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# The Effect of Display Type and Video Game Type on Visual Fatigue and Mental Workload

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## Abstract

This study investigated the effect of display type (plasma TV and CRT TV) and game type (boxing game and tennis game) on visual fatigue and mental workload for both genders during one hour Wii game playing. The use of plasma display to play video games improved significantly CFF threshold ($p<0.001$). But it also caused greater subjective eye fatigue rating ($p<0.01$). The change in CFF threshold for playing boxing game would be doubled than playing tennis game. Moreover, the playing boxing game produced about 70% more eye fatigue rating and about 25% more mental workload than playing tennis game, respectively. The gender effect was not significant on all the measurements.

## Keywords
Critical flicker fusion frequency, subjective eye fatigue rating, video game, NASA-TLX, TV display.

## 1. Introduction
In 2006, Nintendo Company Ltd. launched a new generation of video game console, Wii. Unlike the traditional hand-held video games, Wii adopts a motion-sensitive technology that requires players to act out their characters' activities, such as swinging the game controller like a tennis racket. The "Wii Sports" game allows the users to virtually play the game with a real physical exertion. However, playing video games may increase mental stress and visual fatigue. It often requires higher-order cognitive skills such as strategic thinking, problem solving, and adaptation to rapid change while playing complex video games. Yamada [1] found that the mental workload of playing video game was greater than other visual task, such as watching an animation, and the increase in mental workload is associated with increasing game difficulty [2].

For the display effect, the better image quality of display could improve visual task performance and reduce visual fatigue. Wang and Huang [3] found that using LCD display for after etching inspection (AEI) showed less eye fatigue and better accuracy than using CRT display. This is due to the better image quality and higher refresh rate of the TFT-LCD display. Further, Takahashi [4] compared the display effect on visual acuity after one-hundred minutes TV program watching, and found that watching LCD display had a significantly higher decrease in visual acuity than that of watching plasma display. The behavior of TV program watching is different from TV game playing, and the users tend to have higher motivation, attention and concentration on video game playing. However, information about the evaluation of a plasma display and CRT display for video game playing on visual fatigue and mental workload is lacking.

Thus, the objective of this study is to evaluate the effect of display type and game type on Wii players' visual fatigue and mental workload. The results of this study can provide very useful information for guiding video game playing for both genders.

## 2. Method
### 2.1 Subjects
Ten male and ten female subjects participated in the experiment. All subjects were free from any known musculoskeletal disorders. For male subjects, the average age was 26.7 (±4.7) years, average body height was 172.7 (±5.6) cm and average body mass was 67.8 (±13.2) kg. The average age was 27.3 (±4.2) years, average body height

was 162.6 (±4.0) cm and average body mass was 56.5 (±9.3) kg for female subjects. Their anthropometric data are summarized in Table 1. All subjects were right-handed and had no previous experience in playing Wii games.

**2.2 Experiment design**

The independent variables included gender (male and female), display type and game type. Subject was a random factor and nested in gender factor. Two display types, a 32-in CRT display (SC-32WS2) and a 32-in plasma display (PD3231) were used for evaluation. Moreover, two Nintendo "Wii Sports" games (boxing game and tennis game) were specified in the study. A nested factorial design was employed and a total of 4 experiment combinations were conducted by each subject.

**2.3 Dependent variables**

The dependent variables included the following:

- Objective visual fatigue measure-
  The critical flicker fusion (CFF) frequency was measured by a CFF tester (TAKEI TK502) to assess the subject's visual fatigue and visual sensory sensitivity. CFF is a psychophysical test of the visual temporal resolution. It measures the minimal number of flashes per second at which an intermittent light stimulus no longer stimulates a continuous sensation. The flicker frequency was measured in two different ways: (1) the frequency was increased from 5 to 60 Hz until the subject perceived fusion; (2) the frequency was decreased from 60 to 5 Hz until flicker was detected. The average frequency of the two tests was taken as the CFF measure in a certain condition. The CFF was tested at the beginning and the end of each experiment session. The change in Hz prior to and after experiment was calculated. An increase in CFF threshold indicates an increase in visual sensory sensitivity. On the contrary, a decrease in CFF threshold indicates an increase of visual fatigue [5].
- Subjective visual fatigue assessment-
  The subjective visual fatigue level was assessed by using a 1-20 rating scale, with 1 denoting 'nothing at all' and 20 denoting 'extreme fatigue' [3]. The eye fatigue rating was taken at the end of each experiment session.
- Mental workload measures-
  The subjective mental workload was assessed by using the NASA Task Load Index (NASA-TLX) [6]. NASA-TLX is a multidimensional mental workload rating which contains six factors: mental demand, physical demand, temporal demand, performance, effort and frustration level. The workload assessment using the NASA-TLX is a two step procedure. First, the subject evaluates the weighting of each of the six factors through pair-wise comparisons. Next, the subject gives numerical ratings to each of the six factors. The rating scale ranged from 'low' to 'high' in linguistic terms for all factors except for the 'performance' factor which is rated from 'poor' to 'good'. The overall workload score is calculated by the weighted average of the ratings ranging from 0 and 100.

**2.4 Experimental procedure**

The experimental procedure involved preparation, playing and ending phases. In the preparation phase, the subjects' stature and body weight were measured. The objective visual fatigue measure (CFF) was taken as the baseline data for comparison. In video game playing phase, each subject completed a training session for both tennis and boxing games. The subject was allowed to freely adjust the viewing distance while playing. Each subject played 20 minutes and rested 10 minutes and repeated 2 times, thus a total of 40 minutes play and 20 minutes rest in one hour game playing. In the ending phase, the subjective visual fatigue rating, CFF, and NASA-TLX measures were taken. The CFF difference prior to and after the experiment was calculated.

## 3. Results and Discussion

The analysis of variance results in Table 1 reveal that the effect of display type was significant on CFF change ($p<0.001$) and eye fatigue rating ($p<0.01$). Table 2 presents the mean values of the three independent variables. Table 2 shows that the CFF increase was higher for game playing with plasma display (about 1.37 ±0.81 Hz) than with CRT display (about 1.02 ±0.61 Hz). An increase in CFF change indicates an increase in visual sensitivity. The reason was probably due to the better definition of the plasma display increased the subjects' attention to play and resulted in an increase in visual sensitivity. Some pervious studies also showed some positive effects that the video game playing would shorten reaction time [7] and enhance visual attention [8]. However, some negative effects

were also reported. Playing video game with plasma display produced an increase of 17% eye fatigue rating and 5% of mental workload than playing video game with CRT display (Table 2). The better image quality of the plasma display increased the subject's motivation to immerse him/herself in the game, and increased the effort in playing, and resulted in an increase of subjective eye fatigue and mental workload.

Table 1: ANOVA results

| Source | df | CFF change | Eye fatigue rating | NASA- TLX |
|---|---|---|---|---|
| Display (D) | 1 | *** | ** | |
| Game (G) | 1 | *** | *** | *** |
| Gender (Ge) | 1 | | | |
| D*G | 1 | * | | |
| D*Ge | 1 | | | |
| G*Ge | 1 | | * | |
| D*S[Ge] | 18 | | | |
| G*S[Ge] | 18 | | | |
| Subject (Gender)(S[Ge]) | 18 | | *** | * |

*, Significant at p<0.05; **, Significant at p<0.01; ***, Significant at p<0.001.

Table 2: The response measurements under different level of the independent variable.

| | CFF change (Hz) | Eye fatigue rating (scores) | NASA- TLX (scores) |
|---|---|---|---|
| Display type | | | |
| CRT display | 1.02 (0.61) | 3.86 (1.94) | 46.83 (13.82) |
| Plasma display | 1.37 (0.81) | 4.50 (2.09) | 48.77 (13.89) |
| Game type | | | |
| Tennis | 0.78 (0.48) | 3.10 (1.54) | 42.58 (12.86) |
| Boxing | 1.62 (0.70) | 5.26 (1.90) | 53.02 (12.85) |
| Gender | | | |
| Male | 1.23 (0.75) | 4.11 (2.13) | 44.05 (14.54) |
| Female | 1.17 (0.72) | 4.25 (1.95) | 51.55 (12.07) |

(), standard deviation.

Moreover, the interaction of display and game type significantly affected the CFF change (p<0.05) as shown in Table 1 and Figure 1. When playing intensive sport game such as boxing with plasma display, the CFF change was about 50% higher than playing with CRT display (2.2 vs. 1.45 Hz). But the CFF change was similar for both displays while playing the less intensive tennis game (1.09 vs. 0.82 Hz). It seems that the influence of display type on visual fatigue is less for the less intensive video game.

The effect of game type was significant on all the response measures (p<0.001). The results in Table 2 reveal that the change in CFF for playing the intensive boxing game (about 1.62 ±0.70 Hz) was almost doubled than that of playing the less intensive tennis game (about 0.78 ±0.48 Hz). The intensive and exciting boxing game caused the subjects to allocate more mental resources into visual attention and thus increased visual sensitivity. On the other hand, playing boxing game produced about 70% more eye fatigue feeling than playing tennis game (5.26 vs. 3.10

scores). It seems that the exposure to the more dynamically changing images and moving objects while playing the intensive boxing game induced a higher level of visual fatigue. Additional, playing boxing game produced about 25% increase in mental workload than playing tennis game (53.02 vs. 42.58 scores). The prolonged attention and fast reaction required in playing the intensive and exciting boxing game resulted in a higher mental workload for the player.

Table 1 reveals that the gender effect was not significant for all the measures. However, the interaction effect of gender and game was significant on subjective eye fatigue rating ($p<0.05$) as shown in Table 1 and Figure 2. The eye fatigue rating in playing boxing game was higher than playing tennis game for both genders. Further, it is interesting to note that the eye fatigue rating in playing boxing game was doubled than that of playing tennis game for males (6.05 vs. 2.80 scores). But for females, the eye fatigue rating for playing boxing game increased about 50% as comparing to playing tennis game (5.50 vs. 3.70 scores). For males, there is a higher eye fatigue rating for playing boxing game, and a lower eye fatigue rating for playing tennis game than those of females. Lucas and Sherry [9] indicated that males prefer to play the more intensive competition games, and thus the motivation and involvement tend to be higher when playing the boxing game. On the other hand, females prefer the challenging but less exhaust games, and thus have a higher interests and involvement in playing the tennis game.

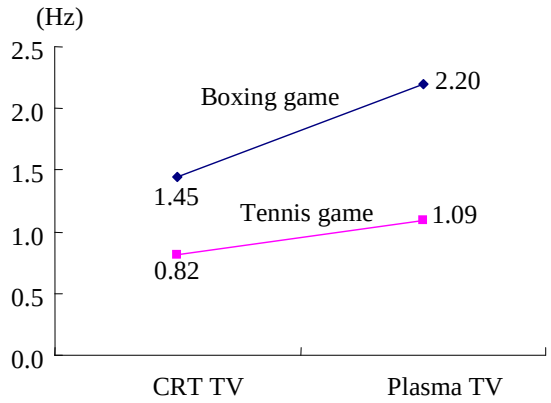


Figure 1: The interaction effect of display*game on CFF change.

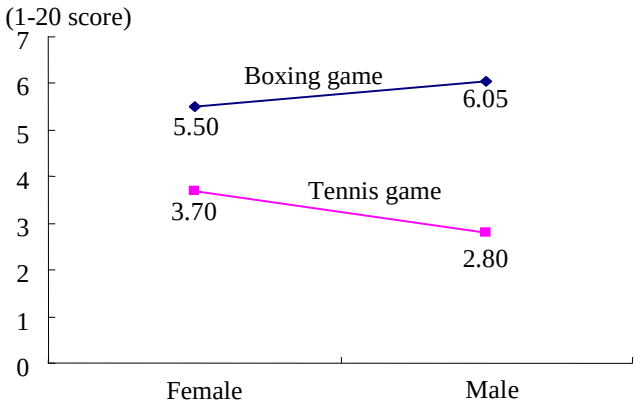


Figure 2: The interaction effect of gender*game on eye fatigue rating.

## 4. Conclusion

The objective of this study is to evaluate the effect of display type, game type, and gender on visual fatigue and mental workload for the Wii players. The study results showed that the better display quality (plasma display) and the more intensive game (boxing game) increased players' motivation and visual sensitivity (CFF threshold

increased), but it also caused an increase in eye fatigue and mental workload. This study not only provides some guilds of video game playing for normal people, but also the findings could apply on virtual rehabilitation field to improve therapeutic effectiveness.

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