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Paper: Expert Viewers' Preferences for Higher Frame Rate 3D Film

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Abstract. *Recently the movie industry has been advocating the use of frame rates significantly higher than the traditional 24 frames per second. This higher frame rate theoretically improves the quality of motion portrayed in movies, and helps avoid motion blur, judder and other undesirable artifacts. Previously we reported that young adult audiences showed a clear preference for higher frame rates, particularly when contrasting 24 fps with 48 or 60 fps. We found little impact of shutter angle (frame exposure time) on viewers' choices. In the current study we replicated this experiment with an audience composed of imaging professionals who work in the film and display industry who assess image quality as an aspect of their everyday occupation. These viewers were also on average older and thus could be expected to have attachments to the "film look" both through experience and training. We used stereoscopic 3D content, filmed and projected at multiple frame rates (24, 48 and 60 fps), with shutter angles ranging from 90° to 358°, to evaluate viewer preferences. In paired-comparison experiments we assessed preferences along a set of five attributes (realism, motion smoothness, blur/clarity, quality of depth and overall preference). As with the young adults in the earlier study, the expert viewers showed a clear preference for higher frame rates, particularly when contrasting 24 fps with 48 or 60 fps. We found little impact of shutter angle on viewers' choices, with the exception of one clip at 48 fps where there was a preference for larger shutter angle. However, this preference was found for the most dynamic "warrior" clip in the experts but in the slower moving "picnic" clip for the naïve viewers. These data confirm the advantages afforded by high-frame rate capture and presentation in a cinema context in both naïve audiences and experienced film professionals.*
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INTRODUCTION

The adoption of the 24 frame per second (fps) capture and projection standard for cinema over 90 years ago has resulted in a particular expectation for motion blur and smoothness in 2D and S3D film. This expectation is a large part of what is known as "the film look"—the aesthetic that distinguishes cinematic content from crisper content typical of higher frame rate (HFR) applications like simulation, games and video. The higher frame rates enabled by the move from film to digital cinema should theoretically improve perceived image resolution, as well as reduce motion artifacts such as strobing and judder (Figure 1).

However, anecdotally some viewers balk at the hyper-realistic imagery and compare it to watching HD video footage.[1] This contrasts with studies in simulation[2] and gaming[3] which show benefits of increasing frame rate, typically to at least 60 fps in these applications.

In a recent study we evaluated the preferences of viewers in pairwise comparisons of cinematic content shot at various frame rates and frame durations (shutter angle—the amount of the frame period in which the sensor is exposed expressed as an angle).[4] Our viewers preferred HFR content both in terms of realism and in terms of overall preference. In a similar experiment, Mackin et al.[5] introduced a (nonstereoscopic) HFR image sequence database of 22 different movie clips captured at 4k resolution, 120 fps and 360° shutter. These were then spatially and temporally downsampled to 2K resolution and frame rates of 15, 30 and 60 fps (by averaging frames therefore simulating a 360° shutter; a control experiment validated the downsampling procedure). In subjective evaluations, participants provided absolute quality ratings of singly presented stimuli. Mean opinion scores increased with frame rate and the benefit of increasing the frame rate was greatest at lower frame rates (i.e., the benefit of doubling frame rate from 60 to 120 fps was smaller than the benefit of doubling from 15 to 30 fps, see also.[6]) Similar to our findings[4] the content of the clip was important and all clips with camera motion showed improved opinion scores when frame rate was increased from 60 to 120 fps.

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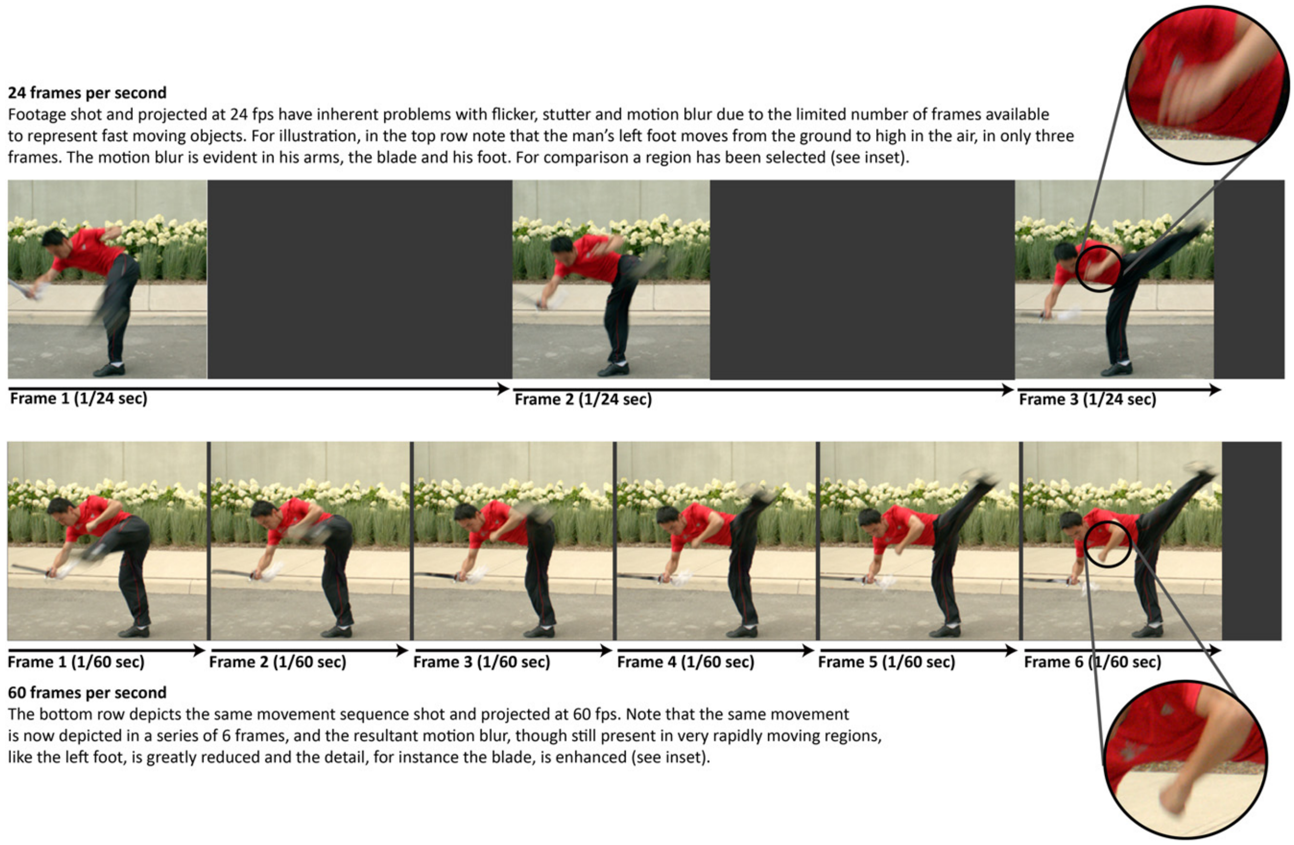


Figure 1. Illustration of the difference in motion blur present in a sequence shot at 24 fps (upper) versus 60 fps (lower). Adapted from a Christie Digital white paper on HFR.

This clear preference for HFR seems to run counter to the criticism leveled against recent HFR films that the content appears "too real." Our viewers and those of Mackin et al.,[5] were predominantly young adults who have grown up with computer games and high-definition video as defining audiovisual experiences. Perhaps these viewers preferred more realistic imagery because they were accustomed to it. The preferences of professional cinematographers, editors, visual effects supervisors, post-production specialists, colorists and other imaging professionals working in film production may differ from those of typical young audience members. These individuals are used to critically evaluating motion picture quality and are often responsible for obtaining a high-quality film look. The current study evaluates viewer preference for frame rate using a variety of film clips in this specialized group of highly trained viewers.

METHODS

Viewers

Participants ($N = 56$, mean age 47.5 ± 11.8 years, 52 male, 4 female) were recruited from the film industry in the greater metropolitan Toronto area by invitations through professional societies and industry mailing lists. The viewers were all imaging professionals working in the film and display industry who were used to assessing image quality as an aspect of their everyday occupation. These "expert" viewers' data were collected in a single experimental session. These data were compared with those of 50 viewers recruited through the Department of Psychology participant pool at York University and previously reported in Ref.4. In the latter, data were collected in two sessions using the same procedures as described in this article. In both experiments, participants wore their normal spectacle correction and gave their informed consent prior to participating. As part of the test procedure, all viewers completed a brief test of their stereopsis prior to participating in the main study and were excluded from the data set if they could not identify letters presented in a random dot pattern with at least 10 arcmin disparity, the largest offset tested here. Some other participants failed to respond on one or more trials. In total 16 viewers were excluded based on these factors (10 of these did not attempt or could not complete the stereoacuity test) leaving 40 viewers in the expert viewer data set.

Apparatus

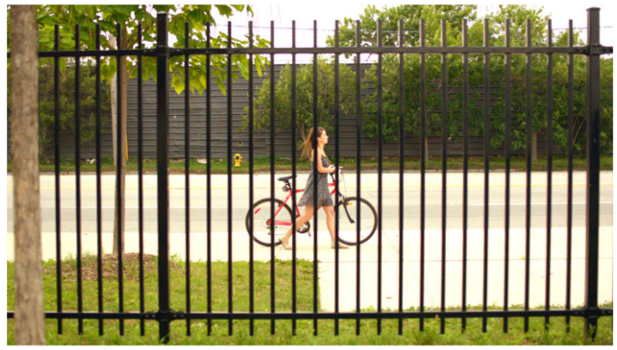
Testing was conducted in a large open studio space (Sheridan College's, Screen Industries Research and Training Centre (SIRT) Pinewood studios) with dimmable lighting. Stimuli were projected on to a Da-Lite silvered screen (22' diagonal) using a Christie Solaria CP4220 projector. Test footage was edited and projected at 24, 48 or 60 fps (per eye) according to the capture frame rate for each clip. Consistent with conventional 3D cinema projection practice, the 24 fps content was triple flashed in presentation (72 Hz per eye); 48

fps content was doubled flashed (96 Hz per eye) and 60 fps material was single flashed. Dark time was constant across the conditions (set via the projector controls).

Separation of the two eyes' views was achieved using a RealD XL circular polarization system that temporally alternated the left and right eye view (frame rate for the combined left and right image sequence was double the frame rate for each eye). Viewers wore matching polarized eyewear to view the 3D imagery, and made their responses on pre-prepared response sheets attached to clipboards. Because the polarizing filters attenuate the projector intensity, the screen luminance was calibrated to a standard S3D white-level luminance of 16 cd/m^2 through the filters. The clipboards were illuminated by a white screen projected between presentation pairs.

Stimuli

Footage was shot and edited at SIRT's Pinewood studio facility. Stereoscopic shots were captured using a 3rd Generation Tango 3D Rig with two Alexa Plus cameras equipped with a matched set of Cooke Pancro lenses. Neutral density filters were used to equate exposure across the conditions. Three different scenes were captured for use in this experiment in which (i) a woman walks slowly by long grass and sits at a *picnic* table (ii) a woman walks alongside a *bike* behind a tall fence and (iii) a Wushu *warrior* completes a complex sword routine. Figure 2 depicts a single frame from each of the three sequences. We obtained separate clips for a range of shutter angles (180°, 270°, 358°), and frame rates (24, 48, 60 fps) for the three scenarios. All clips used during testing were edited to a duration of 10 s and each variant of a given shot was started at the same start point. During testing, the pairs of clips were presented in a pseudorandom order to guard against order effects. To limit the total duration of the study (and avoid viewer fatigue), we did not include the picnic clip when we assessed the effect of frame rate.



(a)

(b)

(c)

Figure 2. Stills from each of the three shots: (a) Bike Shot, (b) Picnic Shot and (c) Warrior Shot.

Procedure

Participants were tested in a single session. At the test facility they were seated in nine rows with 1-m separation between rows for viewing distances of 6.3, 7.3, 8.3, 9.3, 10.3, 11.3, 12.3, 13.3, and 14.3 m from the screen, respectively for each row. Note that it was impractical to test the expert viewers in multiple sessions, therefore the seating area was expanded to accommodate 56 viewers. The distances of 7.3 to 11.3 m correspond to those used in the study with the naïve viewers.[4] Rows were 6.5 m wide and contained 12 seats, centered on the screen.

Prior to testing, informed consent and response forms were distributed, and the task was explained. We then asked viewers to complete a brief demographic questionnaire followed by an S3D letter identification test to verify that they had stereopsis (letters were presented as random dot stereograms, at disparities ranging from 1–10 pixels, for the 2K projector, which corresponded to approximately 1–10 arc min at the fourth row).

During testing, pairs of 10-s clips were presented, separated by a brief dark interval. Following each pair of clips, viewers were asked to indicate which clip they preferred, rating them on 5 attributes (Figure 3) using a five-point scale ranging from strongly prefer clip 1, through neutral, to strongly prefer clip 2. Prior to the experiment, this rating procedure and each of the five attributes were explained verbally to the viewers, any procedural questions answered, and they participated in two practice trials. Viewers were told that the aim of the study was to quantify the perceptual impact of artistic and technical decisions on depth, motion and image quality of 3D media, but they were not informed of the details of the experimental manipulations or any hypotheses until after the session. Following the experiment, viewers reported that the attributes they rated were natural and easy to understand.

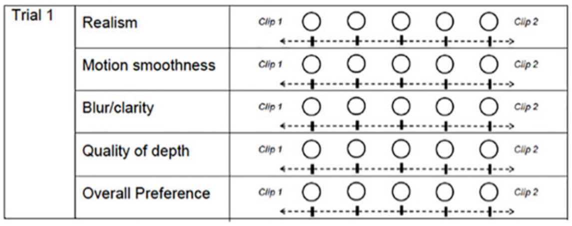


Figure 3. A sample of the response options for a single trial. All five variables were assessed for each pair of clips using the 5-point scale (−2 = strongly prefer first clip, −1 = prefer first clip, 0 = neutral, +1 prefer second clip, +2 = strongly prefer second clip).

A total of 22 paired comparisons were tested, in pseudorandom order, in the session. The order of presentation of the stimuli in each comparison pair was also randomized and therefore unpredictable, even though each paired comparison was only tested one time in the expert session (i.e., in one of the two orders). In our previous experiments with naïve viewers the order of the pairings was counterbalanced across the two sessions; analysis of these data showed no consistent presentation order effects.[4] During testing the experimenter called out the trial number to help the participants stay in sequence. The test session lasted approximately 60 minutes and, when the trials were completed, the questionnaires and response sheets were collected and the participants were debriefed.

Comparisons

For each of the three content types, there were 72 possible ordered pairs of clips for the nine combinations of frame rate and shutter angle. It was impractical to run all 216 comparisons, as each session would last more than 9 hours. Thus, as in our previous study, the test pairs were selected to evaluate key variables: frame rate, shutter angle and exposure duration (the product of frame duration and shutter angle/360°).

Frame Rate. We selected the bike and warrior shots to assess frame rate because these both involved fast motion or potential for strobing and aliasing artifacts. All pairs of comparisons between different frame rates at a fixed shutter angle of 180° were obtained for this analysis. This produced three combinations of 24, 48 and 60 fps for each shot for a total of 6 conditions.

Shutter Angle. To assess the effects of shutter angle we used all three shots. The frame rate was fixed at 60 fps and all pairs of comparisons between different shutter angles were tested. This produced three combinations of 180°, 270° and 358° for each shot (bike, picnic and warrior) for an additional 9 conditions.

Exposure. We tested all three pairs of the following combinations for all three shots: 24 fps-180°, 48 fps-180°, and 48 fps-358°. These comparisons allowed us to test whether the effects of frame rate were similar for the picnic shot (since it was not included in the frame rate series) and whether the effect of shutter angle was similar at 48 fps (since the shutter angle series was run at 60 fps). The comparison between 24 fps-180° and 48 fps-358° is important since they have an equivalent exposure time of about 20.8 ms (there was less than 1% difference in exposure duration). This produced another 9 pairings but because two were common with the frame rate series above only 7 additional conditions were required.

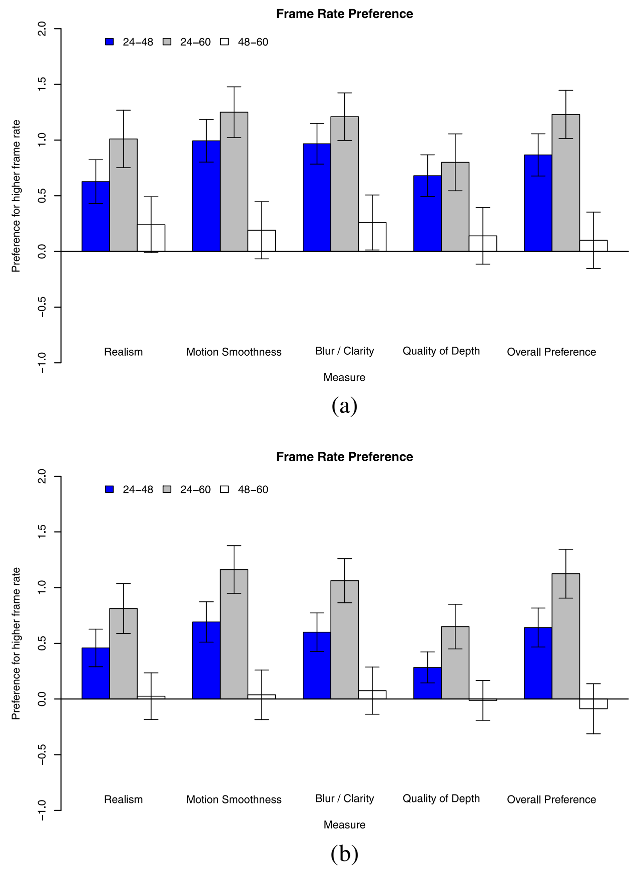


Figure 4. Average preference rating (range −2 to +2) for comparisons of frame rate conditions. Preferences are shown for comparisons between versions of the same clip with different frame rates. Positive values indicate preference for the higher frame rate. Data are for a fixed shutter angle of 180° and are collapsed across clip type. (a) Top panel shows data for young adults from Wilcox et al.[4] and the (b) Bottom panel shows the results from the film industry professional viewers.

RESULTS

As noted above, all paired comparisons were tested in a single session in random order. Subsequently, the preference data were compiled and analyzed using an additive conjoint analysis. Used commonly in market research, conjoint analysis measures the degree to which each attribute contributes to overall preference as represented by its "part-worth" utility and coefficient in a regression model.[7,8] The sum of these part-worth utilities is zero and the viewers' preference for one attribute (over another) is indicated by the difference of their coefficients. In the following sections we examine the coefficients for each of the main groups of comparisons outlined in the Comparisons section above.

Frame Rate

Figure 4 shows the preferences for pairwise comparison of clips with different frame rate, at a fixed shutter angle (180°),

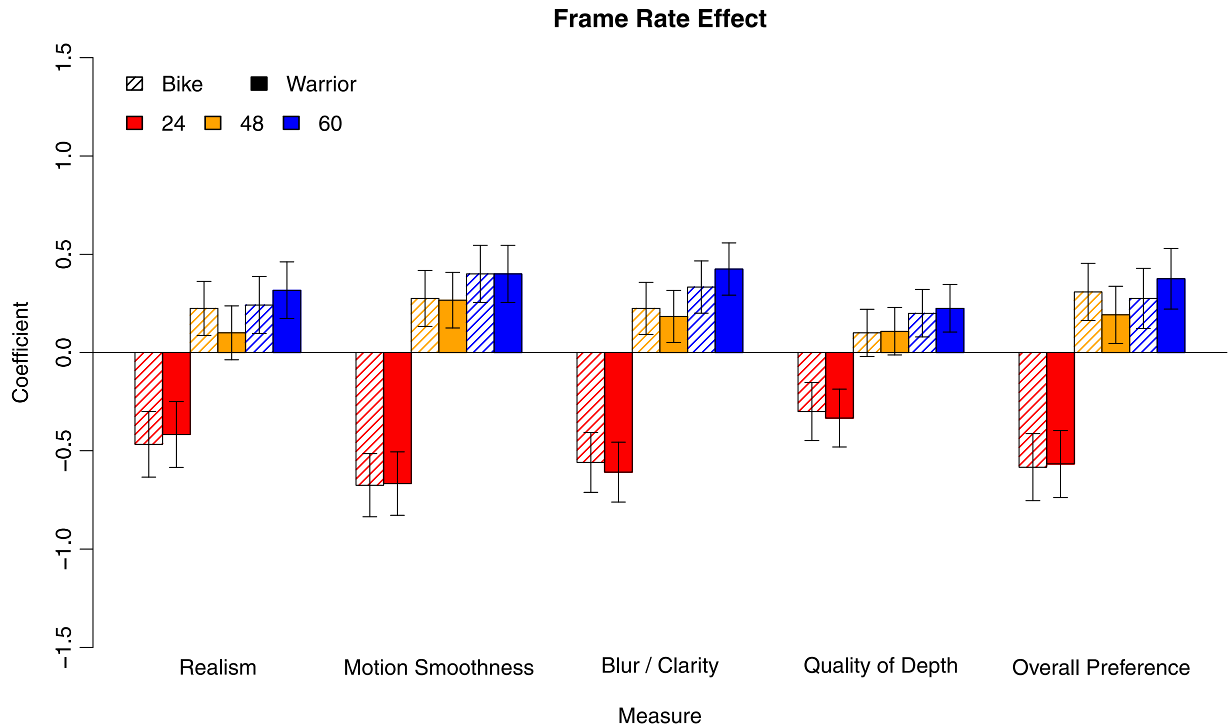


Figure 5. The likelihood of choosing the clip with a particular frame rate is shown here at a fixed shutter angle (180°) for each of the five measurement attributes. The data obtained using the bike and warrior footage is indicated with lined and solid bars, respectively. Each frame rate is indicated by the bar color (24 = red, 48 = orange, 60 = blue). The measure is indicated below each data set. Error bars represent 95% confidence intervals.

for the bike and warrior clips (recall that the picnic clip was not included in this comparison). For both clips, and all measures (realism, motion smoothness, blur/clarity, depth quality and overall preference), there was a strong tendency to choose the clip with the higher frame rate when 24 fps was paired with 48 or 60 fps. However, this graph also shows little or no difference between the preference between frame rates of 48 and 60.

The conjoint analysis confirmed that there was a significant preference for higher frame rates (48 and 60 fps compared to 24 fps), with p values < 0.0001. The coefficient weightings are shown in Figure 5. For both clips, and all measures (realism, motion smoothness blur/clarity, depth quality and overall preference), coefficients were positive for the high-frame rate conditions (48 and 60 fps), and consistently negative for the 24 fps footage, consistent with the bias to choose the clip with the higher frame rate when 24 fps was paired with 48 or 60 fps.

The effect of clip type was only significant for the overall preference measure ($p = 0.0155$). This was consistent with the previously reported results for the naïve viewers where there was a significant interaction between frame rate and clip type. Viewers in both groups preferred the warrior clip when presented at 60 fps compared to 48 fps but had similar preferences for 60 and 48 fps versions of the bike clip. In general, the results of the naïve and expert groups were similar as were the statistical inferences. One difference was that, while there was a significant interaction between frame rate and clip type for motion smoothness and blur/clarity in the naïve group, this was not the case in our expert group. Also, as noted in the methods, there were more viewers in the expert session than in the naïve sessions. Restricting the analysis to viewers seated at distances corresponding to the naïve group produced a pattern of results similar to that found with the complete expert dataset.

Shutter Angle

The preferences obtained for the three shutter angles (at 60 fps) collapsed across clips, are shown in Figure 6. There were no significant differences between any of the comparisons, nor was there a significant preference for any shutter angle on any of the individual measures. A histogram of the responses showed no evidence of bimodality as might be expected from a "film look" versus "crisp image" dichotomy. This pattern of results was the same as that found previously for the naïve viewers.

Equivalent Exposure Comparison

To evaluate the effect of exposure on preferences for the five measures and three clip types, we assessed preferences for 24 fps footage with 180° shutter angle versus 48 fps shot with 180° and 358° shutter angles. Note that the exposure duration is equivalent in the 24-180° and the 48-358° conditions, so if exposure drives preferences, coefficients in these two conditions should be equivalent and positive. However, if frame rate is the critical variable, then we should find the pattern of results observed in Fig. 4, with large coefficients associated with 48 fps, and small (or negative)

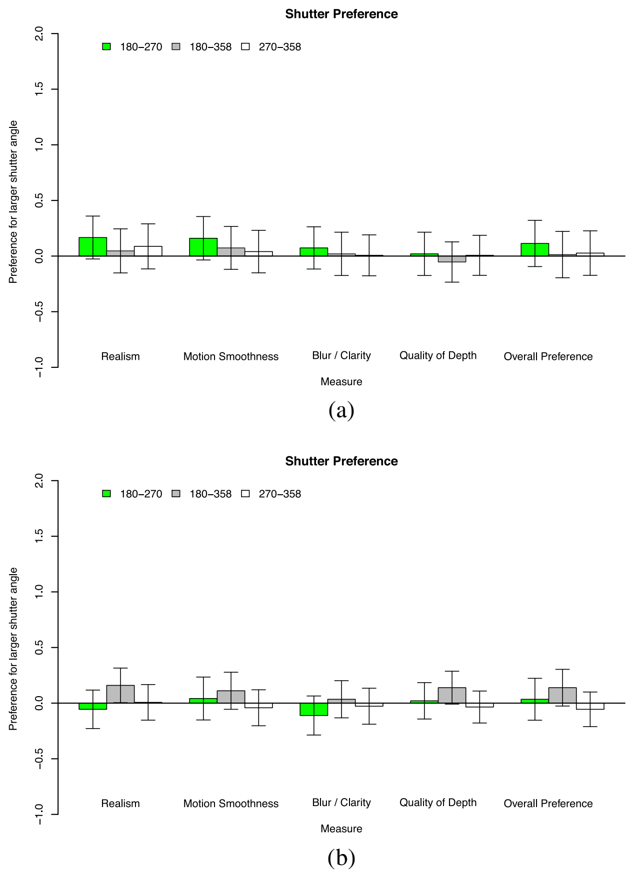


Figure 6. Average preference rating (−2 to +2) for comparisons of shutter angle conditions. Preferences are shown for comparisons between versions of the same clip with different shutter. Positive values indicate preference for the larger shutter angle. Data are for a fixed frame rate of 60 fps and are collapsed across clip type. (a) Top panel shows data for young adults from Wilcox et al.[4] and (b) the bottom panel shows the results from the film industry professional viewers.

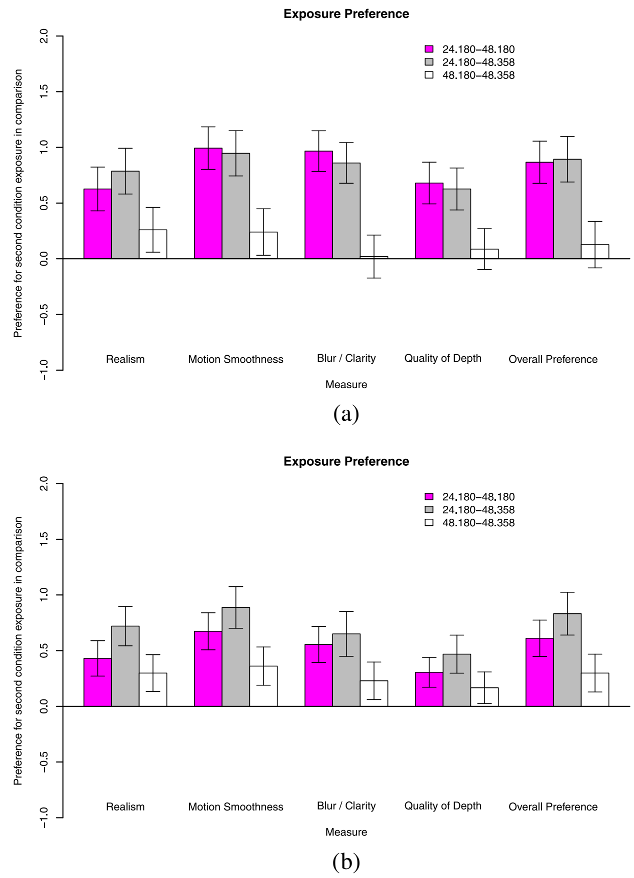


Figure 7. Average preference rating (−2 to +2) for comparisons in which exposure is equated (24 fps with 180° shutter is equivalent to 48 fps with 358° shutter angle) for all measures. Data are averaged across clip type and show coefficients for conditions with 24 fps at 180°, 48 fps at 180° and 358°. Error bars represent the 95% confidence intervals. Positive values indicate preference for the larger frame rate (or shutter angle when both frame rates are 48 fps). (a) Top panel shows data for young adults from Wilcox et al.[4] and (b) the bottom panel shows the results from the film industry professional viewers.

coefficients with 24 fps, irrespective of exposure. The data are shown in Figure 7 for all measures, averaged across clip type.

Fig. 7 shows that, as expected based on the frame rate comparisons above, viewers preferred higher frame rates even when exposure was equated (24-180° versus the 48-358° conditions). However, unlike the naïve viewers, overall our expert viewers showed some preference for a larger shutter angle in these clips. There were significant effects of frame rate and clip ($p < 0.001$) as well as an interaction between frame rate and clip for the motion smoothness measure. The nature of the clip seemed to matter more for our expert viewers as we found only an effect of frame rate and an interaction between frame rate and clip for the motion smoothness measure for naïve viewers in Ref.4 Restricting the analysis to viewers seated at distances corresponding to the naïve group did not affect the results.

Examination of the coefficients by clip type, showed that the coefficients for the 48 fps-180° and 48 fps-358° cases (Figure 8) differed the most for the warrior clip, particularly for the Motion Smoothness and Overall Preference measures but with no significant differences for Quality of Depth. In contrast, for the bike clip the differences between 48 fps-180° and 48 fps-358° coefficients are near zero and differences between conditions are small for the picnic clip. The reduced preference for the 48 fps-180° clip relative to the 48 fps-358° condition for the warrior clip suggests that motion artifacts do impact preferences when they are salient, and when viewers are asked to reflect specifically on motion quality. Interestingly, although the naïve viewers[4] also showed differences for these comparisons, these differences were observed for the picnic clip (mainly for the Motion Smoothness measure) and there were no shutter angle differences for the warrior clip.

DISCUSSION

As we found previously for naïve viewers, in all conditions tested here there was a clear preference for HFRs (48 and 60 fps) compared to a standard of 24 fps, regardless of content (Fig. 4). This finding is consistent with reports of generally beneficial impacts of high-frame rate in simulation and television,[9,10] video[11] and gaming.[3]

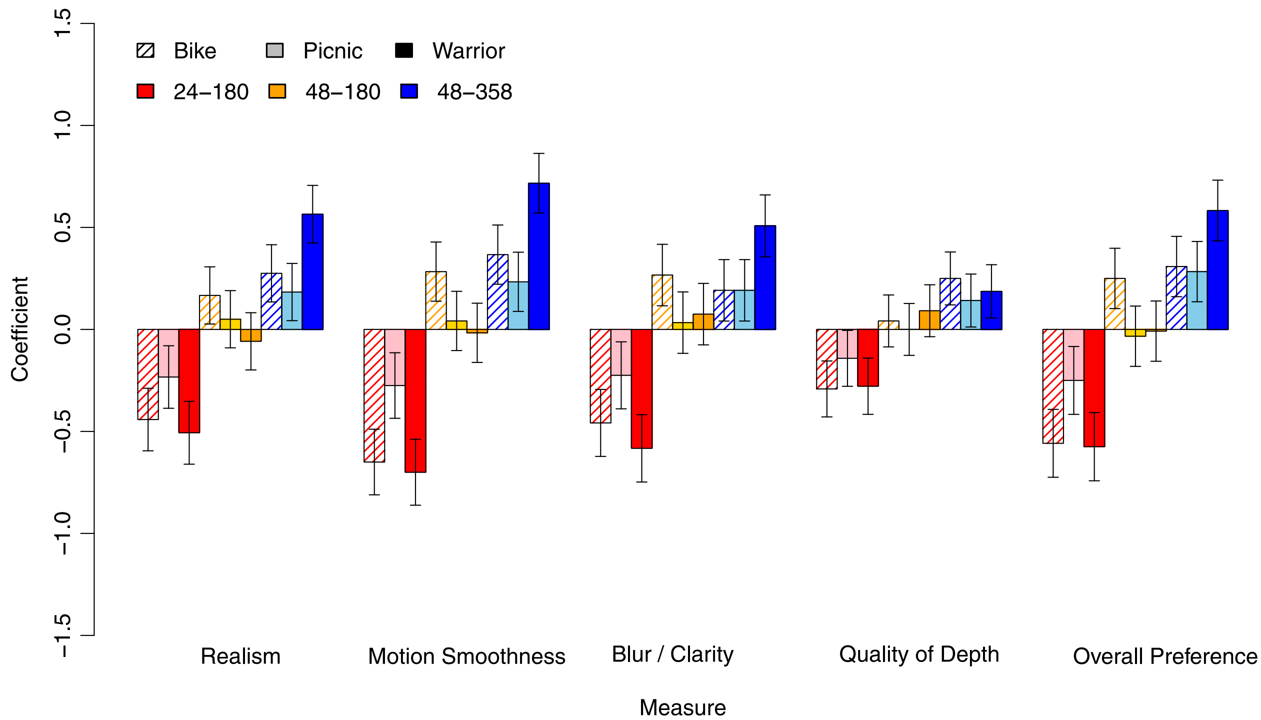


Figure 8. The likelihood of choosing the clip with a particular combination of shutter and frame rate is shown for each of the five measurement attributes. The data obtained using the bike, picnic and warrior footage is indicated with lined, light solid and dark solid bars respectively. Conditions with 24 fps at 180°, 48 fps at 180° and 358° are indicated by the bar colour: red, gold, and blue, respectively. The measure is indicated below each data set. Error bars represent 95% confidence intervals.

Interestingly, there was less additional benefit afforded by further increasing frame rate from 48 to 60 fps for the bike shot. However, for the warrior shot, expert viewers significantly preferred 60 fps compared to 48 fps content in terms of blur/clarity and naïve viewers preferred 60 over 48 fps for motion smoothness, blur/clarity, and overall preference. This shows that the effect of frame rate is content dependent. For an action shot like the warrior clip, the details of the rapid movement are preserved at high-frame rates. It is not surprising that image speed is an important factor; for a perfectly stationary scene there would be no benefit of increased frame rate at all. Overall, our data suggests that the improvement in moving image quality provided by HFRs is perceived and appreciated by both expert and naïve viewers.

At 60 fps, there was no effect of shutter angle on preferences for these clips for any measure (Fig. 6). Consistent with these results, we found that when exposure was equated by comparing 24 fps at 180° with 48 fps at 358°, viewers maintained a preference for the higher frame rate (48 fps). Similarly, in that same set of comparisons, while there was no consistent preference when the frame rate was equivalent (48 fps) but the shutter angle varied (180° versus 358°), we found a clip dependent preference for larger shutter angle (48 fps-358° preferred over 48 fps-180°). However, this preference was found for the warrior clip in the experts but in the picnic clip for the naïve viewers. We speculated in the earlier article that given the intimate nature of the composition in the picnic clip, perhaps viewers were drawn to the softer appearance provided by the large shutter angle, which matched their "film-look" expectations. While we might have expected more "film-look" bias in our expert group, expert viewer preferences were not strongly biased for the picnic clip which showed the weakest effects of both frame rate and shutter in these exposure comparisons (Fig. 8). In contrast, there was rapid motion in the warrior clip and expert viewers had strong bias for a longer shutter angle at 48 fps (along with bias for HFR demonstrated for both groups) and presumably preferred the resulting increase in motion blur.

Beyond this finding there was little evidence for an effect of shutter angle despite its predicted effect on perceived image blur. This lack of an effect could have occurred because the viewer did not perceive the resultant blur or because it simply did not factor in their preferences. One argument in support of the former interpretation is that this manipulation would have less impact because of the high-frame rate used (60 fps) for the main shutter angle comparison. However, the content contained significant motion and significant motion blur variation across shutter angle would be expected even at 60 fps. In other experiments,[12] we have demonstrated that this range of motion blur has a significant impact on letter discrimination, which suggests it should be readily apparent. In support of the latter interpretation, audiences are accustomed to softer images due to blur, and to the manipulation of depth of field within scenes, so perhaps they just accepted these shutter angle manipulations as normal variation in film look and thus the shutter angle manipulation did not influence their preferences. In fact, in cases where shutter angle did affect preferences, observers indicated a preference for *larger shutter angle*; clearly reduction of motion blur was not a main driver of their preference judgements.

Analysis of the impact of camera exposure on motion blur is complicated by the fact that projection systems show each frame for a fixed flash duration. At lower frame rates these flashes are typically repeated two or three times per frame to prevent flicker. This projector exposure may also impact perceived image quality; for example, by producing retinal image blur or aliasing when the eyes move.[12–14] We employed state-of-the-art cinema projection technologies for this study, which at the time of testing corresponded to a triple-flash protocol for the 24 fps content (three flashes per eye producing six flashes every frame for our S3D material), a double-flash protocol for the 48 fps content, and a single flash protocol for the 60 fps content. Except at 60 fps-90°, the flash durations were shorter than the camera shutter duration and thus we expect that they would have a relatively weak impact on motion blur and smoothness. However, future research quantifying the effects of projection parameters and the interaction between projection flash protocols, image motion and eye movements will be important in developing a full understanding of the perceptual effects of HFR capture and presentation.

We note that this study does not address all possible factors that could modulate the effects of frame rate on viewer preference. For example, all our content was shot and presented in stereoscopic 3D but we did not systematically vary frame rate and stereoscopic depth to determine if they interact. Rather we set the stereoscopic depth budget for aesthetic reasons, within established norms for S3D filmmaking. Viewers have surprising tolerance to manipulation of stereoscopic viewing parameters[15] but frame rate is expected to influence stereoscopic depth in frame sequential stereoscopic presentations. Our expert viewers preferred HFR for the quality of depth measure which is consistent with theoretical predictions[16] and previous empirical work.[17] However, it is worth noting that the preference for HFR was typically weakest for comparisons of quality of depth relative to the other four attributes. This suggests that depth quality was not the principle reason for the overall preference for HFRs. Similarly, complaints of hyper-realism often seem to concern the fake nature of props and sets. Our content was filmed on location with minimal set dressing and no elaborate costumes, make-up, or masks. Thus any increased realism in our shots should enhance the experience rather than "give away" a movie set. In related work we are exploring this aspect of high-frame rate cinematic content creation.

The main novelty of the current article is the consideration of expert viewers as compared to typical audience members. Experience and training have long been known to influence aesthetic judgements. In the context of printed images, Boust et al.[18] point out that color imaging experts working on enhancing an image divide it into objects and regions of interest while naïve viewers principally focus on local areas of natural color like sky or grass. Nevertheless, both experts and naïve viewers focused on the colors of materials with which they are familiar based on experience and memory. The goal of the experts is to improve the quality for the general viewer so it is not unexpected that the authors found that the experts focus on features of interest to the viewer or that the viewer's ratings of quality improve after expert enhancements. Similarly, it is perhaps reassuring that film industry experts charged with producing quality products for the public share the public's preferences.

However, experts also know what type of artifacts and defects are likely to occur and might be expected to be more sensitive to them. For example, Cui[19] found that experts and naïve viewers differed most in judgements of print quality in cases of print engine artifacts, presumably because the experts were attuned to these common artifacts. When comparing expert and naïve viewers on judgements of compressed video quality, Speranza et al.[20] found that the two groups showed a small but significant difference in ratings when quality was low but had similar ratings for high-quality content. Expert raters tended to be more critical of poor quality video. Unlike the present study, the viewers in Ref. 20 rated absolute quality rather than making pairwise comparisons. Thus, lower opinion scores could indicate the experts were more critical of the low quality video and not necessarily more sensitive. Anecdotally, our expert viewers reported that they found making quality judgements with a single repetition of pair of clips challenging. Many noted that they are used to being able to review material several times over while focusing on particular aspects or parts of the image. Judging quality after a single pass (like an audience) was more difficult and they may have been less discerning than in their everyday jobs. The requirement to judge multiple aspects of a clip during a single presentation might be expected to impact our viewers' ability to focus on a single attribute, or lead to increased correlation between the measures. Nevertheless, there were consistent differences between measures and across our two studies confirming that viewers could separate these aspects. Furthermore, multifaceted appreciation of the content during a single viewing is typical of most cinematic experiences.

In a similar vein, judgements of overall quality are also complex as they reflect many technical and artistic considerations. HFRs were preferred in this study in overall preference ratings and for ratings of smoothness, sharpness, realism and depth. This suggests that preferences on these latter factors contributed to the overall preference. However, it is possible these factors carried more weight in the overall preference judgements than they would outside the experimental setting because of the demands of the experiment. Even if this were the case though, any overall bias for the film look was relatively weak and readily reversed by drawing attention to these specific aspects of image quality.

The film-look concept ascribes an aesthetic value to the visual characteristics of film including low frame rate. Expert and naïve judgements of aesthetic quality can reportedly be quite different, particularly in art. For example, Winston and

Cupchik[21] reported that naïve viewers accounted for their preference in terms of emotional responses while students of fine art considered the structure and complexity of the artwork. Hekkert and Wieringen[22] found low agreement between expert and naïve viewers' judgements of the quality of artwork. In this case, experts associated quality with creativity, but naïve viewers did not. Here we show that while the film-look aesthetic is anecdotally established, we found no evidence of a strong preference for this aesthetic in either our expert or naïve viewers.

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