Kashiwamata M, Yamada S. Comparison of readability between liquid crystal displays and cathode-ray tubes. Jpn. J. Hyg. 1993; 48: 746–751.
18) Gwiazda J, Thorn F, Bauer J, Held R. Myopic children show insufficient accommodative response to blur. Invest. Ophthalmol. Vis. Sci. 1993; 34(3): 690–694.
19) Gwiazda J, Bauer J, Thorn F, Held R. A dynamic relationship between myopia and blur-driven accommodation in school-aged children. Vision Res. 1995; 35: 1299–1304.