The impact of visual display refresh rate on image quality and viewer comfort

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Introduction

Electronic visual displays can cause visual discomfort and fatigue. Refresh rate, defined as the number of times an image is updated by the hardware in one second, is one relevant factor. Higher refresh rates are more faithful to reality and produce fewer ocular symptoms.[1] Low frame rates are a potential source of visual fatigue.

Aim

- To investigate the effect of visual display refresh rate on image quality, viewer comfort and performance on a reading task relevant for real-world applications.
- To provide recommendations about the minimum frame rate required for comfort.

Methods

- A scan reading task as shown in Fig. 1 was developed where participants viewed a moving text searching for scrambled words. Once they detected a scrambled word, they will press on the button. There was a reward system; 1 point for each correct answer and 1 point was deducted for each false press of the button.
- Eight healthy volunteers were gathered and the Newcastle University Ethics Committee approved the study protocol and all participants gave written informed consent.
- They were asked to wear a portable binocular eye-tracker (Pupil Labs) which was used to record their eye activity and sat in a position which they deemed comfortable in front of a computer (25” LCD display Acer Predator XB252Q).
- The experiment was divided into 3 sections and they were training, adjustment and comparison run. The total duration was 45 minutes.
- Volunteers performed a training run at the beginning of the experiment.
- In the adjustment runs, participants adjusted the speed of the moving text according to their comfort level. There were 8 trials in total with 2 trials for each refresh rate. The average velocity was calculated for each frame rate.
- In the final comparison run, subjects were asked to perform the scan reading task at a fixed high text velocity at 400 pix/s in pairs of different frame rates. After each comparison, the subjective experience such as fatigue, text visibility, and comfort was recorded using a feedback questionnaire. The question regarding headache serves as a control to measure fatigue level which is irrelevant to the visual system.

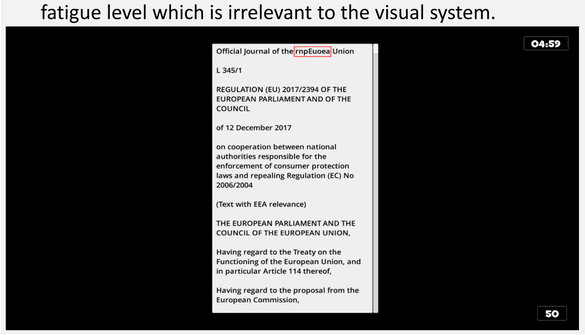


Fig 1. Screenshot showing the task.

Results

- Fig. 2 showed reduced frame rate was reported to cause increased fatigue, more irritated eyes, more blurry text. Consequently subjects showed preference to higher frame rates.
- The refresh rates showed no effects on headache, perceived brightness or task performance as expressed with the d prime value as shown in Fig.5.
- Blink rate has been proposed as possible indicator of fatigue.[2] No effect was found on the total number of blinks among conditions.
- The mean adjusted velocity was considerably lower then the one tested in all of the refresh rates as shown in Fig.3.

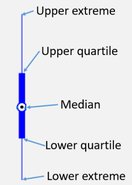


Fig 2. The response after comparison of different refresh rates

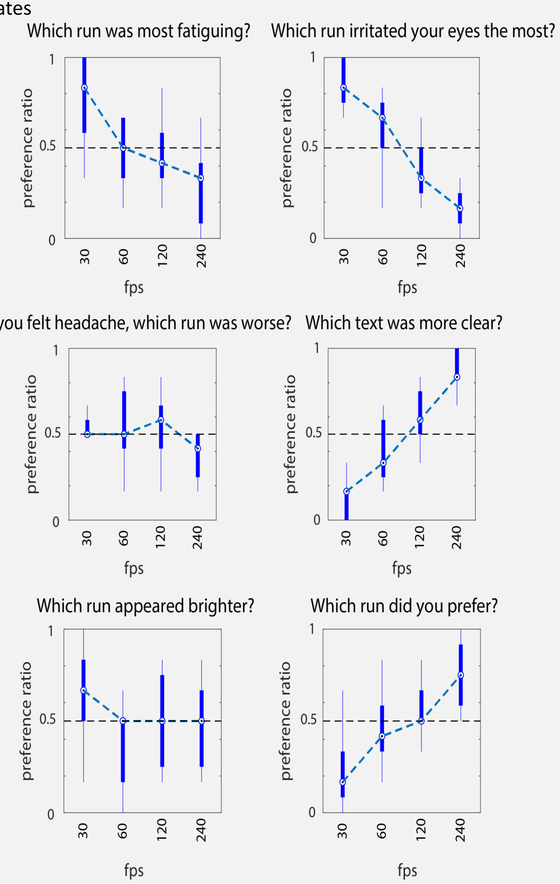


Fig 3. The mean adjusted velocity for each refresh rate

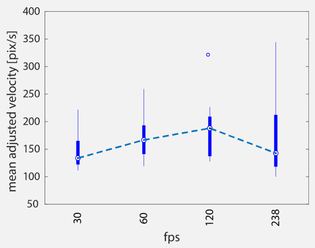


Fig 4. The total number of blinks for each refresh rate

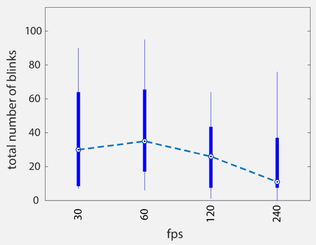
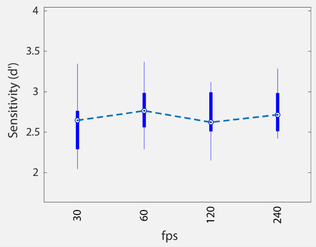


Fig 5. D prime value for each refresh rate



Discussion

- Unlike the cathode ray tube (CRT) displays, liquid-crystal display (LCD) monitors are continuously illuminated so they do not produce visible flicker even at low refresh rates.
- However, low refresh rates still lead to visible artefacts in moving content, e.g. judder or blur.
- Here we show that these artefacts reduced text clarity and produced more fatigue and eyestrain.
- These were detectable up to at least 120Hz, since participants still showed a clear preference for 240Hz vs 120Hz
- Text velocity plays the main role in the severity of the artefacts as a function of frame rate. That means that for increased text speed the effects of frame rate become more prominent.

Conclusion

- Image with higher refresh rates provides a better image quality and viewer comfort in a reading task with moving text.
- Improvements continued up to the highest refresh rates studied, i.e. even 120Hz is too low for comfort on a demanding task.
- Refresh rate did not affect performance, though this could reflect the short duration of the experiment.
- Hence, high refresh rate visual display helps to reduce view fatigue which ultimately improves ocular health and productivity.

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References

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2. Stern JA, Boyer D, Schroeder D (1994) Blink Rate: A Possible Measure of Fatigue. The Journal of the Human Factors and Ergonomics Society 36(2):285-97.