

# Comparing the Effects of Network Latency versus Local Latency on Competitive First Person Shooter Game Players

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## ABSTRACT

Competitive gamers, and especially esports gamers, want lower latency to improve their chances of winning. There are two main sources of latency in competitive computer games: local system latency and network latency. While researchers have studied the effects of both, a direct comparison has not been done, especially for competitive gamers and low-end latencies. This paper assesses the effects of local latency and network latency on experienced *Counter-strike: Global Offensive* players comparing data from two user studies. Analysis of the results shows that local latency has about a 2x higher impact on player performance (accuracy and score) and Quality of Experience (QoE) than does the same amount of network latency.

## CCS CONCEPTS

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

## KEYWORDS

skill, gamer, FPS, user study, esports, lag, CS:GO

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## 1 INTRODUCTION

Computer games are one of the world's most popular forms of entertainment, with global sales increasing at an annual rate of 10% or more [19]. Esports, in particular, are popular and lucrative – the largest esports prize pools are about \$25 million USD [7], and by 2023, there are expected to be about 300 million frequent viewers of esports worldwide, an increase from 173 million in 2018 [9].

Latency between a player's input and the esports game output can impact the responsiveness and consistency of the game, hurting player performance and degrading quality of experience. There are two main sources of latency in esports games – from the local system, such as from the mouse, OS and monitor, and from the

network between the client and the server. While both sources of latency affect the player, they manifest differently – local latency lags all player input until game output, while network latency lags all communication to the server. This means local latency makes game controls feel unresponsive, while network latency makes player actions resolved later by the server. While competitive gamers typically seek to reduce latency or mitigate its effects – the conventional wisdom being “faster is better” – the extent to which both types of latency affect players remains unknown.

There have been studies on network latency and commercial games [8, 10], especially latency and first-person shooter (FPS) games [1–3, 18] owing to the sensitivity of FPS games to network latency and the prevalence of FPS games in the competitive and esports scenes. However, such studies often evaluate non-expert gamers or high-end latencies (e.g., above 150 ms) that are not typically seen by competitive gamers. Other games research has studied local latency, usually focusing on a subset of a full game [12, 15, 16]. While this prior research has been valuable for understanding latency and games, to the best of our knowledge, there has been no direct comparison between local latency and network latency for competitive game players.

This paper compares the effects of network latency and local latency using data from two user studies that measure the impact of latency on experienced FPS game players. For both studies, players skilled at the esports FPS game *Counter-strike: Global Offensive (CS:GO)* (Valve, 2012) played rounds of CS:GO with controlled amounts of network latency or local latency. A total of sixty-eight (68) participants across both studies provide performance (accuracy, score) and opinions (QoE) that are used to assess and compare the impact of different types and amounts of latency.

Analysis of the results shows that from a baseline of 125 milliseconds of total latency, reducing local latency by 100 milliseconds results in an improvement of 6 percent for accuracy, 3 points per minute for score and 1.6 points (on a 5 point scale) for QoE, while reducing network latency by 100 milliseconds results in an improvement of 2 percent for accuracy, 2 points per minute for score and 0.7 points for QoE. In short, local latency has about twice the impact as network latency for competitive FPS game players.

The rest of this paper is organized as follows: Section 2 describes related work; Section 3 summarizes the user studies; Section 4 describes the results; Section 5 analyzes and compares local latency to network latency; and Section 6 summarizes our conclusions and presents possible future work.

## 2 RELATED WORK

For local latency, Ivkovic et al. [11] find significant main effects for local latency on target tracking and acquisition tasks with a greater effect for higher target speeds. Long and Gutwin [15] find target

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speed affects how much local latency increases target acquisition time, with fast targets affected by latencies as low as 50 ms but slower targets resilient to latencies as high as 150 ms. Long and Gutwin [16] also compare the effects of local latency on moving target selection across 4 different gaming devices, demonstrating that latency affects each device differently. Claypool et al. [4] show local latency and target speed exponentially impact target selection time. Spjut et al. [21] show reduced local latencies have a clear benefit in a first person targeting task, more so than does a higher frame rate display.

For network latency and FPS games, Armitage et al. [2] estimate the network latency tolerance threshold for Quake 3 to be about 150-180 ms. Dick et al. [6] show players find 150 ms acceptable for Counter-strike and Unreal Tournament 2003. Quax et al. [18] find UT2003 players suffer with latency and jitter as low as 100 ms. Amin et al. [1] demonstrate player experience determines network latency sensitivity for Call of Duty, with competitive gamers more adept at compensating for impaired network conditions. For network latency and other game genres, Fritsch et al. [8] find players of the role-playing game Everquest 2 can tolerate hundreds of milliseconds of network latency. Hoßfeld et al. [10] show players of the casual game Minecraft are insensitive to network latencies of up to 1 second. Sheldon et al. [20] find some aspects of play in the real-time strategy game Warcraft 3 are not affected by up to a second of network latency.

While useful for understanding the effects of local latencies and network latencies on games, in contrast to our work, these works do not compare local latency to network latency, nor do they necessarily represent competitive FPS player performance.

### 3 USER STUDIES

We use data obtained from two user studies, one focusing on *local latency* [13] and the other on *network latency* [14]. The studies themselves were not designed to be directly comparable, but the settings and methods are similar enough to allow for comparative analysis. Each dataset was obtained from users playing *Counter strike: Global Offensive* (Valve, 2012) with the automatic AK-47 rifle on the small Mirage map in short, free-for-all rounds with 20 AI-controlled bots. The local latency study added a different latency each round (0, 25, 50, 75, or 100 ms), delaying the mouse and the keyboard with a custom tool called *evlag*. The network latency study also added a different latency each round (25, 50, 100, or 150 ms), but delayed the client-server communication with the network tool *clumsy*,<sup>1</sup> on top of < 1 ms of LAN latency.

For the PC's used in both studies, base local latency was measured the same way: using a high-framerate camera to capture and count the frames between the moment a user presses the mouse button and the resulting screen output, repeated 10 times. The local latency study base was measured at  $M = 25.2$  ms,  $SD = 2.8$  ms and the network latency study base was  $M = 24.6$  ms,  $SD = 3.44$  ms. Hereafter in this paper, 25 ms is added to all latency analysis.

For both studies, users were screened to ensure a high-level of skill in CS:GO – a minimum of 100 hours of previous CS:GO play was required in order to participate.

**Table 1: Subjective questions per round**

	Rate (low 1 to 5 high):	Source
Q1	The responsiveness of the round	Long [16]
Q2	Your annoyance with the unresponsiveness	GEQ [17]
Q3	Your frustration in the round	iGEQ [17]
Q4	How much your performance was due to you	Attribution [5]

**Table 2: Demographics**

Latency	Users	Age (yrs)	Gender	FPS Skill
Local	43	21.2 (5.0)	42 ♂, 1 ♀	4.5 (0.7)
Network	25	20.8 (3.0)	25 ♂, 0 ♀	4.4 (0.7)

There was no upper limit on player score – the round ended after 4 minutes in the local latency study and 3.5 minutes in the network latency study. After each round, users filled out a subjective survey consisting of questions on a discrete 5-point Likert scale about the game experience in the preceding round. The questions in common for both studies are shown in Table 1.

## 4 RESULTS

Forty-three (43) users passed screening to participate in the local latency user study, and twenty-five (25) users passed screening to participate in the network latency user study. Table 2 summarizes the participant demographics. FPS self-rating skill is on a five-point scale, 1 (low) to 5 (high). For age and FPS self-rating skill the mean values are given with standard deviations in parentheses.

Figure 1a depicts boxplot distributions for self-reported hours of CS:GO play. The boxes depict quartiles and medians for the distributions. Points higher or lower than  $1.4 \times$  the inter-quartile range are outliers, shown by red pluses. The whiskers span from the minimum non-outlier to the maximum non-outlier. The black pluses show the mean values. The gray box represents the local latency study and the blue box the network latency study. Users in the local latency study average 664 hours of CS:GO play compared to an average of 832 hours in the network latency study. Figure 1 depicts self reported CS:GO skills. The points are mean values with error bars denoting standard deviations. Black is for the local latency study and blue for the network latency study. Based on Figure 1a and Figure 1, while both groups are experienced CS:GO players, the users in the network latency study are somewhat more experienced and skilled at CS:GO than the users in the local latency study.

This difference in skill is born out via aggregate performance in the studies. We measure user performance in terms of accuracy (shots hit divided by shots fired, reported as a percent) and game score (in CS:GO,  $score = 2 \times kills + assists$ , reported as points per minute). The CS:GO log files are mined to determine number of hits, kills and assists by each user for each round, and the *evlag* log files provide the shots fired based on the number of left mouse-button clicks. Table 3 gives the mean weapon accuracy and score from both studies, with standard deviations in parenthesis.

<sup>1</sup><https://jagt.github.io/clumsy/>

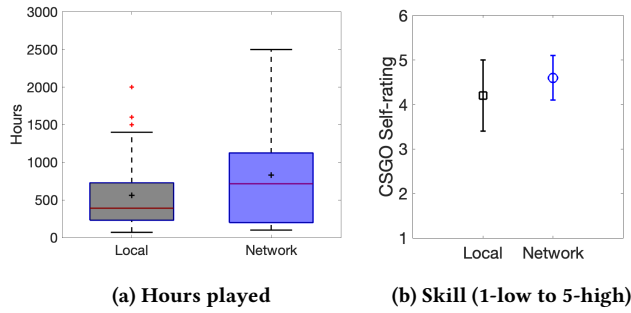


Figure 1: Self-reporting for CS:GO

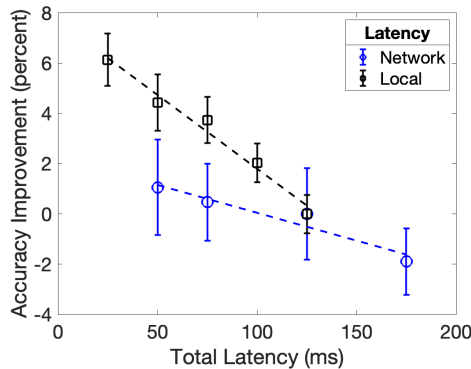


Figure 2: Accuracy improvement

Given the self-reported and observed difference in CS:GO skill between the two groups, for the rest of this paper, we do not directly compare user performance for each group but instead compare the relative impact of latency on performance.

Table 3: User performance summary

Latency	Accuracy (%)	Score (pts/min)
Local	17.8 (4.8)	11.5 (3.2)
Network	19.6 (4.3)	14.5 (3.8)

## 5 ANALYSIS

This section compares user performance (Section 5.1) and Quality of Experience (Section 5.2) for network and local latencies.

### 5.1 Performance

Player performance is assessed by weapon accuracy (i.e., how readily a player hits an opponent with each shot) and game score (based on number of opponent kills and assists with kills).

**5.1.1 Accuracy.** Figure 2 depicts weapon accuracy versus latency. The x axis is the total latency, i.e., local latency plus network latency. The y axis is the weapon accuracy (percent) increase from the 125 ms total latency condition. For example, an accuracy of 15 percent at 125 ms of latency compared to an accuracy of 20 percent at 25

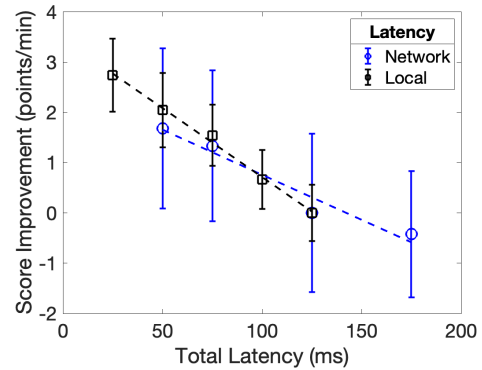


Figure 3: Score improvement

Table 4: Significance (compared to 125 ms)

Total (ms)	Local latency		Network latency	
	Accuracy	Score	Accuracy	Score
25	14.23	<.001	8.56	<.001
50	9.57	<.001	7.32	<.001
75	9.86	<.001	5.13	<.001
100	5.15	<.001	2.33	<b>0.02</b>
175			-2.77	<b>.01</b>

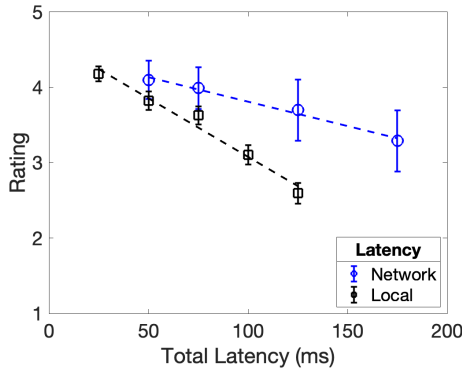
ms of latency would be a 5 percent improvement. The points are the means for all users for that latency condition, bounded by 95% confidence intervals. The dashed lines show a linear regression for the mean values. The blue points and lines denote the network latency study, and the black denotes the local latency study. The regressions fit the mean values well for both studies, with an  $R^2$  of 0.98 and  $p = .001$  for the local latency study, and an  $R^2$  of 0.93 and  $p = .038$  for the network latency study. Visually, the local latency slope is steeper than the network latency slope. As a take-away, a decrease in network latency by 100 ms improves player accuracy by an average of about 2 percent, while a decrease in the same amount of local latency improves player accuracy by an average of about 6 percent.

**5.1.2 Score.** Figure 3 depicts player score versus latency. The axes and points are as in Figure 2, but the data is the score ( $2 \times \text{kills} + \text{assists}$ ) improvement per minute instead of accuracy improvement. The regressions fit the mean values well for both studies, with an  $R^2$  of 0.99 and  $p < .001$  for the local latency study, and an  $R^2$  of 0.96 and  $p = .023$  for the network latency study. Again, visually, the slope for the local latency study is steeper than the slope for the network latency study. As a take-away, a decrease in local latency by 100 ms improves player score by about 3 points per minute of gameplay, while the same amount of decrease in network latency improves player score by 2 points per minute of gameplay. For reference, often less than a single point in a game separates the scores of top CS:GO players.

**5.1.3 Effect Size.** An effect size provides a measure of the magnitude of difference – in our case, the difference with the 125 ms total latency condition. We compare performance with latency to this condition by paired t-tests ( $\alpha = 0.05$ ) for participants within each

**Table 5: Effect size (compared to 125 ms)**

Local latency			Network latency		
Total (ms)	Accuracy	Effect size Score	Total (ms)	Accuracy	Effect size Score
25	1.57	0.94	50	0.24	0.47
50	1.05	0.80	75	0.12	0.45
75	1.08	0.57	175	-0.55	-0.18
100	0.56	0.26			

**Figure 4: QoE**

study and compute the Cohen's  $d$  effect sizes for the same. The Cohen's  $d$  effect size assesses the differences in means in relation to the pooled standard deviation. Generally, small effect sizes are anything under 0.2, medium is 0.2 to 0.5, large 0.5 to 0.8, and very large above 0.8. The results are shown in Table 4 and Table 5. For local latency, all the conditions are significant and reducing latency has a large effect on both accuracy and score, except for a medium effect at 100 ms. For network latency, only the 175 ms condition is significant for accuracy and only 50 and 75 ms conditions are significant for score. Randomly sub-sampling 25 participants from the local latency study pool and re-computing significance (not shown) shows the lack of significance in the network latency study is only partly due to the smaller sample size ( $N = 25$  versus  $N = 43$ ). Reducing network latencies from 125 ms has a small or at most medium effect for all conditions. As a take-away, the effects sizes for accuracy and score are larger for local latency (medium to large) than they are for network latency (small to medium).

## 5.2 Quality of Experience

Quality of Experience (QoE) is assessed from user responses to the 4 survey questions the studies have in common (see Table 1), filled out by users at the end of each round. Responses are a rating given on a discrete 5-point scale and, for the analysis, response data for question 2 and question 3 are rearranged so that a 1 is low (worse) and a 5 is high (better) for all questions.

For each individual question, QoE degrades with network latency and local latency – the linear regressions fit the means well for each question, with  $R^2$  values from 0.901 to 0.999.

For an overall measure of QoE, we compute the mean combined rating, weighting all questions equally. Figure 4 depicts the results. The x axis is the total latency in milliseconds and the y axis is the rating. The points are the means for all users for that latency condition, bounded by 95% confidence intervals. The dashed lines are linear regression fits through the mean values. The blue represents the network latency study and the black the local latency study. The linear regressions fit the means well for both studies, with  $R^2$  0.97 and  $p = .002$  for local latency and  $R^2$  0.99 and  $p = .007$  for network latency. As a take-away, a decrease in local latency by 100 ms improves QoE by about 1.6 points on a 5-point scale, while the same amount of decrease in network latency improves QoE by 0.7 points.

## 5.3 Summary

Table 6 summarizes the linear regressions from the above analysis in tabular form. The regressions fit the mean values well and all results are significant. Slopes for the local latency regressions are about 2x steeper than the slopes for the network latency regressions for all cases.

**Table 6: Linear regression**

Metric	Latency	Slope	$R^2$	P value
Accuracy	Local	-0.059	0.98	<b>.001</b>
Accuracy	Network	-0.022	0.93	<b>.038</b>
Score	Local	-0.027	0.99	<b>&lt;.001</b>
Score	Network	-0.017	0.96	<b>.023</b>
QoE	Local	-0.016	0.97	<b>.002</b>
QoE	Network	-0.006	0.99	<b>.007</b>

## 6 CONCLUSION

Based on results from 68 users playing over 60 hours of CS:GO under controlled latency conditions, local latency has more impact on competitive FPS game players than does the same amount of network latency. In general, for a baseline system with 125 total milliseconds of network latency and local system latency:

- (1) A decrease in 100 ms of *local latency* improves accuracy by 6 percent, score by 3 points/minute and QoE by 1.6 points on a 5-point scale.
- (2) A decrease in 100 ms of *network latency* improves accuracy by 2 percent, score by 2 points/minute and QoE by 0.7 points on a 5-point scale.

Future work may compare local latency and network latency on additional game aspects, such as a broader range of player skills (i.e., non-expert gamers), player versus player (rather than versus bots), other weapon types (e.g., sniper rifles), as well as other FPS games to confirm that our results generalize. Possible studies also include alternate esports game genres, such as Multi-player Online Battle Arena (MOBA) (e.g., DOTA 2, League of Legends) and Real-Time Strategy (RTS) (e.g., Starcraft).

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