In the Eye of the Beholder: The Impact of Frame Rate on Human Eye Blink

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Abstract
We introduce a study investigating the impact of high frame rate videos on viewer's eye blink frequency. A series of videos with varying combinations of motion complexities and frame rates were shown to participants, while their eye blinks were counted with J!NS MEME (smart eye wear). Lower frame rates and lower motion complexity caused higher blink frequencies, which are markers for stress and emotional arousal.

Author Keywords
Frame Rate; Eye Blink; Heart Rate; Stress; Psychophysics

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Introduction
Peter Jackson's "The Hobbit: An Unexpected Journey" has (re)initiated heated discussions concerning the advantage and necessity of high frame rate (HFR) video productions. Parts of the audience complained that the 48 frames per second (fps) used by Jackson create a look that reminds viewers of a video game rather than a movie [7]. Nevertheless, differences to the standard 24 fps cinema format, such as less judder (motion artifacts that occur when low frame rate (LFR) content is shown on higher refresh rate screens) and motion

blur in high speed scenes and smoother slow motion, were convincing arguments for Jackson to use the HFR [2].

In the early days of cinema and film, requirements for synchronization of sound and video and mere cost factors made 24 fps the standard cinematic FR [3]. However, digital video production has helped to overcome cost and synchronization issues and to make HFR productions more efficient.

To the best of our knowledge, we are the first to study the impact of video FR on viewers' psychophysical condition through analyzing changes in the eye blink frequency. We are aiming at finding patterns of physical reaction to different FRs, and thus understanding the impact on the audience's stress level. We are hoping for the results to enable content producers with new production techniques, e.g. patterns of variable FRs that allow intensified emotional response to video content, and thus greater engagement and more immersive stories.

Related Work

Frame rate variations and their impact on the quality of motion pictures have been widely researched and investigated. Thus, the importance of FR for the graphical quality of movie contents is beyond controversy [16, 3, 10]. Nevertheless, the academic and scientific discourse cannot yet fully explain the underlying principles. In order to better describe the complex impact of FR on the viewing experience, psychophysical methods [6] are utilized by different researchers. Cooper developed a model called *Temporal Texture*, which describes "the temporal feel, appearance, or consistency of stroboscopic apparent motion content to an observer." [3] Kuroki compares variations in the human electroencephalographic (EEG) power spectra of observers of different real motion images in comparison to motion pictures in 60 fps and 240 fps [10]. He finds that the EEG caused by the 240 fps film is closer to that of motion in reality than the 60 fps version. With an increasing FR motion artifacts (judder) are reduced [16]. This leads Kuroki to defining 240 fps as the setting for motion images that offers the viewer the highest quality with greatest reduction of blur and jerkiness [11].

Besides the drive for reproducing reality, which stands behind many of the technological developments, movies are mainly a form of visual storytelling. Watching a movie is not only about cognition, i.e. understanding the displayed contents, but also about the feeling and sensation the observed scene evokes in the viewer [9]. One way of investigating arousal and emotional stimulation is to analyze the natural eye blink. Startle responses, stress, and fatigue, to name some examples, have a direct impact on the blink frequency of people [5, 15]. In particular the work by Haak et al. focusses on the effect of stress on the eye blink. The study shows that stressful situations lead to shorter intervals between eye blinks, thus a higher blinking frequency [8].

Methodology

Design

We filmed scenes with three different levels of motion complexity (MC); i.e. strong temporal changes in adjacent frames. One video shows water dripping from a faucet (low MC), the second video shows two hands typing on a computer keyboard (medium MC), and the third video shows people walking in the back-and

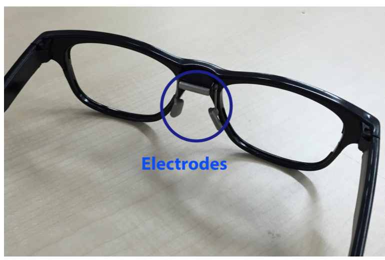

Figure 1: J!NS MEME Prototype showing electrodes around the nose.

foreground (high MC). Each of these three videos was shot in 240 fps, 2K RAW (2048x1024 Pixel) with a SONY FS700 camera. We edited and color corrected the videos in The Foundry Nuke 9.0v8, and exported each video to the H.264/MPEG-4 format in 30 fps, 60fps, 90fps, and 120 fps. In order to avoid changes in replay speed, videos were accelerated accordingly (120 fps: 2x the original speed, 90 fps: 2,67x, 60 fps: 4x, 30 fps: 8x).

The two variables *frame rate* and *motion complexity* lead to a 4x3 within-subject design, resulting in twelve combinations that were counterbalanced in a Latin square. Every participant was asked to watch three video blocks. Every block contained four videos with each one being 30 seconds long. Since the video content was repetitive, there was a risk of losing viewers' attention. Therefore, after every single block the viewers took a two-minute break. Including a five-minute initial preparation and short questionnaire time, the experiment took about 15 minutes per participant.

Participants

We invited twelve participants for our experiment (eleven university students, one faculty), of which seven were male, and five were female. The majority (nine) were between 20 and 30 years old. Three were older than 30 years, with one person being 65 years old. Five of the members had normal visual acuity without any visual aid. The visual acuity of one person in this group was corrected to normal by laser surgery. Seven candidates were depending on visual aids such as contact lenses (three people) and glasses (four people). In the initial questionnaire we asked for information regarding health issues, and sleeping patterns. This was necessary in order to exclude fatigue and medical conditions, which could have altered the eye blinking frequency of candidates. All candidates except for one had their average amount of sleep, or more.

Experimental Setup

The experiment was performed on a Windows 10 64 Bit system equipped with a 3.5 GHz Intel Core i5 Processor, 16 GB of memory, and a 12 GB GeForce GTX Titan X graphics board. In order to be able to present 120 fps video we used the EIZO FORIS FG2421 Gaming Monitor set to 120Hz refresh rate. It has a 23.5 inch screen and offers a 1920 × 1080 pixel resolution.

The eye blinking was tracked with a pair of J!NS MEME glasses. J!NS MEME use electrooculography (EOG) for measuring eye movements, blink, and head postures. They are equipped with five integrated electrodes (three around the nose, two on the ears) as can be seen in Figure 1, motion sensors (accelerator and gyroscope) and a Bluetooth LE (low energy) module (BLE). The electrodes are very sensitive and eye blink detection is easily affected by users touching their face, especially the area around the nose. Hence, all participants were informed to not touch their faces while watching the video clips.

The heart rate (HR) was tracked with a Mio Alpha Heart Rate Monitor Sports Watch that records HR data continuously from the wrist. It is connected to a smartphone (here: iPhone 5s) using Bluetooth 4.0 via Wahoo Fitness, an iPhone application that allows the extraction of recorded results. The purpose of tracking the HR in this experiment was to watch over participants' physiological condition. For instance, the occurrence of alertness and physical exhaustion cause a decrease in heart rate variability [1], and therefore, an increase in the heart rate [12]. In order to avoid a slow decrease in the HR over the time of the experiment we asked every participant to stand up and walk a few steps after each block of four videos to “reset” their HR.

Results and Discussion

In our analysis of the test results we had to exclude the two people. The final data of the J!NS MEME blink detecting showed that candidates No. 11 and No. 12 were not wearing the glasses properly so that their actual blinking could not be detected accurately.

Most people try to pay special attention when being asked to watch a video to not miss any important information. In addition to that, the knowledge that the blinking was measured would most likely have caused participants to mind their blink reflex. Since eye blink can be actively delayed, we had to make sure that participants did not pay attention to their blink. Consequently, we did not explain to the viewers what the J!NS MEME glasses were used for, so that blinking happened as spontaneously as possible. Moreover, viewers of video stories tend to synchronize their blink with pauses in the story, i.e. parts they construe as less relevant [13]. We refrained from using neither a storyline nor cuts in our videos to avoid these alterations of the blinking.

The heart rate monitoring was utilized to enable us to quickly identify states of fatigue, sleepiness, nervousness or other physiological conditions, which could have had an impact on the blinking frequency of the participants [1]. All twelve subjects showed a regular heart beat during the whole experiment with minimal variations, e.g. cf. Figure 2. We could not detect any peculiarities that might have led to changes in the eye blink frequency.

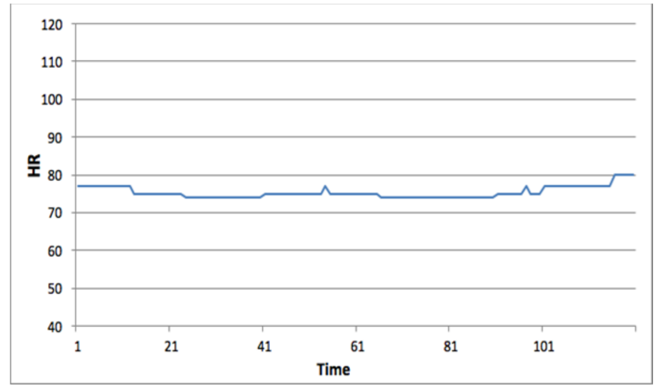

Figure 2: Example of Heart Rate recording for candidate 4 watching the third video block (HR in bpm, Time in sec).

Through our experiment we have gathered data, which illustrates the average eye blink per 30 seconds and user for different FRs. For 30 fps we observed an average blink frequency of 14/30s. Accordingly, we monitored average blink rates of 11/30s for the 60 fps and 90 fps group, and nine blinks per 30 seconds for the 120 fps videos. As Figure 3 shows, the combined average eye blink frequency shows a definite trend towards less eye blinking with HFRs. Most significantly, the data shows five blinks per 30 seconds difference between the 30 fps and the 120 fps clips, and two blinks per 30 seconds between the 60 fps clips and the 120 fps videos.

Since none of the monitored HRs decreased significantly while watching the videos, we expect that neither sleepiness nor other physiological factors are inducing the lower blinking frequency. In accordance

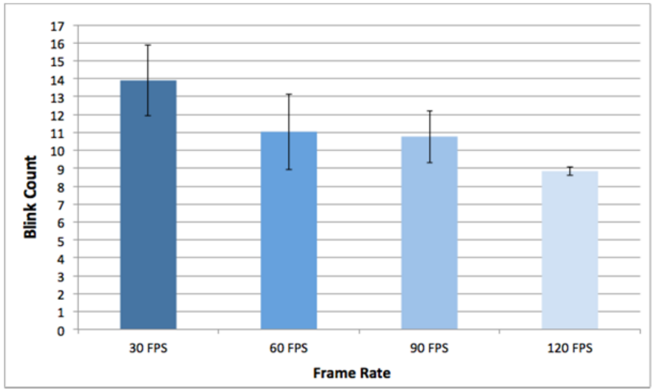

Figure 3: Average blink count for candidates 1-10 per frame rate. Videos of different motion complexity were combined under equal FRs, SD.

with the research presented before (e.g. Haak et al.), we assume that HFRs result in less stress in the viewer, whereas the 30 fps videos cause a certain strain.

The almost equal values of the 60 fps and 90 fps videos could derive from different factors. On the one hand, it might be due to the reluctance of the viewers in familiarization with HFR video. We are predominantly used to low FR contents, since 60 fps films have just recently entered the mainstream through the internet, and cinema (24fps) and TV (30fps) have conditioned our brains over decades. Secondly, the rounded average of eleven blinks per 30 seconds for the 60 fps and the 90 fps group indicates that our studied sample might have been too small for us to gain more distinct data. Furthermore, 30 seconds per video seem to be too short to allow viewers to get used to the displayed FR. We believe that a bigger group of participants and longer video takes would define the differences and draw a more conclusive picture.

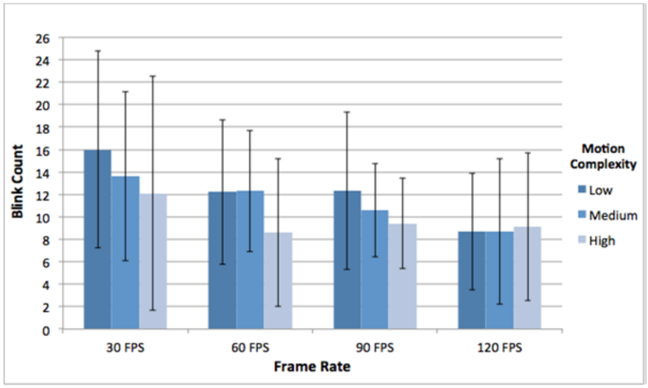

Figure 4: Average blink count for candidates 1-10 per frame rate and motion complexity (MC), SD.

When splitting up the average blink frequencies with regards to the actual video content depicted in the scenes, we find an interesting trend for the impact of MC on the viewer's blink rate. The differences between the separate videos can be seen in Figure 4. Even though the results are not as distinct as in Figure 3, we can still identify a tendency towards lower blinking frequencies with higher MC. When we designed the experiment we assumed that more complex motion would cause more stress on the viewer. Nevertheless, our data shows an opposite tendency. Moreover, the representation of blink rates in the 120 fps domain, with a blinking frequency of approximately 9/30 seconds for all three levels of motion, induces further questioning of our initial assumption.

Less motion content causes the image to be closer to a still image, which allows the viewer to pay more attention to the actual FR, because there are fewer temporal changes between frames that can be observed. Therefore, the LFRs become more obvious and cause greater stress on the viewer. Higher motion content, on the other hand, does not give the viewer the chance and time to pay active attention to the FR, but asks him to follow to the temporal changes in the frames. However, in the 120 fps domain MCs do not seem to matter, because even when a still image (no temporal changes between frames) is displayed in 120 fps for 30 seconds, the FR should not be recognizable anymore, at least to the untrained eye.

It has to be mentioned that the wide standard deviations (SD) show that our sample was too small and videos were too short for the obtained data to be significant. Moreover, we only visually controlled if participants were actually looking at the screen. The monitor was placed in front of a white wall on a plane table in order to avoid distraction. The chances, that viewers were still (un-)intentionally looking at the wall or the table existed nevertheless. In such a rather small sample group this might have been another factor influencing our results. Despite all that, we believe that we found evident trends that LFRs cause more stress on the viewer. Nevertheless, further research and testing is necessary in order to be able to draw a more coherent picture, especially when talking about different MCs in combination with various FRs.

Conclusion

We were investigating the impact of different frame rates on viewers' stress level. For this we studied the influence of different frame rates on viewers' eye blink frequency. The results confirm that a higher frame rate causes less stress on the viewer, expressed by a lower blinking frequency. Contrary to our assumptions we found that higher MC causes lower blink rates in observers.

This is a very interesting trend, because one would assume that more complex motion causes more stress. However, our data shows that less displayed MC results in higher blinking frequencies expressing more stress. We believe that this is due to the perceptibility of the actual FR in LFR domains. However, in the 120 fps domain, where FRs are not recognizable the blinking frequencies present equal values for all three MCs.

In addition to the eye blink frequency, we also constantly monitored the heart rate of all participants. There were no significant changes that could have explained the variances in blinking. In conclusion, the gained data suggests that there is an impact of video FR on viewers' stress level, measurable through the blink frequency.

Future Work

The next experiments require different video settings and a bigger group of participants. Longer videos shall give the viewer a chance to get used to different FRs. We will study the phenomenon of the impact of MC on viewer's eye blink in greater detail with bigger samples and longer videos. We also intend to conduct the upcoming experiments in a dark environment and hand out questionnaires after the experiment.

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