

Impact of Graphical Fidelity and Frame-Time Stutter in a First-Person Shooter Game

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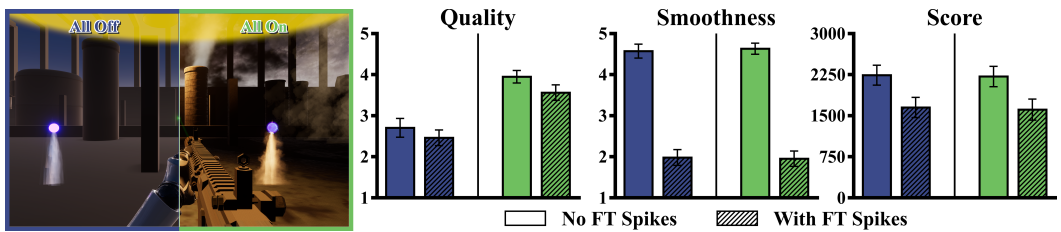


Fig. 1. The composite game screenshot (left) shows the **All Off** (all visual enhancements are disabled) and **All On** (all visual enhancements are enabled) graphics settings. Users play with and without frametime spikes (large temporal gaps in successive frames) during aiming. Bar plots (right) report mean Quality, Smoothness, and Score for no frametime (FT) spikes (solid bars) and with FT spikes (hatched bars), bounded by 95% confidence intervals. With both graphics settings, frametime spikes reduce perceived smoothness and score, and higher graphics settings are generally preferred by players. However, score and perception of smoothness are independent of graphics settings.

Frametime spikes and graphical fidelity both matter for the feel of first-person shooter (FPS) games, yet their combined effects are not well understood. This paper examines how graphics settings and frametime spikes during aiming interact with player performance and experience. We developed a custom FPS game with configurable textures, lighting, and visual effects, and induced frametime spikes of 0 ms, 225 ms, or 675 ms during play. Twenty-one participants completed all combinations of graphics and spikes while providing performance data and subjective ratings for visual quality and smoothness. Results show that graphics quality primarily affects perceived visual *quality*, while frametime spikes primarily reduce perceived *smoothness*. Performance (i.e., score and accuracy) declines with larger spikes but remains largely unchanged across graphics settings. These findings suggest that spike magnitude, rather than graphics quality, is the dominant factor shaping smoothness and performance, while players still notice higher-quality graphics.

CCS Concepts: • **Applied computing** → **Computer games**; • **Human-centered computing** → *User studies*; Laboratory experiments.

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1 Introduction

Advances in game rendering technologies continue to push hardware and software performance, with improvements in lighting, textures, and visual effects contributing heavily to player experience [Ivanova 2023]. In first-person shooter (FPS) games, visual clarity and responsiveness are especially important, as higher frame rates reduce end-to-end latency and have been shown to improve aiming accuracy, tracking, and overall player performance [Tamas 2019]. However, a high frame rate by itself is not enough – variations in frametimes, particularly large frametime spikes (or stutters), can disrupt gameplay and noticeably degrade the perceived quality and smoothness of the experience [Liu et al. 2023]. Maintaining both high quality visuals and stable frame pacing is increasingly difficult as games adopt more complex rendering pipelines and higher graphical demands.

Prior work has examined frametime variation and its impact on players [Denes et al. 2020; Klein et al. 2023; Watson et al. 2019], showing that frametime stutters can reduce both player performance and experience. Research has also explored how game visuals affect player experience and performance [Caluya et al. 2025; Gerling et al. 2013; Hicks et al. 2019], but typically without jointly examining the interplay between graphics quality and frametime spikes on player Quality of Experience (QoE). While the effects of frametime spikes and graphics settings have each been studied independently, their combined influence on QoE – especially during fast-paced FPS gameplay – remains less understood.

Our study addresses this research knowledge gap by evaluating how graphics quality and frametime spikes jointly affect player performance and QoE in a controlled FPS setting. Using *Lead Rush*, a custom-built FPS with adjustable graphics and precise frametime spike injection, we varied graphics quality through three toggle groups (textures, VFX, and lighting) and induced frametime spikes of 0 ms, 225 ms, or 675 ms. Participants played short rounds spanning all combinations of graphics settings and spike magnitudes, while *Lead Rush* recorded gameplay metrics (e.g., score, accuracy) and player-reported ratings of visual quality and smoothness. This setup enables analysis to determine if graphics settings make spikes easier to notice, and if either graphics or spikes (or both) affect performance and how players rate smoothness and quality.

The remainder of this paper is organized as follows: Section 2 reviews related work; Section 3 describes our experimental setup, graphics conditions, and measurement methods; Section 4 presents and analyzes the experiment results; Section 5 discusses the findings and their implications; Section 6 outlines limitations; and Section 7 concludes the paper and identifies directions for future research.

2 Related Work

This section describes related work in three main areas: frametime variation and adaptive displays, frametime variation and cloud games, and graphics quality.

2.1 Frametime Variation and Adaptive Displays

Since player input relies on real-time visual cues, especially in fast-paced FPS games, frame rates and frametime variability significantly impact player experience and performance. Klein et al. [Klein

et al. 2023] studied variable frame timing, where frame intervals fluctuate. They found that large deviations affected motion smoothness but had minimal impact beyond perception.

Liu et al. [Liu et al. 2023] examined QoE when a game had frametime variation by artificially increasing CPU load to induce frametime variations in the FPS game *Valorant*. They observed that greater frametime variation reduced QoE.

Technologies like VSync and G-SYNC are designed to help mitigate frame rate variation by dynamically synchronizing refresh rates with frame rates. Lee et al. [Lee and Chang 2015] found that higher server tick-rates and VSync improved player accuracy in FPS games. Watson et al. [Watson et al. 2019] found G-SYNC improved player performance in *Battlefield 4*, an FPS game. Denes et al. [Denes et al. 2020] optimized motion quality by adjusting refresh rates based on visual target speed. Their tests of 50-165 Hz displays showed adaptive refresh rates provided smoother visuals than fixed refresh rates, benefiting G-SYNC monitors and VR/AR headsets. Although these techniques help ameliorate variations in frame rates, they cannot mitigate the effects of large frametime spikes.

2.2 Frametime Variation and Cloud Games

Some studies have examined how network jitter during cloud game streams – affecting frametime variation – impacts QoE. Rossi et al. [Rossi et al. 2022] studied mobile cloud gaming on smartphones, finding that game streams reacted to network perturbations compared to traditional online games which increased frametime variation. Suznjevic et al. [Suznjevic et al. 2016] evaluated adaptation algorithms for commercial systems under varying network conditions, showing that added jitter forced the system to lower frame rates and resolutions.

Xu et al. [Xu and Claypool 2024] built a QoE model from four user studies across 11 games, considering frame rates and frametime variations. They confirmed that while average frame rate generally correlated with QoE, it did not always predict satisfaction accurately. They found that frametime variation and interruption severity were strong predictors of player experience, explaining about 90% of gaming quality variations. Additionally, interruption frequency had little effect on experience, and models focusing on the lowest frame rates failed to consistently capture player satisfaction across different games and conditions. Similar findings were reported for VR cloud FPS games, where network jitter and RTT were found to be key predictors of QoE [Rossi et al. 2024].

2.3 Graphics Quality

Prior work has looked at how graphics settings affect performance and experience. Claypool and Claypool [Claypool and Claypool 2007] found that lower resolutions hurt aiming when targets were harder to see. Stanik and Miłosz [Lukasz Stanik and Miłosz 2025] showed that enabling settings like shadows or particles reduced frame rates. Caluya et al. [Caluya et al. 2025] found that low texture quality led to more navigation mistakes. Watson et al. [Watson et al. 2024] discussed trade-offs in graphics quality for competitive gaming, and claimed players often preferred lower quality settings.

Other studies focused on user experience. Gerling et al. [Gerling et al. 2013] and Hicks et al. [Hicks et al. 2019] found that visual effects made games look and feel better. Jumani et al. [Jumani et al. 2024] found that higher graphics quality improved comfort in VR. Hillaire et al. [Hillaire et al. 2008] showed that some users preferred depth-of-field blur, which slightly reduced performance due to visibility issues.

Given that increasing graphics quality can induce more frequent and larger frametime spikes, our study evaluates how graphics quality and frametime spikes interact during FPS gameplay. Unlike prior work, which has studied graphics settings or frametime variation separately, we evaluate how graphics and frametime spikes together impact both how well players perform as well as how the game feels in terms of smoothness and visual quality. We also investigate whether higher

graphics quality makes players more sensitive to frametime spikes, or if the two factors operate independently.

3 Methodology

To investigate the effects of graphics quality and frametime spikes in a FPS game, we designed and executed a user study constructed around a configurable FPS game.

3.1 Game Description

Lead Rush is a FPS game developed in Unity 2023 as a research tool for user studies on frame rates and frame-time variations [Tokey et al. 2025]. *Lead Rush* features procedural animations, positional audio, and a configurable experimental harness for data collection, extended with a logging system to record performance metrics. We upgraded *Lead Rush* to Unity 6, changed the pipeline to Unity's high-definition render pipeline (HDRP), replaced the environment props with HDRP assets, and added additional visual effects. For this study, we capped the frame rate at 120 f/s.

We exposed three different on/off settings: VFX, Textures, and Lighting. These combine for a total of eight combinations, as shown in Figure 2 ordered from lowest to highest visual fidelity as reported by the players during the study. Each setting changes the level of visual detail while keeping gameplay and game mechanics identical. Hit markers appear on successful hits (yellow) and destruction (red) of an enemy, although these are not shown in the figure.

The game involves controlling a first-person camera view to shoot and destroy one enemy at a time while avoiding contact with the enemy. Enemies are purple floating orbs that require 5 hits to destroy. The enemy orbs move toward the player, navigating around obstacles. If an orb collides with the player avatar, both are eliminated, and the player avatar respawns at the starting position. After an orb is destroyed, a new one respawns in 100 milliseconds. The orb's respawn location is dynamically set within a torus-shaped area, 4 to 6 Unity meters from the player avatar, avoiding blocked areas. The orb oscillates vertically between 0.9 and 1.1 Unity meters above ground (once per second) and moves at 3.1 meters per second, slightly faster than the player avatar's 3 meters per second. A Unity Navmesh¹ is used for navigation.

The game provides visual and audio cues for enemy direction and proximity. Yellow arcs flash along the screen edges, growing brighter as the enemy gets closer. Positional audio indicates enemy location, with distinct sounds for hits, destruction, and shooting.

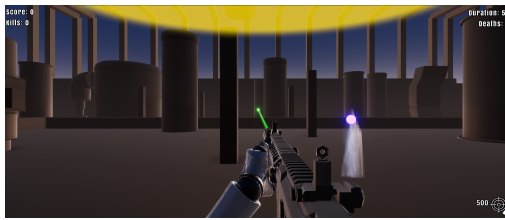
Although *Lead Rush* has various types of weapons typically found in commercial FPS games, our user study restricted players to only have a fully automatic (click and hold to fire repeatedly) weapon with a 750 rounds/minute fire rate. The game detects hits via hit scan (not propagated projectiles) and provides a green laser pointer to assist the player with aiming. The weapon has procedural recoil, sway, camera shake and aim-down sight animations. The weapon has unlimited ammo, with 31 shots before a reload is required. The weapon automatically reloads when the ammo is empty, but the player can also press 'R' to perform an on-demand reload. The reload animation takes about 2 seconds to complete.

Players earn 10 points per hit and 100 points per kill but lose 100 points per avatar death. Each missed shot deducts 1 point. Scores can drop below zero. A player's score and kills are both shown as an overlay in small font in the upper right corner of the screen.

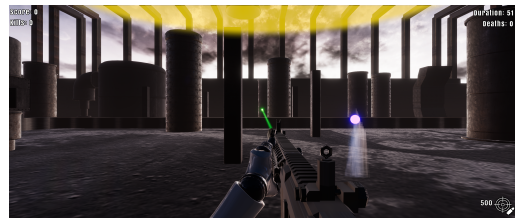
3.2 Modifications for Experiments

For our study, *Lead Rush* was instrumented to introduce controlled frametime spikes during specific game events and to control graphics quality on a per-round basis. To throw a frametime spike of a

¹Navmesh: <https://docs.unity3d.com/ScriptReference/AINavMesh.html>



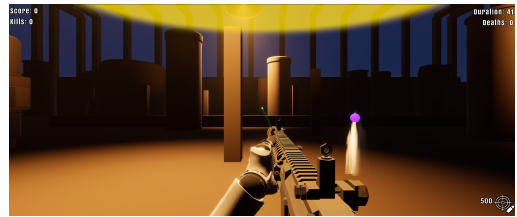
(a) All Off



(b) Textures Only



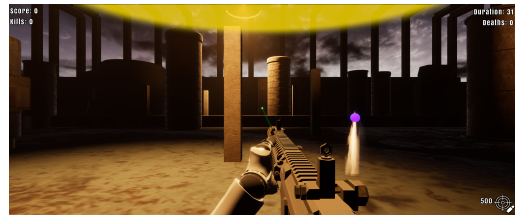
(c) VFX Only



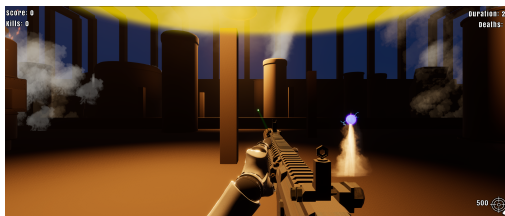
(d) Lighting Only



(e) Textures + VFX



(f) Textures + Lighting



(g) VFX + Lighting



(h) All On

Fig. 2. Graphical fidelity comparison across texture, VFX, and lighting combinations.

fixed duration, the game calculates the runtime of the main loop and then runs a busy loop for the difference between the selected duration and the main loop time. The timing is measured with nanosecond precision. A test harness records the frametime spike sizes during specific game events and also records objective player performance and subjective QoE.

On Target (aiming-based spike). When enabled, a frametime spike is triggered when the player's reticle gets close to targeting an enemy orb. An invisible collider surrounding the orb oscillates between 2.5 and 3.5 Unity units every 2 seconds, introducing randomness to the spike timing. A spike occurs when the reticle intersects with the invisible collider, with no additional spike until the reticle exits the collider. The cool down between spikes is 0.75 seconds, determined through a pilot study.

In addition to the spike event, the game exposes a set of graphics toggles that can be controlled from a configuration file. These toggles are applied in groups so that each round enables or disables whole categories of visual features in three groups (see Figure 2):

- **VFX Group:** toggles all visual effects, including player VFX (muzzle flash, hit particles), enemy VFX (orb and destruction effects, smoke effects), and environment VFX (ambient particles such as amber, smoke, and sparks). The visual impact of settings in this group is shown in Figures 2c, 2e and 2g.
- **Texture Group:** toggles the HDRI skybox and texture quality. When disabled, the skybox and textures are replaced with a solid color. The visual impact of this group is shown in Figures 2b, 2f and 2e.
- **Lighting Group:** toggles dynamic lighting, including the scene's point lights. The visual impact of this group is shown in Figure 2d, 2f, and 2g.

These options were combined into eight graphics settings that range from lowest to highest quality. Some shooting and feedback elements, such as the laser, hit markers, and all user interface elements, were always enabled to preserve clear shooting feedback. The other toggles were turned on or off to change visual quality while keeping gameplay the same. To help with combat the enemy at all settings, a static smoke effect was shown underneath the orb, assisting with height and depth perception.

The spike magnitudes were 0 ms, 225 ms, and 675 ms, selected based on pilot tests (675 ms was “just playable” and 225 ms was an in-between “medium” condition). The frame rate was set to 120 f/s for all rounds. For the 0 ms spike, no extra delay was added. For the other conditions, additional delay was added on top of the base framerate to create the desired spike. The round configuration file combined each of the eight graphics settings with the 3 spike magnitudes, yielding 24 total experimental conditions.

Each participant completed three practice rounds followed by the main experiment rounds, as summarized in Table 1. The practice rounds familiarized participants with the range of graphics qualities and the presence or absence of stutter. The main study consisted of all 24 combinations of graphics settings and spike magnitudes, with each combination presented once.

Table 1. User study round configuration.

Round Type	Details
Practice Rounds	3 rounds: – All On (no spikes) – All On (max spikes) – All Off (no spikes)
Primary Rounds	24 rounds: 8 graphics settings × 3 spike levels
Total Rounds	27 (3 practice + 24 primary)

A session ID was used to track each row of a Latin square so that graphics settings and spike magnitudes were balanced across participants. After a user completed a session, the session ID was incremented and saved to a file. For a new session, the ID was read from the file, and the corresponding row of the Latin square was used to determine the sequence of rounds.

After each round ended, players were asked questions regarding their experience for that round:

Table 2. Computer system for user study. Data was collected using NVIDIA GeForce Experience (v3.28.0.412 - Experimental).

CPU	Intel Core i9-11900K
GPU	NVIDIA RTX 4070 Super FE
RAM	32 GB DDR4
Storage	Samsung 970 EVO SSD
Mouse	Logitech G502
Keyboard	Logitech G910
Display	Alienware AW2524H (500 Hz, 1920×1080)
Latency	<20 ms (at 500 Hz)
PC Latency	$\mu = 5.1$ ms, $\sigma = 10.3$ ms
System Latency	$\mu = 7.6$ ms, $\sigma = 10.3$ ms

- *Rate the visual quality of the round*
(Very Low) 1 to 5 (Very High), via a slider.
- *Rate the visual smoothness of the round*
(Very Choppy) 1 to 5 (Very Smooth), via a slider.

The game generated logs to track player actions, performance metrics, and enemy interactions, which were used in our analysis.

Each session lasted about 30 minutes. Every participant was given a \$10 Amazon e-gift card and play testing credit.

3.3 User Study Procedure

The user study procedure was approved by our institutional review board (IRB) and was as follows:

- (1) *Recruiting*: Students were recruited via relevant mailing lists and an official Discord play testing channel, with interested participants selecting their preferred time slots using Slottr.²
- (2) *Informed consent and demographics*: Before starting, each participant was given a consent form that informed them about the content of the game and study procedure, and then completed a demographic survey (all questions optional).
- (3) *Reaction time test*: Each participant did a reaction time test similar to the Human Benchmark Reaction Time Test³ [Xu and Claypool 2025].
- (4) *Practice rounds*: Participants started by playing three practice rounds during which they were informed about the QoE questions presented at the end of each round. The practice rounds were shown as examples of the conditions they would experience, consisting of: All On (no spikes), All On (spikes), and All Off (no spikes). These settings were chosen to give participants a reference for expected conditions during the main rounds.
- (5) *Main rounds*: After the practice rounds, participants completed the 24 main rounds, shuffled via a Latin square so that the order of graphics settings and spike magnitudes was balanced across sessions.
- (6) *Collection*: Log files from each session were collected and backed up by the study proctor.

3.4 Hardware and System Performance

System specifications are provided in Table 2.

²Slottr: <https://www.slottr.com/>

³Reaction Time Test: <https://humanbenchmark.com/tests/reactiontime>

The duration of the frametime spikes thrown was recorded by the game's log system. For the 225 ms and 675 ms spikes, both conditions show means of 225.0 ms and 675.0 ms, respectively and standard deviations from 0.05–104 ns. Minimum and maximum values are close to the target values – differences are well below 0.01%. This indicates extremely good control over frametime spike conditions created by the game.

The game behaved as expected when no spikes were active, holding a steady 120 f/s across all graphics settings. Mean frame rates stayed between 119.3–119.98 f/s with almost no variance, confirming that only the injected spikes affected smoothness, not the graphical elements (Table 3).

Table 3. Mean frame rate and standard deviation for each graphics setting (no spikes).

Graphics Setting	Mean f/s	SD
AllOff	119.98	0.01
Light	119.87	0.14
VFX	119.98	0.01
VFX/Light	119.32	0.69
Tex	119.98	0.01
Tex/Light	119.76	0.23
Tex/VFX	119.98	0.01
AllOn	119.30	0.79

3.5 Demographics

A total of 21 participants took part in the study. Table 4 summarizes their demographics. Numeric values are reported as means with standard deviations in parentheses. Participants were young adults ($M = 20.1$, $SD = 1.6$) with a mix of gaming backgrounds. They self-rated their general gaming skill and FPS skill on a scale from 1 (low) to 5 (high). On average, participants reported moderately high general gaming skill ($M = 3.9$, $SD = 0.6$) and moderate FPS skill ($M = 2.8$, $SD = 1.0$). Reaction times (RT) were fairly quick ($M = 188.5$ ms, $SD = 22.8$), consistent with a wide range of player experience levels. Outliers were removed by excluding reaction time samples with an absolute z -score greater than 3.

Table 4. Participant demographics.

Users	Age	Gender	Gaming Skill (1–5)	FPS Skill (1–5)	RT (ms)
21	20.1 (1.6)	♂13 ♀7	3.9 (0.6)	2.8 (1.0)	188.5 (22.8)

4 Analysis

This section analyzes player experience and then player performance.

4.1 Player Experience

After each round, participants provided two QoE ratings on a 1–5 scale: one for the *visual quality* of the round and one for the *visual smoothness*. Figures 3–6 show these results. Graphs show means with 95% confidence intervals.

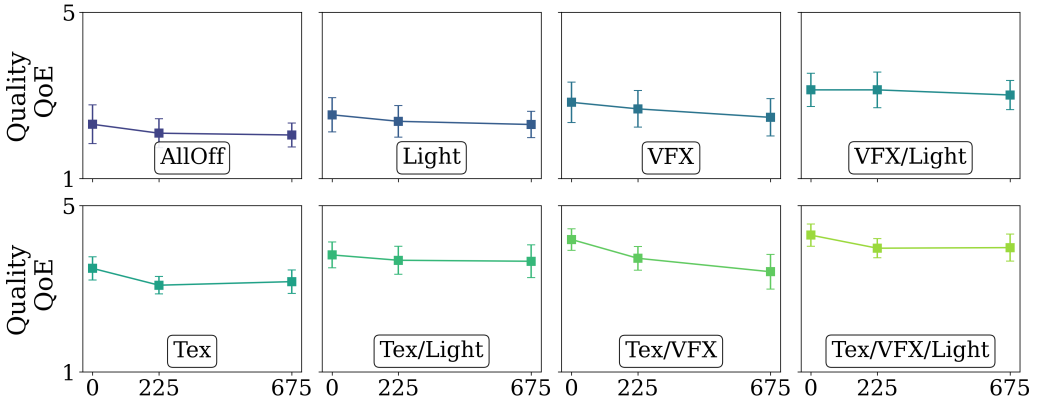


Fig. 3. Visual quality QoE versus frametime spike magnitude for each graphics setting.

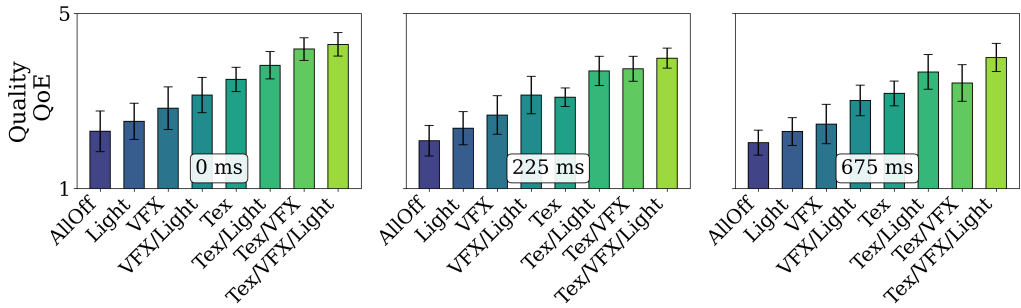


Fig. 4. Visual quality QoE versus graphics settings for each frametime spike magnitude.

4.1.1 Visual Quality. Figures 3 and 4 present the visual quality ratings. In Figure 3, the x-axes are the frametime spike magnitudes (0 ms, 225 ms, 675 ms) and each subplot corresponds to one graphics setting. Across the 225 ms and 675 ms spike conditions, the mean number of frametime spikes per round was $M = 27.96$ ($SD = 4.04$, Median = 28). In Figure 4, the x-axes are the eight graphics settings (from *AllOff* to *Tex/VFX/Light*) and each subplot corresponds to one spike magnitude.

From Figure 3, visual quality is lowest when all effects are disabled and increases as textures, VFX, and lighting are enabled. For a fixed graphics setting, increasing the spike magnitude from 0 ms to 675 ms lowers the mean quality rating slightly, with mean visual quality ratings slightly lower at both 225 ms and 675 ms than at 0 (no spikes).

Figure 4 shows that for every spike magnitude, visual quality increases steadily from the *AllOff* condition to the full *Tex/VFX/Light* setting. The ordering of settings holds across all spike levels: players noticing when textures, VFX, and lighting were enabled and rating those rounds higher than the lower-quality graphics ones.

4.1.2 Visual Smoothness. Figures 5 and 6 show the visual smoothness ratings. Figure 5 plots smoothness versus spike magnitude for each graphics setting, while Figure 6 plots smoothness versus graphics setting for each spike magnitude.

In contrast to visual quality, Figure 5 shows that visual smoothness is dominated by frametime spikes. For all graphics settings, smoothness ratings are high when there is no spike (0 ms), drop

noticeably at 225 ms, and are lowest at 675 ms. Differences between graphics settings for a fixed spike magnitude are small and largely within the confidence intervals.

Figure 6 reinforces this observation. For each spike magnitude, smoothness varies only slightly across the eight graphics settings, while the separation between curves for 0 ms, 225 ms, and 675 ms is large. This suggests that perceived smoothness is driven primarily by frametime spike magnitude rather than graphics setting.

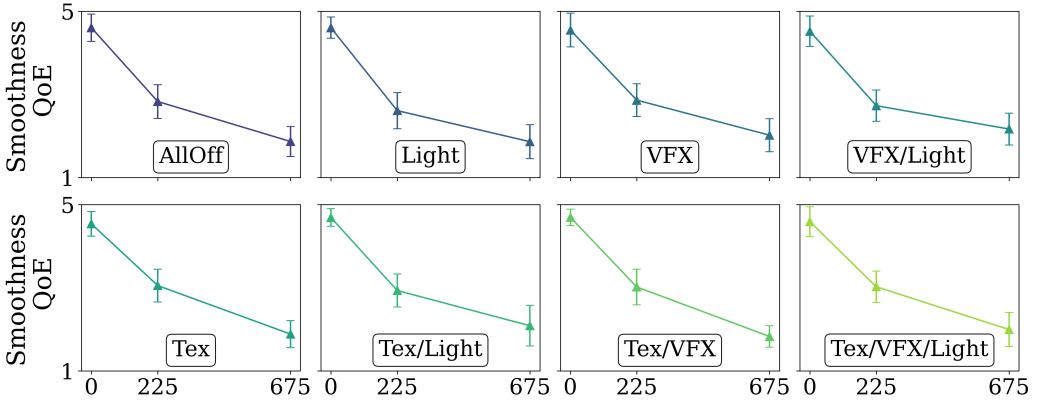


Fig. 5. Visual smoothness QoE versus frametime spike magnitude for each graphics setting.

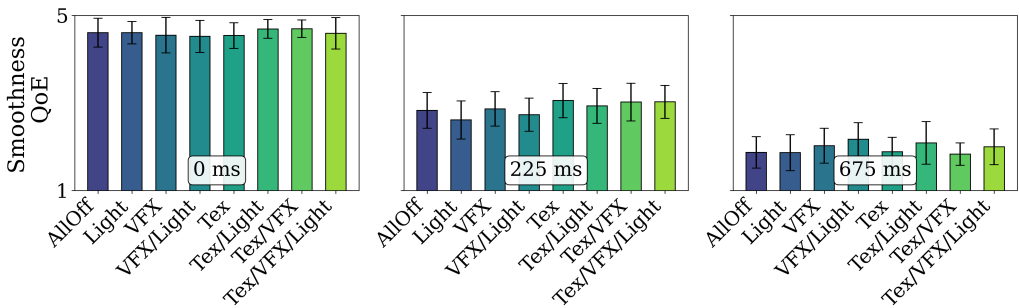


Fig. 6. Visual smoothness QoE versus graphics settings for each frametime spike magnitude.

4.2 Player Performance

To evaluate player performance, we use two metrics: *score* and *accuracy*. Figures 7 – 10 present player performance results across frametime spike magnitudes and graphics settings.

4.2.1 Score. Score is computed directly from gameplay events, as described in Section 3.

Figures 7 and 8 show the mean score per round. In Figure 7, the x-axes are the spike magnitudes and each subplot corresponds to a graphics setting. In Figure 8, the x-axes are the graphics settings and each subplot corresponds to a spike magnitude.

From Figure 7, scores tend to decrease as spike magnitude increases. For most graphics settings, rounds without stutter (0 ms) have the highest scores, with scores dropping for 225 ms spikes and

further for 675 ms spikes. The downward trend is visible across all settings, indicating that large frametime spikes make it harder for players to maintain performance.

Figure 8 shows that graphics settings have almost no effect on score. For a fixed spike magnitude, the score curves remain mostly flat, with small differences across settings. The main performance changes come from spike magnitude, not graphics configuration.

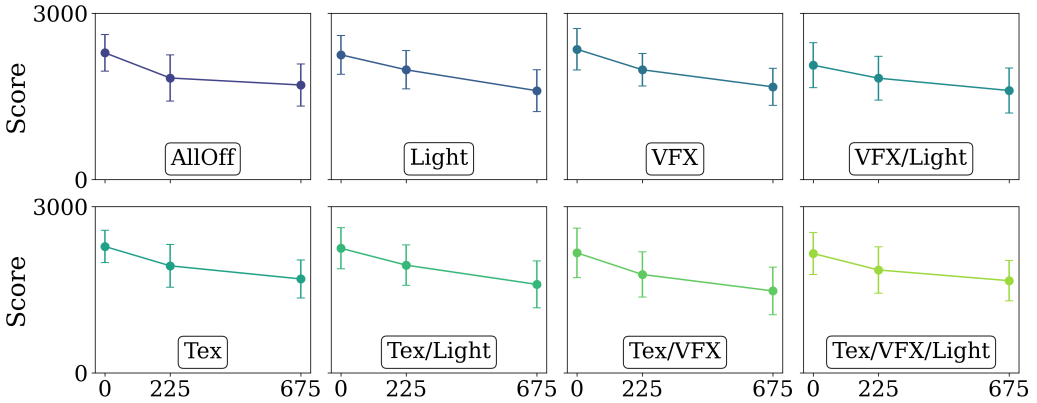


Fig. 7. Score versus frametime spike magnitude for each graphics setting.

4.2.2 Accuracy. Accuracy is the percentage of fired shots that hit an enemy.

Figures 9 and 10 show the accuracy results. As before, Figure 9 plots accuracy versus spike magnitude for each graphics setting, while Figure 10 plots accuracy versus graphics setting for each spike magnitude.

Overall, accuracy is less sensitive to configurations than score. In Figure 9, there is a small downward trend in accuracy as spike magnitude increases, but the changes are modest and the error bars overlap for most conditions. This suggests that while large frametime spikes can slightly reduce hit rate, players are still able to aim about as accurately, even with frametime spikes. Overall accuracy decreases from 48% at 0 ms to 44% at 675 ms, statistically significant for paired t-test, $t(20) = 3.02, p = .0068$, with a medium effect size ($d_z = -0.66$). One possible explanation for this is that players tend to reduce their mouse speed to maintain accuracy, meaning that when frametime spikes were thrown, players slow down mouse movements to gain a steadier hand. Analysis confirms total

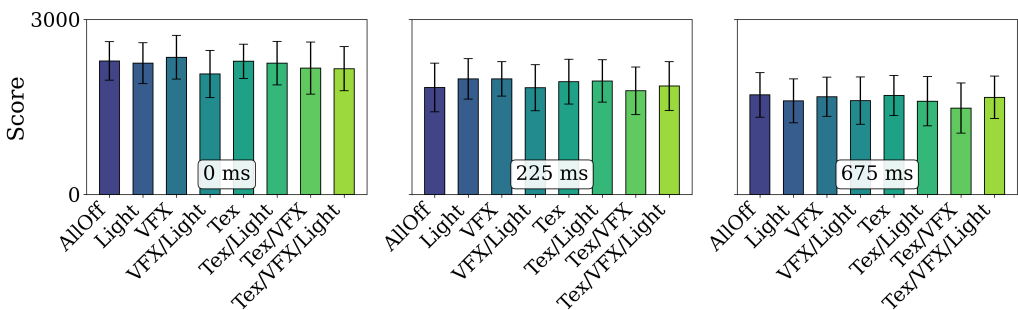


Fig. 8. Score versus graphics settings for each frametime spike magnitude.

mouse movement decreases from 59.3 degrees/s for 0 ms to 53.8 degrees/s for 675 ms, $t(20) = 4.04$, $p = .00064$, $d_z = -0.88$, and remains significant with a Bonferroni correction ($p = .0057$).

Figure 10 shows that accuracy, like score, changes little across graphics settings. The curves remain mostly flat, with only small differences between *AllOff* and higher-quality settings.

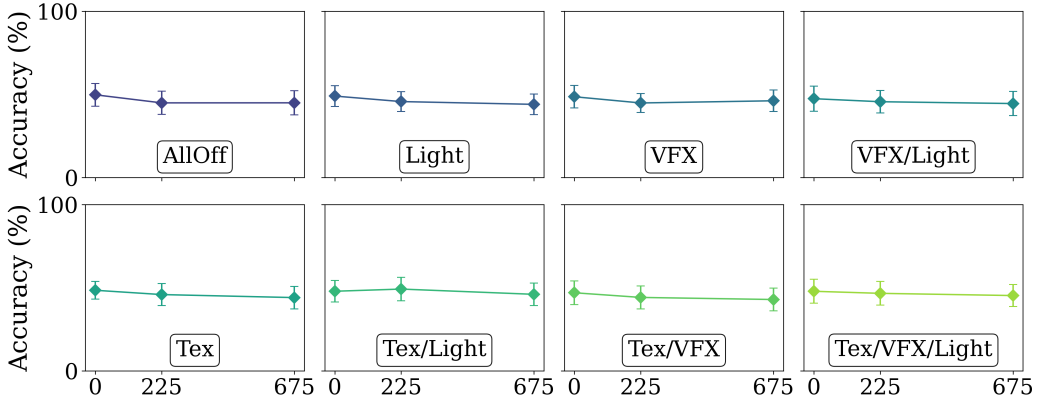


Fig. 9. Accuracy versus frametime spike magnitude for each graphics setting.

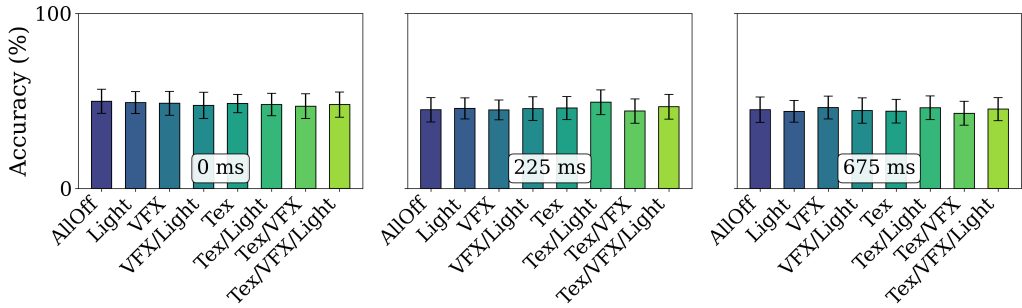


Fig. 10. Accuracy versus graphics settings for each frametime spike magnitude.

4.3 Summary

Overall, players reported lower perceived quality when all settings were turned off and for rounds with frametime spikes. For smoothness, players reported decreased smoothness for rounds with frametime spikes, but graphics settings had no effect on perceived smoothness. Player scores were impacted by frametime spikes but remained unaffected by changes in graphics settings. Paired t-test results are reported in Table 5.

5 Discussion

Graphics settings had clear effects on how players *perceived* the game, but little effect on how they *performed*. Players consistently rated higher-fidelity settings (e.g., textures, VFX, lighting) as having better visual quality, and these preferences held across all frametime spike magnitudes. In other

Table 5. Paired t-tests across different graphics and frametime spike settings. Significant p – values are in bold.

Metric	Comparison	$t(20)$	p	d_z
Quality	Spike vs. No Spike	5.2	< .001	1.4
	AllOff vs. AllOn	-8.6	< .001	-1.9
Smoothness	Spike vs. No Spike	14.4	< .001	3.2
	AllOff vs. AllOn	-0.3	0.8	–
Score	Spike vs. No Spike	8.2	< .001	1.78
	AllOff vs. AllOn	0.7	0.5	–

words, players noticed and appreciated visual improvements, but these changes did not translate into measurable differences in score or accuracy.

Performance was instead dominated by frametime spike magnitudes. Across all graphics settings, scores dropped as spikes increased from 0 ms to 675 ms, and accuracy declined slightly as well. Distance travelled by the player avatar per round also increased as spike magnitude increased, suggesting that players move more during rounds with frametime spikes as they try to get away from enemies. This trend remained mostly consistent across different graphics configurations, showing that graphics quality does not meaningfully help or hurt a player’s ability to shoot, aim, or survive. The primary driver of all measured in-game performance metrics was frametime spike magnitude.

For perceptual measures, visual quality and smoothness behaved differently. Visual *quality* ratings rose predictably with higher-fidelity settings, while frametime spike duration did not degrade visual quality significantly. In contrast, visual *smoothness* ratings were driven almost entirely by spike magnitude and remained mostly unaffected by graphics settings. This suggests players enjoy nicer visuals when no spikes are present, but when a frametime spike occurs, the perceived stutter feels roughly the same regardless of how the game looks.

Overall, these results show that graphics quality affects how good the game *looks*, but not how well players *perform*. Performance and smoothness track frametime spike magnitude, not the graphics setting. This reinforces the understanding that graphics will not change gameplay performance, and suggests developers should focus on avoiding frametime spikes to preserve player performance, while treating visual fidelity as a separate lever for making the game look better when it is already running smoothly.

6 Limitation

A limitation of our study is that there are additional elements that could be varied. We manipulated textures, particle effects, and a point light, whereas games also have settings such as resolution, field of view, depth of field, anti-aliasing, anisotropic filtering, shadows, ambient occlusion, post-processing, and ray tracing – all of which may influence performance and experience in different ways.

Some games also allow players to adjust the density or volume of meshes, grass, trees, and other environmental objects, which can affect visibility in FPS gameplay. We did not test any of these visibility-related settings, and we deliberately kept enemy visibility consistent across all graphics combinations based on pilot studies.

Our analysis was also limited to gameplay for a first-person shooter. Results from the aiming-centric task may not generalize to other genres where graphics settings could interact differently with gameplay (e.g., racing, open-world, or strategy games). Nor are the frametime spikes and magnitudes necessarily representative of those encountered “in the wild”.

Another limitation is the imbalance in the independent variables. We tested eight graphics levels but only three spike magnitudes (0, 225, 675 ms), with a large gap between 225 ms and 675 ms. Our study had 24 conditions (8×3), but we had only 21 participants so that although a Latin square was used, full balance was not achieved.

The game was deliberately simple, focusing only on basic movement and shooting. Most commercial games include richer environments, multiple enemy types, and more complex visual effects that may change how players perceive both quality and frametime spikes.

Finally, we collected only two QoE measures – visual quality and smoothness – after short rounds. Longer play sessions or additional QoE dimensions (e.g., comfort, clarity, or perceived responsiveness) may reveal effects that our short rounds do not capture.

7 Conclusion

Frametime stability and graphics quality both contribute to how players experience first-person shooter (FPS) games. This study examined their effects using a custom FPS game, *Lead Rush*, configured to run at a fixed 120 f/s while systematically varying graphics settings (textures, VFX, lighting) and frametime spike magnitudes (0 ms, 225 ms, 675 ms). A total of 21 participants each played 27 short rounds covering all combinations for graphics settings and frametime spikes, with objective score and accuracy data as well as subjective perceived visual quality and smoothness scores collected after each round.

The results show a separation between the roles of graphics quality and frametime spikes. Visual quality increases as more graphical features are enabled, indicating that players notice and prefer higher-quality settings, although frametime spikes still slightly reduce perceived quality for all settings. In contrast, perceived smoothness is dominated by frametime spike magnitude: smoothness scores drop sharply from 0 ms to 225 ms and further at 675 ms, with minimal interplay with graphics settings. Player performance follows a similar pattern – large frametime spikes reduce both score and accuracy, while graphics quality has little measurable effect on either metric.

These findings suggest that maintaining stable frametimes matters more for player performance and perceived smoothness than does increasing graphics quality, even though higher-fidelity visuals are noticeable and preferred. Developers may therefore prioritize minimizing frametime spikes to preserve responsiveness, while players seeking performance gains may benefit more from reducing frametime deviations than from lowering graphics settings alone.

Future work could explore how the effects of graphics settings and frametime spikes extend to other game genres, and how hardware factors such as display size or refresh rate interact with graphics quality and frametime stability. Such studies can further inform design choices for both game developers and competitive players.

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