Toward Understanding Display Size for FPS Esports Aiming

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ABSTRACT

Gamers use a variety of different display sizes, though for PC gaming, monitors in the 24 to 27 inch size range have become most popular. Particularly popular among many PC gamers, first person shooter (FPS) games represent a genre where hand-eye coordination is particularly central to the player's performance in game. In a carefully designed set of experiments on FPS aiming, we compare player performance across a range of display sizes. In two experiments, we compare 12.5 inch, 17.3 inch and 24 inch monitors on a multi-target elimination task, once with stationary, and once with moving targets. We find that aiming improves as display sizes increase. Next, we highlight the differences between 24.5 inch and 27 inch displays in a third experiment using very small targets. We find a small, but statistically significant improvement in aiming when using the larger monitor. Overall, our results indicate that in typical desktop gaming settings with freely varying head position and field of view, FPS aiming improves as display size grows, though improvements begin to decline as size approaches 30 inches.

CCS CONCEPTS

• Human-centered computing → Pointing devices; **User models**; **User studies**; **• Applied computing → Computer games**.

KEYWORDS

pointing devices, mouse, display size, first person targeting, games, esports

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1 INTRODUCTION

First person shooter (FPS) games are one of the most popular esports genres. A key feature of FPS games, particularly when using a mouse as the input device, is the high level of skill required to quickly and accurately hit targets. A variety of factors contribute to a player's ability to complete these tasks, including the input, graphics, and display systems. To this end, we present three experiments investigating display size impacts on FPS aiming tasks. These studies cover some of the space between a carefully controlled lab environment and natural usage patterns in gaming. For example, most players do not strictly control viewing distance or room brightness, though these parameters are essential to well controlled scientific experimentation. The primary contribution of this work is studying the effects of display size on natural player behavior, with uncontrolled viewing distance and head motion.

2 RELATED WORK

We leave a broad review of related work to others [10], and provide here only a focused overview of some of the most relevant topics.

Today, computer systems for competitive games most often use a desktop monitor as their main display. These monitors have a variety of specifications including size, refresh rate, latency, and resolution, while also giving the players freedom to customize other features such as brightness or contrast as they wish. This creates a dynamic environment that can affect gameplay in many ways.

Many have studied the effects of temporal display characteristics FPS gaming, with lower latency and to a lesser extent, high frame rates improving performance [6, 14, 23]. Liu et al. expanded this work to include network latency [11–13]. Madhusudan and Watson considered in-game settings [17], finding that most players choose to reduce visual quality to improve reduce latency. Others explored the impact that adaptive synchronization (e.g., G-SYNC) has on player performance, finding that such synchronization can improve performance [19, 28].

As to visual (spatial) display characteristics, the study most directly related to this work was published in 2022 by Kim et al. [10]. They also varied display sizes from 13-65", but in contrast to this work, they maintained a constant display field of view by controlling the viewing distance of the player. Their main finding is that the smallest display size (13") demonstrates a statistically significant disadvantage to aiming performance when compared to larger display sizes, with no significant improvements in performance for displays larger than 26".

Other work has studied display size, but outside the context of FPS gaming, in desktop and VR settings. A few studies report that larger display size has a variety of positive effects resulting in improved reaction times [3, 4, 18, 25] and greater immersion [5].

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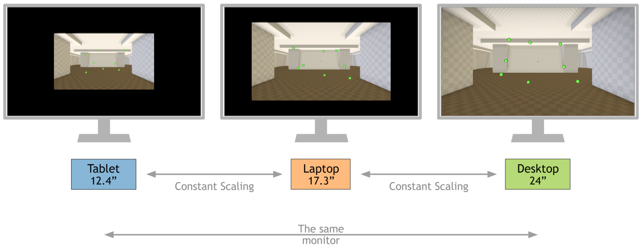


Figure 1: Experiment 1 — emulating smaller display sizes with black borders on a 24-inch monitor.

In contrast, other studies show that larger display size has little or even negative effects at a variety of similar tasks [20, 21, 27] Our work focuses on FPS gaming, which requires precise aim and high levels of aiming skill, and we hope to provide some clarity on this open question, at least for this type of game-specific task.

While Fitts's Law applies to simple FPS targeting tasks [15] that pan or rotate the environment rather than translating the pointer, whether it applies to complex FPS scenarios is less clear. Fitts's Law models selection of static and well-known targets, while as others have pointed out [2, 7], FPS games often include moving targets, perceptual challenges, tactics and strategy (e.g., which target to hit next), and timing. Caution should be used when applying Fitts's Law to FPS actions.

3 EXPERIMENT 1: DISPLAY SIZE VARIATION

This experiment tests the effects of varying display size as target size (task difficulty) also varies. Participants used a 24 inch monitor to simulate 3 different display sizes: 24 inches, commonly used in desktop setups; 17.3 inches, available on laptops; and 12.5 inches, as is tablet displays. These three display sizes are common, and scale by a common factor (~1.4).

3.1 Equipment

We used FirstPersonScience [1, 24] (FPSci) to implement this experiment, a tool purpose-built for these types of FPS aiming task experiments. Multiple other FPS studies have shown valuable results using FPSci [9, 23, 26]. This program is similar to commercially available aim trainers, but allows low level control of the game loop and experiment configuration.

To hold other display characteristics (e.g. brightness, color gamut) constant, we emulated display size changes using one 24-inch, 240Hz monitor, as shown in Fig. 1. The large display size used the full 24-inch monitor, while the smaller sizes left the region outside the central rendered area black.

All participants used a Logitech G203 mouse.

3.2 Task and Methods

A player's task for this experiment was to shoot targets. They began their task by pressing shift while aiming at a red centering target, after which 8 static (green) targets appeared at the same time. The player then had to move the mouse to align the in-game crosshair with each target, and left click once to eliminate it. To complete the task, the player had do eliminate all 8 targets. Each target spawned in one of 8 separate regions, organized in a grid around the centering target, at a random location within their assigned region.

Table 1: Experiment 1 — Per-participant experiment structure. Note that order of displays and target sizes varied.

Design structure	Count/Description
Experiment	3 sessions - one per display size
Sessions	15 block repetition
Blocks	4 trials - one per target size
Trials	8 targets - all same size
Targets	All appear simultaneously, stationary

Each player performed this task repeatedly in 180 trials. We grouped these trials into three sessions, one for each display size, consisting of 60 trials each. The order within which players worked with each display size was counterbalanced across participants. Within each session, we grouped trials into 15 blocks, each consisting of four trials. A block is a construct that allows us control over the ordering when repeating trials.

Within each block, a player had to shoot at each of four different target sizes. Within each trial, all eight targets were the same size, where the smallest size was particularly challenging. The order of the size trials within each block was randomized.

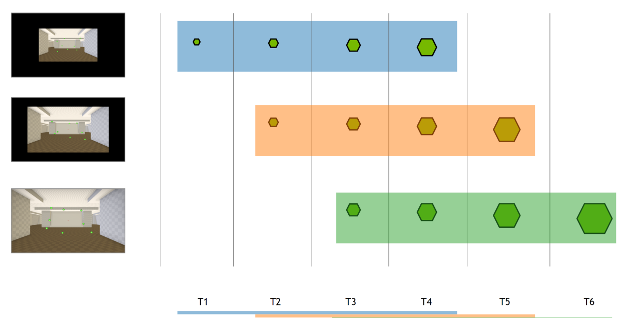
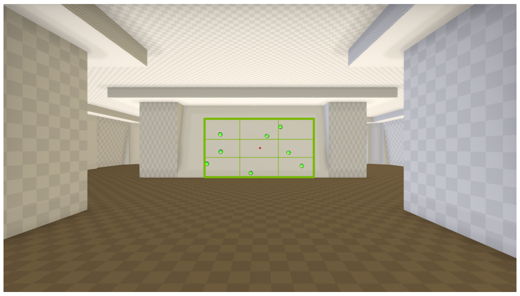


Figure 2: Experiment 1 — Target size varied in proportion to display size.

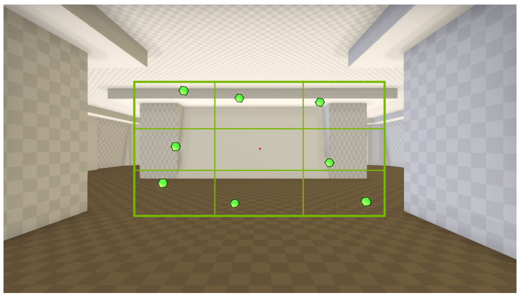
Target sizes varied in proportion to display size, as they would in typical gameplay (Fig. 2). On each display, the four target sizes also varied by the same proportion, so that three target sizes on the 24-inch display were the same absolute size as three target sizes on the 17.3-inch display, and three target sizes on the 17.3-inch display were the same absolute size as three on the 12.5-inch display.

To ensure that mouse movement difficulty was similar across all display and target sizes, we increased the average distance required to shoot larger targets. Larger targets could spawn farther from the display center, with the increase in this distance proportional to the increase in target size, as shown in Fig. 3. In the terminology of Fitts' Law [16], this gave all target sizes a similar index of difficulty (ID).

It took each participant roughly 15 minutes to complete the experiment.



(a) Task with smaller targets



(b) Task with larger targets

Figure 3: Experiment 1 — Controlling difficulty during shooting tasks with smaller (a) and larger (b) targets. The green grid (visible here only, not during actual tasks) shows how the range of target distances varied with target size. Each grid cell (except the center) contained exactly one target.

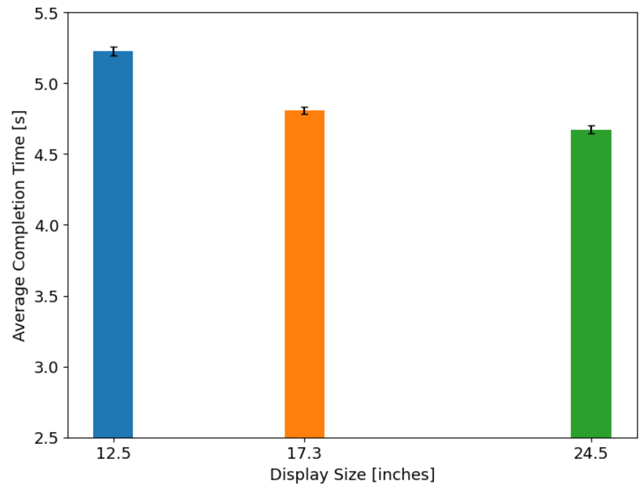


Figure 4: Experiment 1 — the effect of display size on task completion time with static targets, averaged across all participants. Bars show standard error.

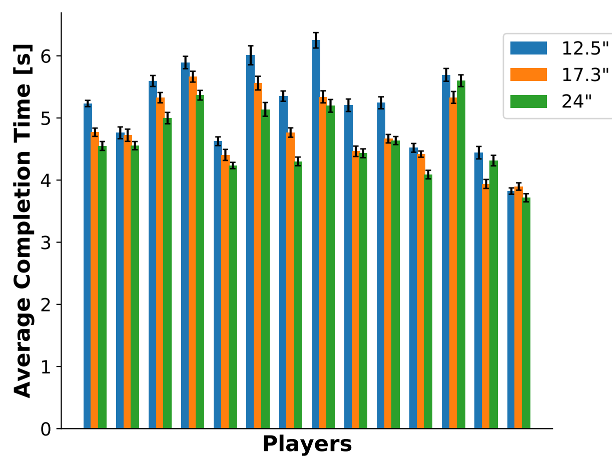


Figure 5: Experiment 1 — average task completion time per participant by display size. Times nearly always increased as display size decreased. Bars show standard error.

3.3 Participants

14 participants aged 11 to 34 completed this experiment. One of them identified as female, the others as male. All participants were experienced FPS gamers, and played from their own homes. To avoid any potential confounding factors from use of different machines and displays, we sent identical systems to each participant. Participants could end the experiment at any point, if they chose. Note that each participant attempted to shoot a total of 1440 targets, meaning that over all participants, 20160 targets were shot at.

3.4 Results

Figs. 4 and 5 show mean trial times across display size. We conducted student's t-tests comparing each pair of these three means, and they were all statistically significant ($T(839) = 9.7173$, 12.9238 and 3.5158; all with $p \leq 0.0005$). Target size did not significantly affect task times. Shooting accuracy (number of hits over number of shots) was high and did not vary significantly.

3.5 Discussion and Limitations

As display size dropped, players needed more time to shoot targets. The increased distance to larger targets likely explains the similarity of times across target sizes.

Yet these display size effects should be interpreted cautiously. Firstly, since we emulated smaller display sizes, display resolution declines as size does, since fewer pixels display the same content. Player distance from displays also often declined with display size, because many players would move closer to displays when they were smaller (along with some targets on them). We made these compromises to keep the remote experimental task fairly simple, and to learn about player performance in a more natural setting. However, it is worth noting that Kim et al. [10] showed trends similar to our own, even when resolution and distance were controlled carefully.

4 EXPERIMENT 2: DISPLAY SIZE VARIATION WITH MOVING TARGETS

Having found that smaller display sizes increased the time needed to shoot static targets, we decided to examine display size effects on shooting moving targets — also quite common in FPS games. While static targets often test a player's 'flicking' skills, moving targets require more continuous visual tracking. Since this second experiment's design and methodology were largely the same as in the first, we note only the differences here.

4.1 Task and Methods

A player had to shoot the target 10 times to destroy it; rather than only once, as in the first experiment. The player's weapon was capable of automatic fire at a rate of 20 shots per second, which allowed the players to simply hold down the mouse button while maintaining aim on the target. This continuous tracking is generally more challenging than the first experiment's 'flick' task.

To simplify our procedure and limit the length of this experiment, we used only three target sizes, leaving out the smallest size from experiment 1. Each player performed 450 trials, with each display session containing 150. Each session contained 10 blocks of 15 trials (5 trials each for the 3 different target sizes).

Targets appeared one at a time, within a centered box (not a grid, as in experiment 1), with an area that varied in proportion to target size. All targets were at the same distance from the player (radius).

Table 2: Experiment 2 — Similar breakdown of the session, block, trials, and targets count. Note that we had one less target size, and only one target appeared at a time.

Design structure	Count/Description
Experiment	3 sessions - one per display size
Sessions	10 block repetition
Blocks	15 trials - 3 per target size
Trials	1 target - size based on trial
Targets	Moving, jumping

When spawned, each target chose a random angular speed (across azimuth), and maintained it until destroyed. To control variation in difficulty across target sizes, targets chose speeds from ranges related to their size, in a manner similar to the location grid in the first experiment: smaller targets from a lower speed range, and larger targets from larger ranges. These ranges did not overlap with one another, and increased in proportion to target size.

When spawned, each target also chose a random direction (clockwise or anticlockwise). After a random time between 0.4 and 1 seconds, the target would reverse direction half the time (i.e. on a coin toss). This potential direction reversal would recur during each second until the player destroys the target.

Targets would also occasionally 'jump' (move up in elevation, then back down), which is a behavior quite commonly seen in FPS games. The upward speed varied in proportion to target size. Simulated gravity then reduced speed and eventually target direction, returning the target to its original elevation. The target would jump in this fashion at a random time in every second.

It took each participant roughly 20 minutes to complete the experiment.

4.2 Participants

We had 12 participants aged between 11 to 34 years in this study. One identified as female, and the others as male. Many participated in the first experiment as well, but all had participated in other similar studies, giving all similar levels of experimental experience. Across all participants, a total of 5400 attempts were made at shooting targets.

4.3 Results

Fig. 6 shows mean trial times across display size. T-tests with all three pairs of these means showed that they all differed significantly (T(599) = 5.4631, 8.7563 and 3.5493; all with $p<0.0005$). Again, target size (and speed) did not significantly affect task time, and task accuracy did not change significantly.

4.4 Discussion and Limitations

Overall, shooting each moving target in this experiment took longer than shooting each static target in the previous experiment (a trial with one moving target took about half as long as a trial with eight static targets). However, the relative effects of display size on shooting times in both experiments were similar: the smaller the display, the more time players needed to destroy targets. In this experiment, the increased speeds of larger targets is the likely explanation for the similarity of times across target sizes.

Given how similar this experiment is to the first, the same cautions of resolution and player distance apply, along with the same naturalistic player environment explanations for these limitations.

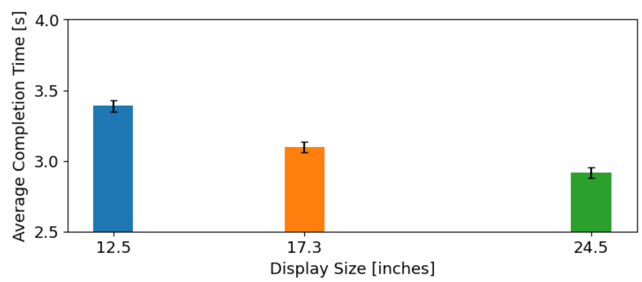


Figure 6: Experiment 2 — the effect of display size on task completion time with moving targets, averaged across all participants. Bars show standard error.

5 EXPERIMENT 3: LARGER DISPLAYS AND SMALLER TARGETS

In our first two experiments, we found that increasing display sizes up to 24 inches in size improved shooting performance for targets that were at least somewhat easy to see. Our third experiment examined this effect for larger sizes, 24.5 and 27 inches; and for very small targets of just a few pixels in size. This experiment was also reported in part in a previous blog post [22].

5.1 Equipment

This experiment also was built with FPSci, but used two different displays, both with 360Hz refresh rates. The 24.5-inch display was an Alienware 25, and had a resolution of 1920x1080 (1080p); while the 26-inch display was an Asus ROG Swift PG27AQN, and had a resolution of 2560x1440 (1440p).

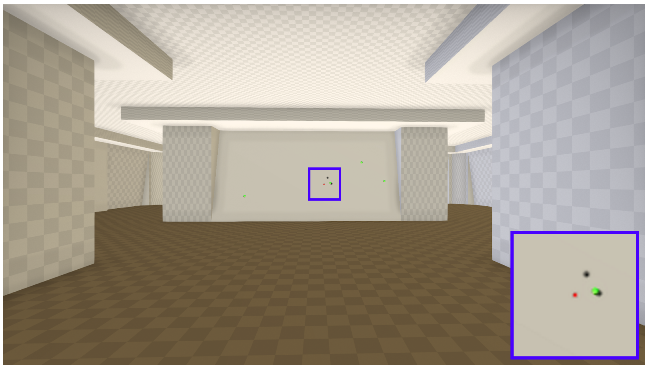


Figure 7: Experiment 3 — Its very small targets were designed to amplify the effects of slight differences size and resolution. The inset at lower right zooms in on the target in the center.

5.2 Task and Methods

In this experiment, the task was specifically designed to amplify the relatively small differences in display size and resolution, its defining feature being that the targets all had the same very small size. In fact, they may not even be visible in the screenshot in Fig. 7. In the task, the player had to destroy 4 static targets that appeared simultaneously as the task began, in random locations within a (invisible) rectangle centered within the initial view. Similar to the first experiment, the player completed the task when they clicked on each of the 4 targets one time.

Participants completed this task in 150 trials. The trials were formed into two sessions, each using a different display and containing 75 trials. Display session order was counterbalanced across participants.

Table 3: Experiment 3 — this breakdown still retains the session, block, trials, and targets count structure. However, the simpler design and the lack of different target sizes allow us to skip the multiple block and trial types distinction.

Design structure	Count/Description
Experiment	2 sessions - one per display size
Sessions	Single block
Blocks	75 trials - all similar
Trials	4 targets - all same (single) size
Targets	All appear simultaneously, stationary

All trials were performed in-person with the researcher/experiment coordinator present with participants. It took roughly 20 minutes for each participant to complete all 150 trials.

5.3 Participants

13 NVIDIA employees, including 2 of the authors, performed this experiment. They came from a different experimental pool than those in the first two experiments. Each participant had the option to decline or stop participating at any point. Across all participants, a total of 7800 targets were hit.

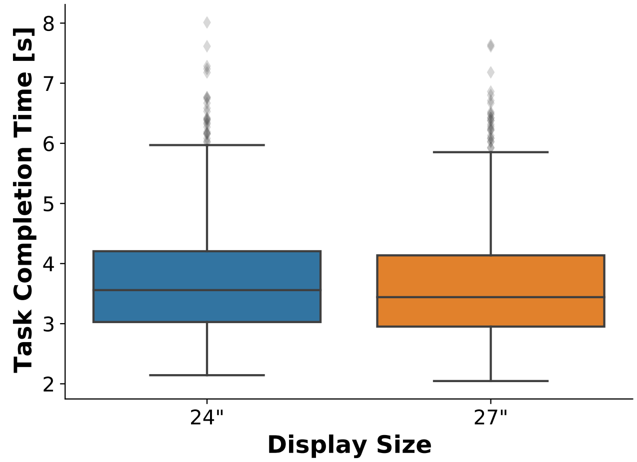


Figure 8: Experiment 3 — box plot comparing overall completion time distributions for the 24.5 and 27 inch display sizes. Despite the small effect size, the difference in means reaches statistical significance in a paired T-test.

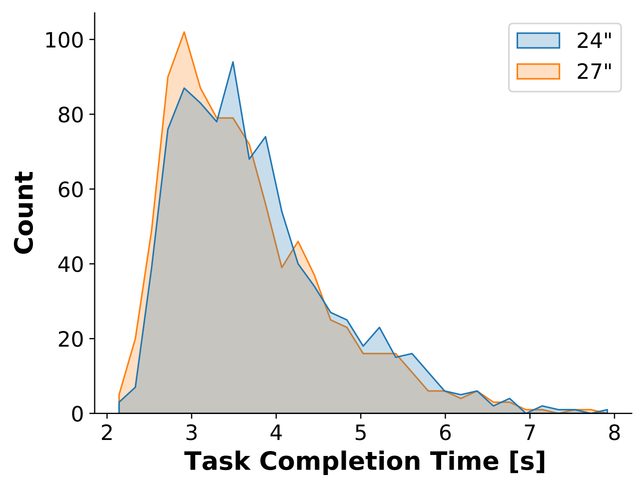


Figure 9: Experiment 3 — histogram comparing completion time distributions shows a minor shift in mean and mode.

5.4 Results

One of the participants had difficulty with this (challenging) task, so we excluded their results from this analysis, leaving 12.

The mean completion time for the 24.5" 1080p trials was 3.75 seconds, while for the 27" 1440p display, it was 3.64 seconds. Using the slightly larger, higher resolution display therefore reduced mean completion time by 111 ms, or 3% of the total task time. In a pairwise T-test, the difference between these means was statistically significant (T(899) = 3.6081, $p<0.0005$). Figs. 8 and 9 show the distribution of completion times around these means. Pairwise T-tests on accuracy did not reach statistical significance.

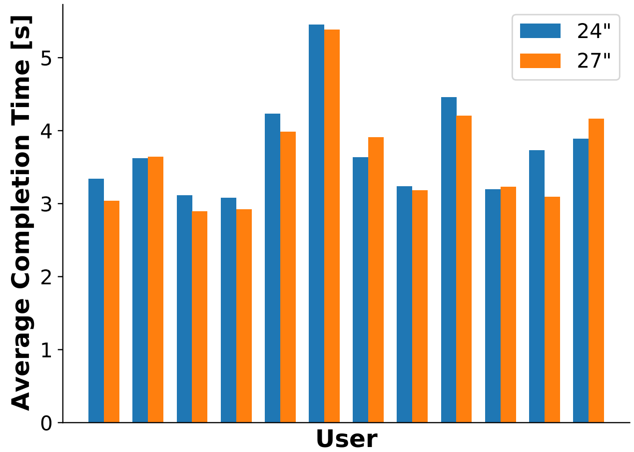


Figure 10: Experiment 3 — per-participant average completion times showing no clear overall trend, but .

5.5 Discussion and Limitations

This experiment shows that shooting performance continues to improve as display size grows to 27 inches (and resolution with it). However, while significant, this improvement is slight, may only be available for small targets, and may require expertise to realize.

A closer look at experimental results shows how the improvements brought by larger display size diminish. The histogram in Fig. 9 shows that slightly more trials were completed in a shorter time with the larger, higher resolution display. When we examine completion times per participant (Fig. 10), the variation is much greater between participants than between display sizes. This likely implies that skilled users will outplay novices, even when the novice has the bigger display. However, when players are evenly matched, then the display may still provide the winning edge.

Nevertheless, as in the first two experiments, the same resolution and player-display distance cautions apply. In addition, this study used two different physical displays rather than simply emulating display size, raising the concern of other possible display confounds, such as brightness, contrast, and color gamut differences.

6 GENERAL LIMITATIONS AND FUTURE WORK

Since these experiments were designed to measure player performance as display size varied — while also allowing for a variety of participant behavior — there are limitations to our results. First, viewing distances were not measured or controlled. Detail on the retina could therefore have varied with display size, offering an alternative explanation for display size effects. Furthermore, the resolution of the in-game rendering was allowed to change with display size. Thus the effects we presented here could arise not only from display size and viewing distance, but also rendered resolution. Future work should strive to control one or more of these factors, and study the effects of isolated changes. Skill likely also has an important relationship to display size effects. While we tried to combat this through our repetitive design, future experiments might account for skill differences. Our experiments do not examine or control for head movement, and variability in distance from the display. Our goal in these experiments was to examine display size effects in environments with more external validity, that is settings in which gamers typically play. However, there are other works that do account for these factors[10].

Avoiding confounds in resolution can be difficult. On one hand, one might control resolution by using different physical displays, as we did in our third experiment. Yet this creates the possibility of additional confounding differences impacting results, such as brightness, contrast, color space, and subpixel arrangement. On the other hand, one might use only one physical display, as we did in our first two experiments. Yet varying resolution in this case can introduce visual sampling artifacts, since pixel sizes do not change with display size. Future work on display resolution should consider these challenges.

Viewing distance and head rotation can be controlled with a chin rest or bite bar, and could be measured with a variety of head tracking sensors. We chose not to control these factors for these studies, though ideally we would have measured what naturally happened using head tracking. A future study could focus on measuring and reporting changes in natural viewing distance arising from display size, which would shed more light on likely reasons for the performance changes observed in these studies.

Display size changes can be quite significant, with people regularly interacting with displays from small phone displays of several inches to 80+ inch TVs and even theater-sized displays. Moreover, virtual reality headsets afford even wider fields of view to users than are possible with most fixed displays. The design space available for display size studies is so large that we recommend a more focused study that considers a reasonable range from laptop to TV sized displays, specifically in regard to FPS aiming. A study coupling viewing distance to display size makes sense as changing display size may encourage different viewing distance, creating interesting effects in the field of view subtended by the display.

Finally, as in-game scenes get more nuanced, there is scope for examining the relationship between size and perceptibility in a complex environment.

7 CONCLUSIONS

This set of experiments offers evidence that larger display sizes can improve FPS shooting performance, especially for the most competitive of gamers, as in esports. To improve such performance, there are many other skills and equipment players should train and optimize first, like game-specific and fundamental aiming skills, computer system latency, and CPU/GPU performance; as well as the right balance of practice, diet and exercise [8]. Still, once all of the basics are in place, this work suggests that another small performance increase is possible by using a slightly larger, higher resolution display for FPS aiming tasks. Furthermore, for tournament organizers looking to provide a fair experience for professional competitors, screen size should ideally be matched for all players.

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