Evaluating the Effects of Image Persistence on Dynamic Target Acquisition in Low Frame Rate Virtual Environments

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Motivation

- Frame rate may be limited by tracking systems, CPU/GPU load, networking.
- Low frame rate conditions (dubbed high persistence or HP) have visual artifacts.
- Previously developed technique of low frame rate low persistence (LP) involves blanking the screen while waiting for fresh content (see figure 1).
- LP removes visual artifacts but adds visual strobing + decreased brightness.

Task

- Modeled dynamic target acquisition task on trap shooting as well as previous VR distal pointing tasks [2].
- Target could take one of 10 paths: 5 horizontal x 2 elevations. (figure 3)
- User would position the hand controller to intercept the target. (see figure 2)
- User would press the under button on the intersense IS-900 wand.
- If successful, the target would explode and a sound would be played.

User Study and Analysis

- Six-sided CAVE-type system.
- Between-subjects design.
- 30 volunteers. (10 HFR, 10 HP, 10 LP)
- Procedure: pre-test high frame rate (HFR) block, 5 training blocks, then final post-test HFR block
- Analysis via ANOVA
  Three within-subjects factors (block, elevation, horizon), one between-subjects factor (visual condition)
- Performance metric of "closeness" was angular distance between center of target and ray when user clicked button. (see figure 2)

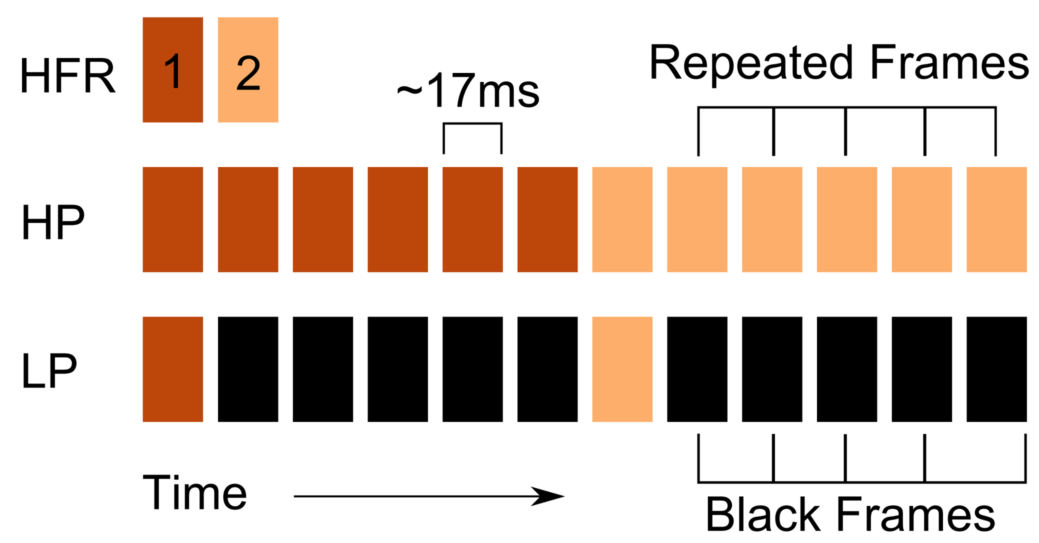

Figure 1: Comparison of rendering two frames (dark orange and then light orange) of content for the different experimental conditions (HP + LP). High frame rate (HFR) displayed content at 60 fps, HP and LP displayed content at an effective frame rate of 10 fps.

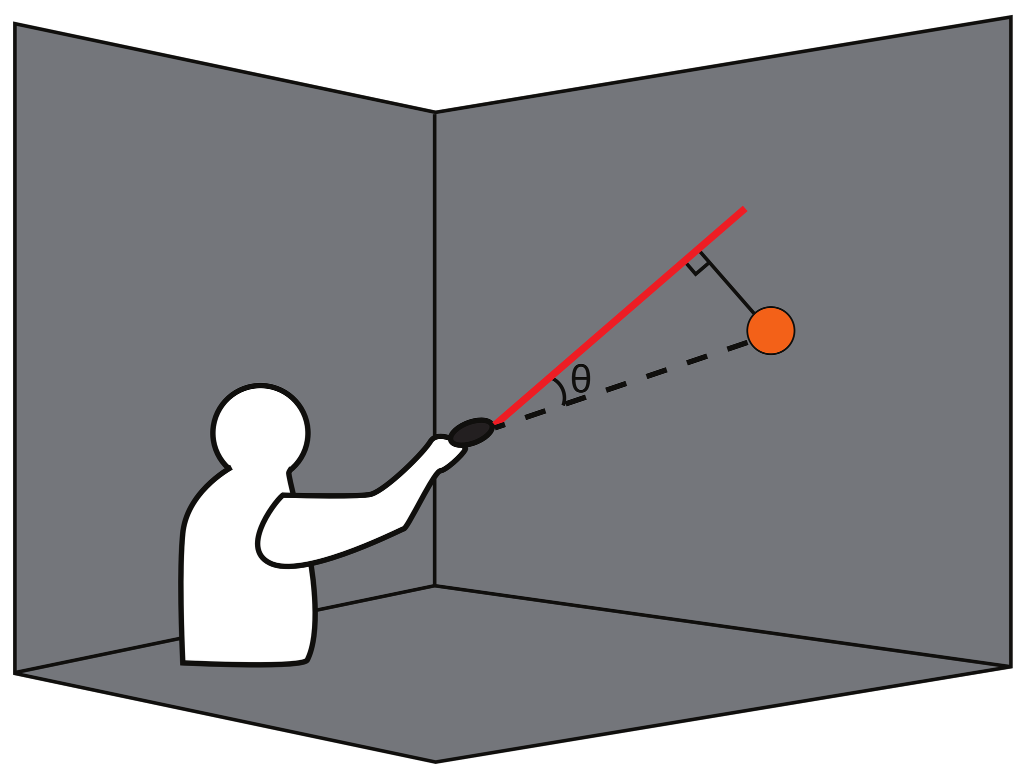

Figure 2: Diagram showing task paradigm (user selects moving orange target sphere with red raycasting wand) and also how angular closeness performance metric is determined.

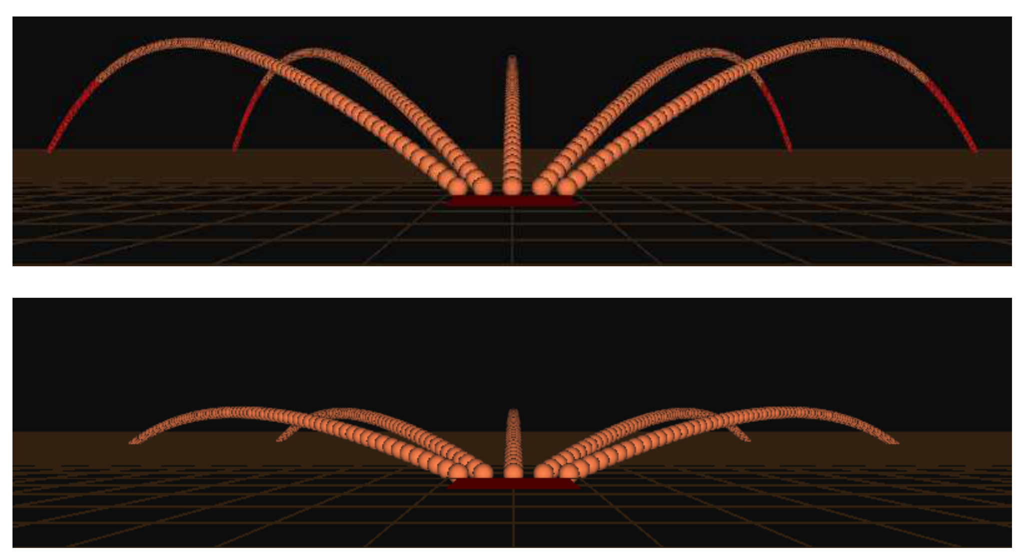

Figure 3: Tracings of the 10 different paths the target object would take during the study. Top picture illustrates the 5 high elevation trajectories. The bottom image illustrates the 5 low elevation trajectories.

Result 1: Better HFR performance replicates results of previous work.

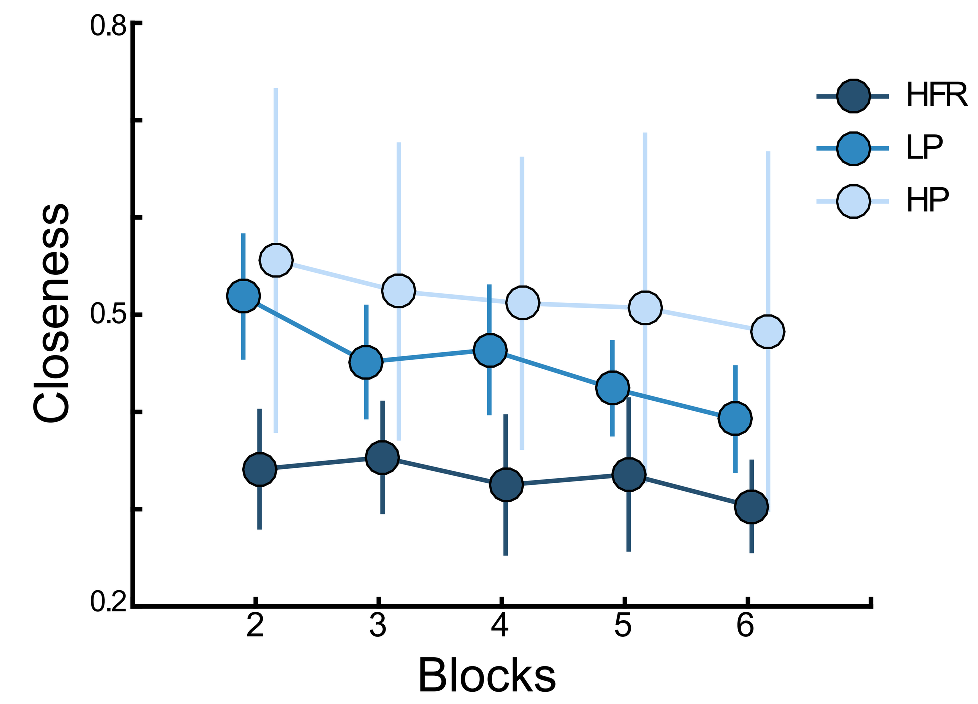

Figure 4: Angular closeness means for three visual conditions. Mean closeness significantly decreased through blocks indicating learning. Lower closeness scores are better.

Training blocks show main effect of visual condition ($p < .001$)

- HFR > HP ($p < .001$)
- HFR > LP ($p < .05$)
- HP vs LP non significant ($p = .93$)

Result 2: HFR post-test shows participants received equally beneficial training in all visual conditions.

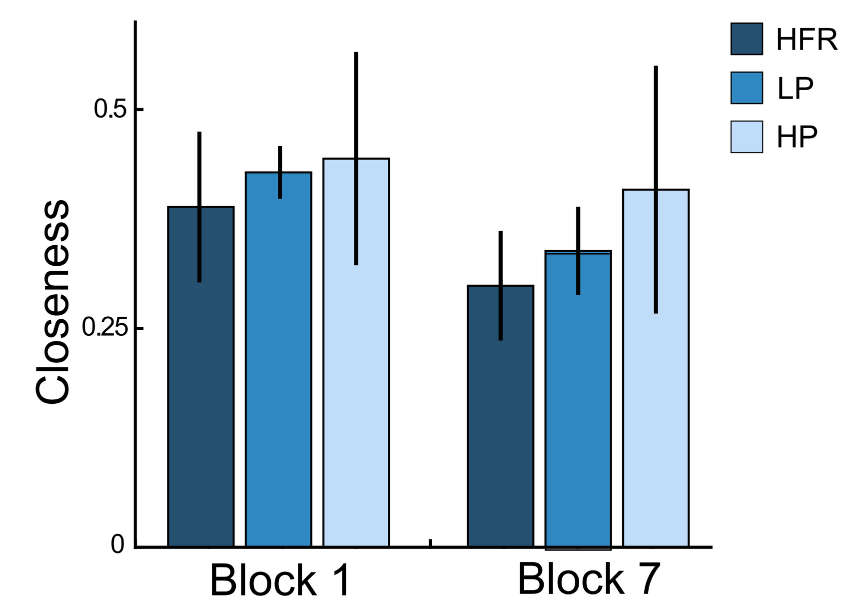

Figure 5: Angular closeness means from the HFR pre-test (block 1) and HFR post-test (block 7). Irrespective of the visual condition in Blocks 2-6, participants performed significantly better in Block 7 as compared to Block 1.

Pre and Post Assessment (HFR)

- Main effect of block ($p < .001$)
- No effect of visual condition ($p = .149$)

Result 3: Comparison of HFR and LP in the upper elevation and center horizon shows LP technique may be useful in some trajectories.

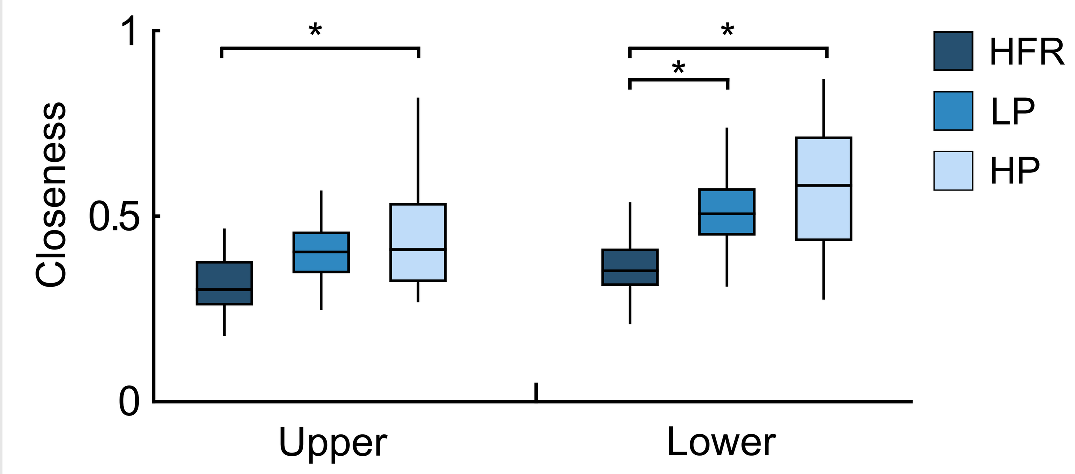

Figure 6: Angular closeness for the three visual conditions separated by the two target elevations. In the upper elevation, performance in the HFR condition and that in the LP condition are not significantly different.

Training blocks show elevation and visual condition interaction ($p = .031$)

lower elev.	HFR > HP ($p < .005$) HFR > LP ($p < .005$) HP vs LP non significant ($p = .934$)
upper elev.	HFR > HP ($p < .05$) HFR vs LP non significant ($p = .104$) LP vs HP non significant ($p = 1.0$)

Similiar results in center horizon trajectory.

Conclusion

- Training of dynamic target acquisition under degraded visual conditions transfers well to performance under a baseline high frame rate task.
- Certain tasks when in a low frame rate condition may show benefit from a low persistence adjustment

References:

[1] D. Zielinski, H. Rao, M. Sommer, and R. Kopper. Exploring the effects of image persistence in low frame rate virtual environments. In Virtual Reality Conference Proceedings, pages 19–26. IEEE, 2015.

[2] R. Kopper, D. A. Bowman, M. G. Silva, and R. P. McMahan. A human motor behavior model for distal pointing tasks. International journal of human-computer studies, 68(10):603–615, 2010.