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Frames That Matter

The Importance of Frames per Second in Games

Faculty of Arts

Department of Game Design

Author: Rickard Hagström

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Supervisor(s): Masaki Hayashi, Berglund-Rogert Jakob

Examiner: Iwona Hrynczenko

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Abstract

There's been a lot of debate behind frames per seconds in gaming recently and many people come with all kinds of strange claims. For example, that the eye can only see 30 frames per second, its more "cinematic" and that it is the optimal framerate for games.

This thesis studies about the importance of frames per second within games and the history behind frames per seconds, in games and all the way back when movie industry began. What is best for higher player performance and what should developers strive for?

There was a personal preliminary test with an extended playthroughs of each game, to see if the playstesters would experience similar issues. Afterwards two quantitative tests with two different methods, a blind test and a performance test, are conducted to measure if any player notices the differences, how the framerate can affect the player's performance and what they preferred.

Key words: Computer Games, Console Games, Frames per Second, Framerate, Hertz, Esports, Movies.

Abstrakt

Det har varit en hel del debatt om bilder per sekund inom spel under de senaste åren och det har kommit fram alla möjliga konstiga påståenden. Till exempel, att ögat kan bara se 30 bilder per sekund, det är mer ”filmiskt” och att det är den optimala bildhastigheten för spel. Denna studier handlar om hur viktigt bilder per sekund inom spel är och historien bakom bilder per sekund, allt ifrån spel till filmindustrins början. Vad är bäst för högre prestationer för spelarna och vad bör spelutvecklare sträva efter?

Ett personligt förberedande test med utsträckt igenomspelning av båda spelen, för att se om speltestarna skulle få ett liknande problem. Därefter två kvantitativa tester med två olika metoder, ett blindtest och ett prestandatest, genomförs för att mäta om någon spelare märker skillnaderna, hur de olika nivåerna av bilder per sekund kan påverka spelarna prestanda och vad de föredrog.

Nyckelord: Dataspel, Konsolspel, Bilder Per Sekund, Framerate, Hertz, Esport, Filmer.

Glossary

Glossary for all short hands and abbreviations found on this thesis

FPS – Frames per Second

Hz – Hertz

PC – Personal Computer

GPU – Graphics Card

CPU – Processor

CRT – Cathode Ray Tube

NTSC – National Television Systems Committee

PAL – Phase Alternate Line

UT – Unreal Tournament

TLOU – The Last of Us

NES – Nintendo Entertainment System

Bots – Non-player Controlled Character

Mod – Modification to a game

Playthrough – A game session

USAF – The United States Airforce

Esport – Electronic sports

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1 Introduction

In recent years, along with the release of the eight generations of game consoles, a lot of people claim that 30 frames per second is more cinematic and that it is the optimal framerate for games. The misconception that our eyes can't interpret and see over 30 frames per second is a flawed statement and far from the truth. Yet this notion has affected games for some time now and it has become worse for a large group of players.

Among those who claim this are game publishers, developers like Ubisoft, From Software, Evolution Studios, Ready At Dawn and so forth. They have brought up statements about their games being more cinematic with a framerate closer to the movies. The game industry leans on other medium's history and therefore games often get compared to movies.

The most recent examples might be Assassin's Creed Unity (Ubisoft Entertainment. 2014), the developers made the PS4 version identical to the Xbox One version even though the PS4 is slightly more powerful. The Order 1886 (Sony Computer Entertainment. 2014) which looks visually impressive at first glance. Then there's Driveclub (Sony Computer Entertainment. 2014), which is a racing game, there the player needs to be able to react as fast as possible to whatever comes up next.

With these few examples have resulted in games run in only 30 frames per second, which is closer to the majority of movies that run in 23.976 frames per second. Somehow this means that these games would have a more cinematic and better game experience than if the games had higher framerates. If this is true, how come they do not lower it to exactly that amount of frames for that "True Cinematic Experience"? Below you'll see some of the developer's explanations and reasons to why they locked them at 30fps.

Game director of The Order 1886, Dana (via Amini, 2014) said:

We're going for this filmic look, so one thing that we knew immediately was films run at 24fps. We're gonna run at 30 because 24fps does not feel good to play (Dana Via Amini. 2014, unpagged).

What is more important, the cinematic vision or the framerate? This implies that the more frames, the better gameplay you get. How about Anime? There is a technique called “Double Frames”; to only draw 12 frames and then duplicate them. Therefore, shouldn’t Anime related games like Dragonball Xenoverse (Bandai Namco Entertainment) try to do that as well for the “True Anime Experience”?

World level design director of Assassin’s Creed Unity’s. Guérin (via Langley, 2014) said:

I don't think it was a good idea because you don't gain that much from 60fps and it doesn't look like the real thing. It's a bit like The Hobbit movie, it looked really weird (Guérin via Langley, 2014, unpagged).

A game is not a movie, and it’s hypocritical when this framerate debate exists for movies.

Driveclub, Game director, Rustchynsky (via Makuch, 2014) said:

It’s always a tradeoff, ultimately. And I think we’ve made the right choices to make the best driving game we could have made.
(Rustchynsky via Makuch, 2014, unpagged)

This is a reasonable argument, which they want to focus on higher graphical fidelity over fluid motion.

1.1 Hypothesis & Purpose

The purpose of this investigation is to find out to what extent the frame rate is important in games and if games require a change of industry standard from the previous 30 frames per second.

To achieve the purpose, following questions was posed:

Do the players notice the difference in framerates and how does it can affect player’s performance? Does it Increase or decrease with higher frames per second and if so, which is the optimal framerate? And what does the word “cinematic” in games really mean to a player?

To answer these questions multiple platforms, control inputs and games were tested. For the tests, two very different games were chosen, a fast paced game versus a “cinematic” game. This allowed me to see which of them it affected the test subjects the most.

2 Background

There have been multiple other studies on the subject, I looked for research to find out as much as possible about frames per second, mainly for the games but also movies and other related studies on the subject. I also looked into different technologies, like graphics cards and monitors. The majority of the sources for my research consist of articles from either game, movie or tech related websites about the subject; frames per second, framerate and so forth.

2.1 Brief History of Frames per Second

It has always been important with frames per second for both movies and games, even in the earliest of days. One of the earliest uses and focus on frames per second was for a high-speed photography sequence of a galloping horse, to see if whether all of the horse's hooves were off the ground or not at any time during the sprint. They had to use multiple cameras to cover the short distance the horse needed to run by.

Early cameras like Bouly's Cinematographe from 1892 used a spin mechanism, the cameraman would have to spin it up themselves. For more or less frames per second that got recorded all depended on how fast the individual spins it and usually they spun it faster during scenes with rapid movements.

These early movies ran mostly just above the flicker fusion threshold, which is the line between a rapidly changing slideshow of pictures and fluid animation. It's supposedly around 18 frames per second and those additional few additional it becomes fluid enough for movies. 23.976 frames per second has mostly been a standard ever since.

Monochrome CRT's were introduced 1922 and in 1954 color CRT televisions was introduced. It stands for Cathode Ray Tube, which is a vacuum tube containing an electron gun and a fluorescent screen used to view images. About the same time both PAL and NTSC were also introduced. Its two different types of color encoding systems that affect the visual quality of the content viewed on analog televisions. They NTSC uses a 30 frames per second, 60 Hz and while PAL has a 25 frames per second and a framerate with 50 Hz. Hertz (Hz) is the unit of frequency, vertical refresh rate is the amount of times a display

refreshes to show a new image, which means 60hz displays refreshes 60 times per second to show a new image.

Almost for an entire century, it has been a similar framerate and people are used to less precise 24fps, with its inherent natural motion blur. The Hobbit used 48 frames per second to reduce eyestrain and provide additional clarity, especially for a movie to be shown in 3D. Which also results in higher production costs and so forth.

In an article by Fenlon (2014) he mentioned The Hobbit. Producer & Director Peter Jackson (via Fenlon, 2014) made a long statement on Facebook about 48 Frames per Second.

We've all seen thousands of films like this over the last 90 years--but there is often quite a lot of blur in each frame, during fast movements, and if the camera is moving around quickly, the image can judder or strobe (Jackson via Fenlon, 2014 unpagged).

When it comes to games, some may think that 60 frames per second was recently achieved for console games, but it has been around all the way back in the NES era. Arcade machines had improved performance that made it possible to run certain games in 60 frames per seconds, the first games with it released between 1985-1990 like Space Harrier, Outrun and After Burner. The earliest types of 3D games that ran at 60 frames per second were games like Daytona USA that was released in the arcades 1993. There have been plenty of console games ever since that have run at 60 frames per second. For the PC there's far more game titles and the limitation tends to just be whatever hardware the computer has.

In the early days of Esport in games like Counter Strike 1.6, CRT Monitors could reach higher, much higher Hertz than the flat monitors at the time and therefore competitive players used to stay with the massive CRT monitors. For essentially all Esport competitions that require fast paced movement have gone with higher framerate and low response time monitors.

2.1 The Difference Between Games and Movies

How frames per seconds are used are very different because of two things. First of all movies are Pre-Rendered, which means that it's essentially set in stone. It all begins with a cameraman that direct the camera at the scene, to only show exactly what they want to show the viewer. Whenever they're done with recording a scene, the post production phase begins and they edit in exactly what kind of additional effects they want for the movie. When the movie is set and done, it will have a set amount of frames depending on the movie length and the viewer won't be able to affect what is shown. This is, in other words non-interactive passive entertainment.

Meanwhile, games use something called Real-time Rendering. This is mostly used for areas of computer graphics where an individual can interact in certain ways. For example environment within a game, that the player can walk, look and turn a character around 360 degrees. Whatever occurs within the playable area somehow would have to be displayed on the screen, therefore the graphics card will then render frames rapidly of whatever happens in the moment and what the camera shows within that environment.

For the complexity of the game, like Shaders, Shadows, Anti-Aliasing, Ambient Occlusion, PhysX, Post Processing and so forth effect used in these will have an impact on the GPU and reduce the amount of frames. Graphics doesn't have inherent blur so certain games try to imitate movies by adding additional effects, like blur that will also impact the performance of the GPU. For console games, it tends to be locked at either 30 or 60 frames per second while PC games may not even have any frame lock at all, the graphics card will then attempt to push out as many frames as possible. It requires a monitor that has a high enough frame frequency to handle it as well.

2.2 Previous Work

There are plenty of informative articles and videos about frames per seconds for movies and games, everything from developers that defends the very limited 30 frames per second, to when the earliest console games that ran with 60 frames per second. Here are some of the most relevant points to consider.

Frames per second is a mechanical term that can't really be applied to us, when our eyes are biological and takes in a constant flow of information and not the frames. All we can do are estimates of how much the eye can perceive, our capabilities and reaction times. According to research from The United States Air Force (USAF) and about their navy pilot's reaction times, spot detection abilities and more.

In the article by Brand, Dustin D. (2001) Mentions a United States Airforce study.

The USAF, in testing their pilots for visual response time, used a simple test to see if the pilots could distinguish small changes in light. In their experiment a picture of an aircraft was flashed on a screen in a dark room at 1/220th of a second. Pilots were consistently able to "see" the afterimage as well as identify the aircraft. (Brand, 2001, pp 1).

In another report (Morris. & Hamilton, 1986). From United States Airforce: Department of the Navy Aerospace med Research Laboratory stated that "Simple reaction times ranged from 143 to 461 msec, with a mean of 223 msec"

Through some simple math, they were able to discern that pilots mean milliseconds equates to roughly 13-14 frames in a 60fps game and out of those two first frames, are all it takes for the eye to process an image. While in a 120fps game that is around 27 frames and out of those four first frames for the eye to process an image.

Read & Meyer (2000) states:

The human eye and its brain interface, the human visual system, can process 10 to 12 separate images per second, perceiving them individually. The visual cortex holds onto one image for about one-fifteenth of a second, so if another image is received during that period an illusion of continuity is created, allowing a sequence of still images to give the impression of motion. (Read & Meyer, 2000, pp 23-24)

This essentially means that at 12fps, you would see the individual images, a higher amount of frames per second equal's higher fluidity for the illusion of motion, but it still has to pass the flicker fusion threshold.

3 Method

I used quantitative measurement for my two tests, with two very different games and platforms. This allowed me to observe and analyze the players experience and what they thought of the difference in quality from games, genre to genre, controller to keyboard and mouse, and if there was a pattern of a player's performance, the games, and compare the framerates. In preparation for this, played through the test myself to see if I could notice any difference as well. I estimated to have around 10 players for the tests and the players played one at a time.

3.1 Preliminary Test

For this experiment, I figured that the Unreal tournament franchise would be a prime example to work with, the franchise is known for its fast phased multiplayer shooter gameplay on the PC platform. In the new game that's currently in development, Pre-Alpha it already got easily adjustable framerate lock in the options menu. Therefore, there's no need to adjust it via configuration files as in many other games. The game is still being developed, it's not fully optimized and with a 2-3 year old GPU isn't able to handle the higher framerate with higher graphical settings. Therefore the game will be set to the lowest graphical settings through all the tests, so there's no visual difference except for the framerate.

In preparation I tried out, and experienced everything for myself, therefore I played several hours trying out different framerates, as well as putting it to extremes with incredibly fast camera movement. The framerates that I decided to look into were from 18fps, 24fps, 30fps, 48fps, 60fps, to 120fps. The 18fps is the Flicker Fusion Threshold, 24fps is movie standard framerate, 30fps is the low "Cinematic" framerate, the 48fps is The Hobbit framerate, 60fps is the medium framerate and lastly the 120fps is the highest framerate.

Since it's a competitive game, I therefore include gaming peripherals like Headset, Keyboard and mouse. Additional software to collect and gather the information from the tests, Fraps allows me to take screenshots from the game and with Photoshop I could mark each picture with whatever framerate was used. With those pictures I turned it into table

data in excel. Lastly, with my phone I took a picture to show off screen tearing in Unreal Tournament Pre-Alpha.

Hardware

- **CPU**, Core i7-3930K S2011 3.20GHz 12MB
- **GPU**, MSI GTX 680 2GB
- **Monitor**, Benq XL2410T 120hz
- **Headset**, Senheiser PC 360
- **Mouse and Keyboard**, Razer Deathadder and Razer Blackwidow
- **Camera**, Sony Xperia Z2.

Software

- **Game** Unreal Tournament Pre-Alpha (2015)
- Fraps
- Photoshop
- Excel

In preparation for the method of the blind test there's another prime example, but for a completely different reason. The Playstation 4 exclusive game called The Last of Us: Remastered, which has a function to switch between 30 or 60 frames per second. It is a slow stealth and a survival game with a linear story. It is considered to be one of the greatest and most "cinematic" games of all time. I therefore used a movie centric monitor; BenQ EW2430 and a Qpad QH-90 splitter to make the Senheiser PC 360 headset compatible with the PS4 controller for much better sound quality. The recording software I used was the Playstation Share feature and broadcasted to Twitch.tv.

I had to play through the entire game and to decide which Acts the players had to play through. Therefore, I streamed the entire playthrough, which I later could review about how long each act took to clear out. The ones I felt were good enough choices, I played through an additional time and I also put it to the extreme to see if I personally could notice

any major differences, The best way to visually see the differences were to spin the camera in a rapid phase and I did this in several areas.

Hardware

- Playstation 4
- **Monitor**, Benq EW2430 60Hz
- Qpad QH-90 Headset Splitter
- **Headset**, Senheiser PC 360

Software

- **Game**, The Last of Us Remastered
- Playstation Share, Twitch.tv

3.2 Method of the Performance Test

Before the actual test, each player will get some preparation to get used to the game and map. Because the players would most likely get better and learn over time after each test, therefore they have free range to play for about 20-60 minutes with the optimal settings in 120fps. It should've been enough time for them to get adjusted to the game, enough time to practice and hopefully reach their optimal potential before the actual test.

From there we will be able to see a decline in performance whenever they played with the lower framerates. They randomly picked between three letters that represent a hidden framerate. After every letter they had picked, I blocked their view for a short moment and changed the framerate settings, every individual had a 10 minutes to play match with each letter and its framerate. They either started with 120fps, 60 fps or 30fps. After each match the frame rate will be changed accordingly. I assigned it like this: A: 30fps / B: 120fps / C: 60fps.

It is a Deathmatch free-for-all mode, there all the players play against each other, kill or be killed. It will take place on one of the few fully textured and finished maps called Outpost 23. Each player will play against 5 bots set to be around the difficulty "Skilled" which is around 2.75-3.5 out of the 1 – 8 scale, the higher the number the more difficult the bot

supposed to be. I gathered the statistics, ranking from 1-6 against the bots, kills/score and death. I compared the statistics from each individual's performance and to see if there's any difference in whatever framerate they played in.

A survey about the players experience while playing with the different framerates that hopefully answer additional questions about their experience with the game. The majority of these survey questions will be able to answer from 1 to 5, if it's excellent or not.

- Have you played fast phased twitch shooters like Unreal Tournament before?
- Did you experience anything strange visually on either playtest?
- Did you experience anything strange with the controls on either playtest?
- How playable was "A" from 1 to 5?
- How playable was "B" from 1 to 5?
- How playable was "C" from 1 to 5?
- Can you point out which framerate belongs to each letter?

3.3 Method of the Blind Test

Even though this method is more reliable with higher numbers, I could still possibly get some useful information out of it. The players will first off play through Chapter 1, Act 1 – Prologue. It will work as an introduction to the game and for them to get used to the controls. For the test they will play from Chapter 3 – The Outskirts, Act 3 – Museum and stop at as fast as the next Act begins – The Capitol Building. They played from location A to B, then I told them to look away for a short moment while I changed the framerate lock and continued to play from B to C. The prologue takes about 15 minutes and each act is estimated to take around 20-30 minutes. The players picked a letter randomly, either A or B and it represented a certain framerate. They had two options and played with either:

Act 3(with 60fps) - Act 4(with 30fps) / Act 3(with 30fps) - Act 4(with 60fps)

There's no measurable data to compare that would tell any reliable information about a frame rates impact on the player's performance. It's just for me to observe and assist whenever they need help to progress any further. The main focus was to gather stats out

from a survey that will have similar questions to what the Unreal Tournament survey had, about their experience with the game.

Once again for the majority of these survey questions they were able to answer from 1-5, for example if it's excellent or not.

- Have you played The Last of Us before?
- Did you experience anything strange visually in any Act?
- Did you experience strange with the controls in any Act?
- How playable was Act 3 from 1 to 5?
- How playable was Act 4 from 1 to 5?
- Can you point out which framerate belongs to which Act?

When they're done with the play through and answered all the questions in the survey I revealed the purpose of the experiment. I will show them The Last of Us put to the extreme just like my preliminary test and if they notice the differences in side by side example, then they would answer the last survey about cinematics.

- Did it feel more cinematic with 30fps? Also define the word cinematic.
- Do you prefer to have to have a higher framerate in sacrifice of better graphics?
- If TLOU was on the PC with 30fps, would it be tolerable when you can do such fast paced twitch movements as in UT?

4 Result of the Research and Experiment

In the experiments 7 players participated in the Unreal Tournament performance test, while only 4 people participated in the blind test for The Last of Us. All of the subjects were male, all were Caucasian and ages ranged from 18 to 28. Everyone had previous experience with games, but the least experienced individual lastly played games when he was a young teenager.

4.1 Result of the Preliminary Test

From the personal test I noticed that there was a couple of differences between Unreal Tournament and The Last of Us. Console games tend to have very few graphical options and the movement is generally slower with a controller. With high enough sensitivity you can easily notice how the game becomes much more blur when to compare each framerate.

In Unreal Tournament I first played 18fps, which is unplayable. After 10 minutes I began to play with another frame rate. 24fps was borderline unplayable, 30fps reaches felt like a minor improvement, after a while I sort of adapted to the framerate by avoiding rapid movements. It is just above the limit to become playable and it's the very minimum requirement. With 48fps it became even more fluid and in 60fps, it was only minor issues and the screen tearing became much less noticeable. While 120fps was the optimal in this test and everything moves fast and smoothly. The more frames, the less space it's in between the frames and more fluid and seamless it became.

Since a movie count as passive entertainment, where the viewer can't interact in any kind of way or form. While games are real-time rendered entertainment there the player can interact and affect the environment.

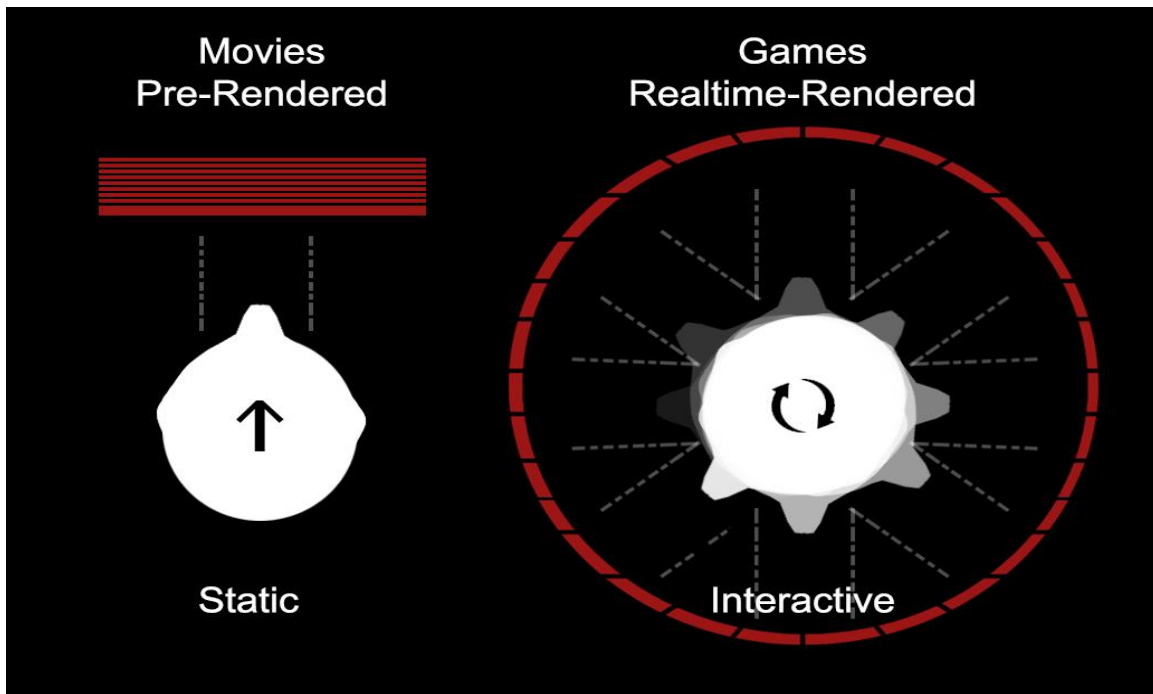


Fig 1. Difference in Movies and Games, (Hagström, 2015)

In *The Last of Us Remastered*, it hides the lack in frames, by increasing the amount of blur and other effects. When I switched from 60fps to 30fps the blur increased immensely, and with increased camera movement sensitivity you can easily notice how the game becomes much more blurry in 30fps. While *Unreal Tournament* has nothing to cover up the lack of frames. It can only be each individual player's own fault or limits, instead of the game that limit the players.

4.2 Result of the Performance Test

Every individual had played fast paced twitch shooters before either previous iterations of *Unreal Tournament* and/or *Quake*. It was pretty much straight forward for them and the majority thought that they just needed 10 minutes of practice, the only additional help they required from me was the alternative modes for the weapons and the dodge button on the mouse side button. Everyone managed to play through all the matches with the different frames per seconds, and to come in first place all matches.

As we can see in the Table1. below with the player's statistics, overall there is a 10 point gap in the score/kills between 30fps versus 120fps. There is about a 15.8% increase in performance from 30 to 60 frames per seconds. While it's about a 23.87% increase in performance from 30 to 120 frames per seconds. A single 1% consists of 0.4428 points to score/kills. The amount of deaths also increased by 2.6 - 3.2 points when they played from 30, 60 to 120 frames per seconds. 14.5% increase from 30 frames per second to 60 frames per second. 11.9% increase from 30 to 120 frames per second.

Table 1. UT Statistics Score & Death, (Hagström, 2015).

FPS		P	L	A	Y	E	R	S	COMBINED	OVERALL
30	Score	44	47	33	33	50	58	45	310	44,28
60		48	39	58	41	56	54	63	359	51,28
120		54	56	46	43	58	55	72	384	54,85
30	Deaths	19	36	33	16	15	17	19	151	21,57
60		22	31	41	21	34	20	20	173	24,71
120		20	31	43	18	29	19	29	169	24,14

According to the table 2. below, the players recognized that there was something wrong visually, the players noticed a lot of screen tearing when they played with the lower framerates. It was most apparent in 30fps, while 60fps, it was more tolerable, while 120fps there was no issue at all. Also slightly more than half agrees that it became harder to control, harder to aim and input lag.

The maximum combined is 35, the overall maximum score is 5 and the lower they rate it means they didn't notice any while the higher numbers means they noticed more issues.

Table 2. UT Rated Experience, (Hagström, 2015).

	P	L	A	Y	E	R	S	COMBINED	OVERALL
VISUALLY	5	3	5	5	5	5	5	33	4,71 / 5
CONTROLS	4	2	5	1	5	5	4	26	3,71 / 5

The next table 3. below, shows which letter they believed had the highest framerate and best to play with. As we can see the players strongly recognized the letter A, represents

30fps only got 11 points in total. Meanwhile the players had a much higher approval with the letters B and C, they were also somewhat similar amount which means they had a harder time to differentiate between 60fps and 120fps.

The maximum combined is 35, the overall maximum score is 5. The lower they rate it, the less enjoyable it was, while with higher means they had a more enjoyable experience.

Table 3. Which letter the players preferred, (Hagström, 2015).

	P	L	A	Y	E	R	S	COMBINED	OVERALL
A (30)	2	2	1	1	2	2	1	11	1,57
B (120)	4	3	5	5	3	5	5	30	4.28
C (60)	5	5	3	3	4	4	3	27	3,85

Lastly, in Table 4. the players had to drag and assign all the three letters to a framerate. Here you can compare and see what framerates, they actually played with in the table 3. Above. Two out of seven players answered incorrectly and mixed up the 60fps and 120fps. While everyone once again recognized and pinpointed the lower 30 frames per second. Bold text are correct answers.

Table 4. UT Assign each letter to a framerate, (Hagström, 2015).

LETTER	PLAYER'S FRAMERATE						
A	30	30	30	30	30	30	30
B	60	120	120	120	60	120	120
C	120	60	60	60	120	60	60

4.3 Result of the Blind Test

The blind test got fewer individuals most likely because of the long periods to play each act and that there's less interest to begin a heavily story driven game without being able to finish it. Only one individual wasn't aware of The Last of Us, while another had seen an extended playthrough, but no one of them had ever held a PS4 controller or played the game before. One of the players also required to have the aim controllers inverted, so when the player pulled up with the thumb stick, the aim will instead turn downwards.

The introduction prologue section didn't help much with the gameplay mechanics and the players encountered issues; puzzles and obstacles for the later acts that I used for my test. They got easily confused and didn't really know what to do in certain scenarios and where to go. For example, at the very start of the actual test, they had issues to deal with the first initial infected zombies and its obstacle, which was just to pull a garbage container towards the blockade so they could jump over and continue forward. I therefore had to sit beside them and assist them whenever they felt they needed it.

In the first table, the players recognized had a much harder time to see if there was anything wrong visually, two individuals noticed the increased amount of blur with the lower framerates. While the controls didn't seem to have much of any issues at all or very minor. Other than that it was just that they had to get used to the new Playstation 4 controller.

The maximum combined is 20, the overall maximum score is 5 and the lower they rate it means they didn't notice any while the higher numbers means they noticed more issues.

Table 5. TLOU Experience during the playthrough, (Hagström, 2015).

EXPERIANCE ANYTHING STRANGE...					OVERALL
VISSUALLY?	3	1	2	4	2.5
CONTROLS?	3	3	1	1	2

In the Table6. below we can see which Act all of the players preferred, and it appears that the 4th Act was slightly better for them. Half of the players preferred the 4th act slightly more than the 3rd Act, even though only one of the players had 60 frames per second in the 4th act. The first player didn't notice a difference and mixed up the framerates and the acts. While the second player just mixed up the Acts/Framerate. The two last individuals got it right, except that the last player still preferred the 4th Act with the 30 frames per second over the 3rd Act with the 60 frames per seconds.

The maximum combined is 20, the overall maximum score is 5 and the lower they rate it means it less enjoyable while the higher numbers means they had a greater enjoyable experience.

Table 6. TLOU Player Guess Act & Framerate, (Hagström, 2015).

HOW PLAYABLE?					OVERALL
ACT 3	3	4	5	4	4
ACT 4	5	4	5	5	4,75

In Table 7, they dragged what framerate belongs to which act. The numbers in bold numbers mean they answered correctly, while regular sized numbers were incorrect and to which order of frames per second they played with. 2 out of 4 were correct and 3 out of 4 individuals played with 30 frames per second in the 4th Act.

Table 7. TLOU Assigned Act & framerate, (Hagström, 2015).

ACT	PLAYER'S FRAMERATE			
3	30	60	60	60
4	60	30	30	30

In the final Table 8, which consists of a couple of questions related to this “cinematic” ordeal. Two players voted 3 out of 5 which means that they didn’t really know what to think of it, while the other two felt that it weren’t any more cinematic with only 30 frames per second.

The second question got a slightly more positive response with two individuals that voted 4 out of 5, that they indeed would have liked to have a more responsive and higher framerate instead of extreme graphical fidelity.

The third question on the table is about if the players would find The Last of Us more tolerable if it was on the PC platform, with its faster movement and if it still would have been locked at 30 frames per second. They thought that it would be a very bad idea and this got a very negative response to the overall score that only reached 1.75 points.

The maximum combined is 20, the overall maximum score is 5. If they disliked it, they would give it a 1, or middle ground (3) means that they don’t really have an opinion on it. While the higher numbers mean they had a more ideal and supports the idea.

Table 8. TLOU Cinematic survey, (Hagström, 2015).

	P L A Y E R S				OVERALL
MORE CINEMATIC WITH 30FPS?	3	3	2	1	2,25
SACRIFICE GRAPHICS FOR FPS?	3	3	4	4	3,5
WOULD TOLERABLE TLOU ON PC?	2	3	1	1	1,75

Lastly, only two out of the four individuals decided to define the word cinematic. Participant N defined it as a non-controllable section of the game where it works just like a movie, with no player interaction.

A cinematic is a film sequence within the game.

Meanwhile, Participant A defined it as more about how movies are made, with the dramaturgy build up with a linear heavily story driven campaigns.

Cinematic for me has always been that the game trying to emulate the films in the structure and focus of the story, even great emphasis on cutscenes can provide a "cinematic" experience.

5 Analysis and Discussion

In my research and according to the USAF studies, we can greatly surpass 30 frames per second misconception and that we vastly underestimate our own capabilities. After a certain age, it is expected to have gradual loss of vision, which ties into why the majority of Esport competitors are young, usually from 16 to 30 years old. That's when they can have the best sight, reaction time and of course it varies from person to person.

In the majority of Esport it's considered to be a minimum requirement with 60 frames per second due to the majority of monitors being in 60Hz. For casual gamers that is a suitable amount, but in games like Counterstrike, professionals go much further than that. Especially in Esport competitions the professional players want to have the optimal conditions and settings for tournaments. Professional Esport players tend to remove unnecessary effects such as blur, which only distracts and make it harder to see what's going on in the scenery, sometimes they even detract additional effects to gain more frames per second.

The only reason anyone would claim that 30 frames per second is better is that they haven't experienced anything better themselves, but there are exceptions. Not every individual may be able to see the differences. It's like pilots that you need to train your senses to become better, and at a certain stage there for the individual players might need better components to improve his/her performance.

Another big factor is that it depends on what game and platform it is, for fast paced games, like racing games, fighting games and first person shooters. It doesn't just affect the game visually, but it the delay with input lag that can ruin a player's experience. People generally performed better the higher framerate they had access to. In first person shooters, racing, fighting games, just action games in general and for these games it is crucial to have a high enough framerate. Since TV's generally only have 60Hz, it tends to be mostly fine for the consoles, while on the PC there are higher standards.

In the Performance Test and from my observation when they played Unreal Tournament it looked like they did slower movements with the camera to avoid the screen tearing effect

as well. As if the players adapt to the framerate, slower movements to avoid the disruption between the frames.

According to the statistics of the performance test, with higher framerates the players generally got more kills, but they also played more recklessly and got themselves killed more often. In comparison to when they played in 30 frames per second, they apparently played more conservatively, which resulted in less deaths and less kills.

Unfortunately, I couldn't test beyond the 120 frames per second limit with this setup, due to a only a 120Hz monitor, it would've been interesting to see if player's performances continue to improve or if it becomes stagnant after a certain point. But the only minor upgrade available at the moment would be to go from 120Hz to a 144Hz monitor. It's not until recently consumer flat screen monitors have reached upwards 144Hz. While CRT monitors like the Samsung SyncMaster 900 had 160Hz and have been around since the late 1990's.

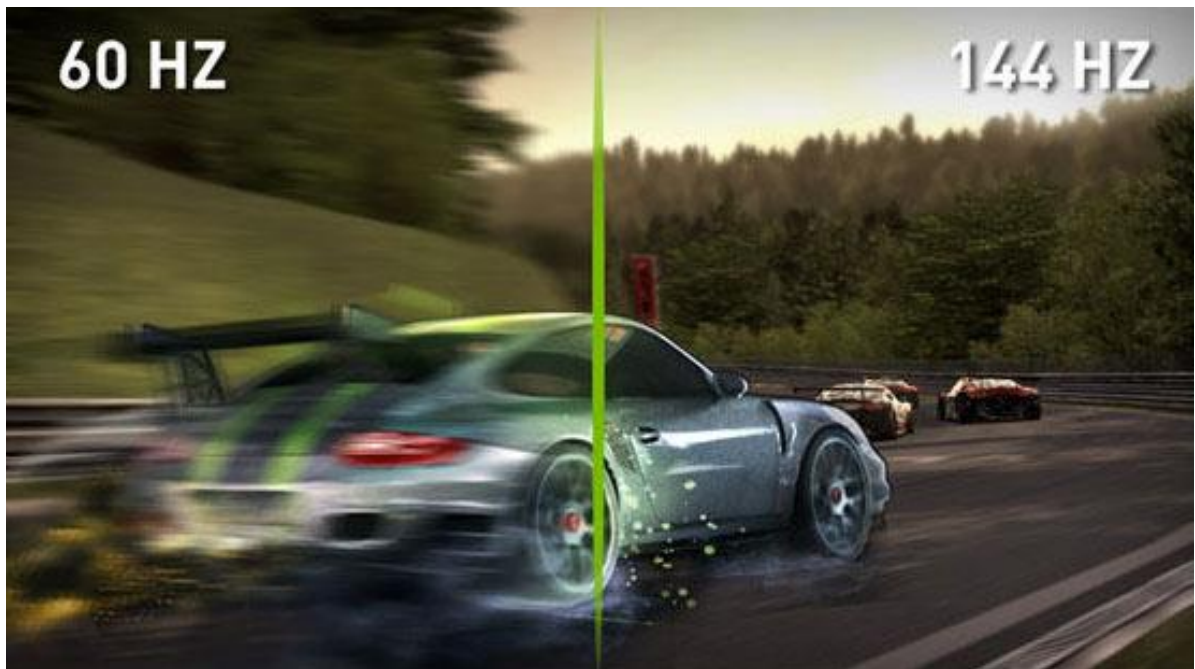


Fig 2. 60Hz vs 144Hz Illustration, (ASUS, 2015).

When it comes to hardware, the biggest requirements are graphics cards and the monitor it's going to output to with high enough Hertz (Hz). And no matter how many frames managed to push out, the Hertz of the monitor will limit it.

The major issue the players noticed while playing Unreal Tournament with the lower framerates was the screen tearing that could have been avoided, if I had access to NVidia's or AMD's recently developed monitors that use an additional module called G-sync or FreeSync. Then the 30fps might not have received as much negative feedback.



Fig 3. Screen tearing (Hagström, 2015) in Unreal Tournament Pre-Alpha (Epic Games Inc, 2014).

Regular monitors that have a set amount of Hertz, while the graphics card and the game's framerate vary. Screen tearing is caused when a frame is sent to the monitor from the GPU and gets out of sync with a monitor refresh, the result of this is several frames being displayed at once. This mismatch causes artifacts and the whole tearing effect, the only way to stop this is to force the GPU to wait on the monitor and only send frames in sync with its refreshes with a V-sync function. Unfortunately, V-sync is very demanding and can cause the game to stutter.

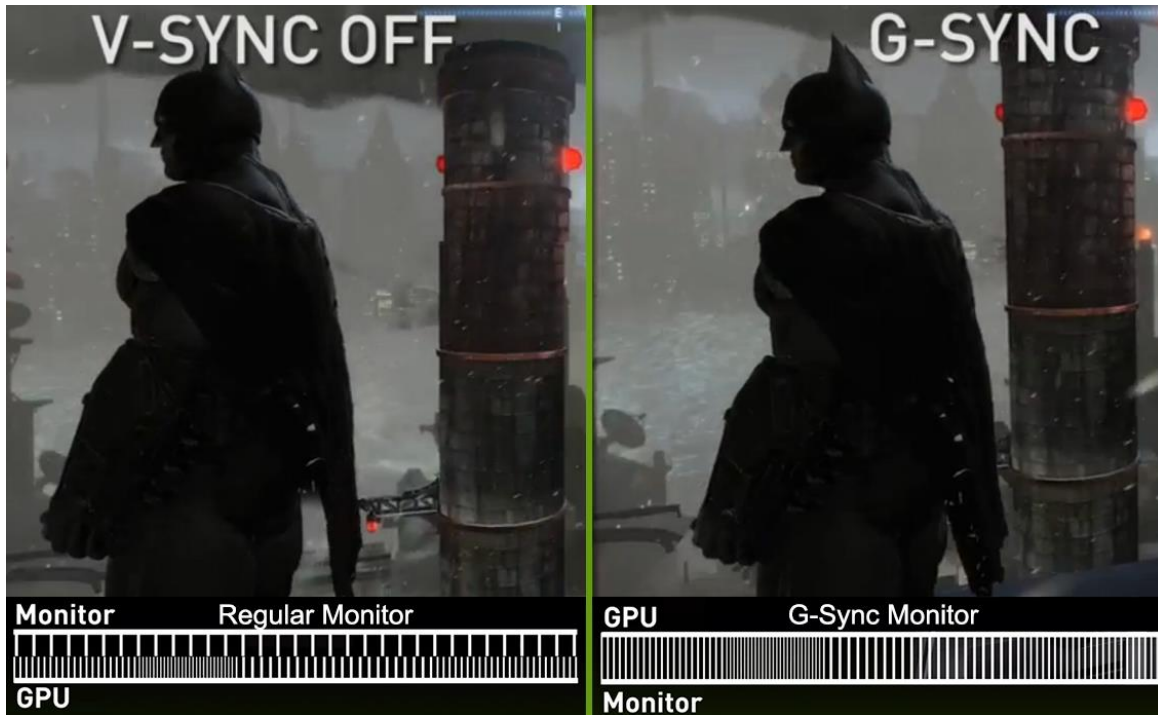


Fig 4. Batman Arkham Knight, G-sync Monitor vs Regular Monitor (Engadget. 2014).

The Blind Test did not get any substantial and reliable information and too few individuals that participated and overall issues. With both the selected levels for the test and they did not get used to the controllers even with the extended time practice time, they needed a lot of additional instructions. The statistics didn't get much of any result either, it was lukewarm response to all of the questions. The only big response was if a game like The Last of Us was on the PC and ran like Unreal Tournament with 30 frames per second, which was a strongly negative.

The Players didn't notice too many issues in TLOU. The main character in the game doesn't play as a super fit super soldier that can do everything easily, the character is old and therefore the gameplay designed to be generally slow. Thanks to the console and controller of choice TLOU avoids jagged and sluggish camera movement with its slower gameplay.

30 frames per second might feel more “cinematic”, but 60 frames per second will look more fluid. It therefore depends if the developer wants the player to feel like they either watch a movie or be in the movie. From the two individuals that defined cinematic for me both make sense, Nicolas said is what I’ve always considered to be cinematic as well. But considering how the game industry has pushed the whole “More Cinematic” label onto games, as if it’s more storyline driven as movies, while Alex definition also makes a lot of sense. But why would that have to impact the framerate and performance of the game if it’s only story related?

6 Conclusion

The performance test clearly indicates a better experience and improve with higher framerates. While in The Last of Us had insufficient data to say for certain, but from what I gathered, the players couldn't tell the framerates apart as easily.

There are multiple factors to consider; what Game and genre, platform, control input and monitor, Hertz and the individual players. The more frames the better, this means that the player won't be limited by the hardware's capabilities and the only thing that stands in his/her way are their own capabilities. Casual player's or Professional Gamers, the PC platform allows the players to have a far higher rapid and precise movements. Instead of the game to limit the framerate and players, the only limit is whatever the player can do accomplish. The higher framerate a game has won't deteriorate a players the experience, it can only improve. But having too low can surely ruin someone's experience.

The minimum acceptable framerates is 60 frames per second, I draw the line there because most TV's and monitors that cannot display any more than 60Hz. Balance between frames per second and graphical fidelity. There are very few exceptions, for games that has fixed cameras, which players can't move the camera around freely. Prime examples would be South Park Stick of Truth and Hearthstone. Both run with 30 frames per second and neither of them requires any rapid movements in a 3D environment.

The two definitions for the word cinematic, it has nothing to do with framerate and it just appears to be mainly just as a marketing term for publishers.

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Appendix

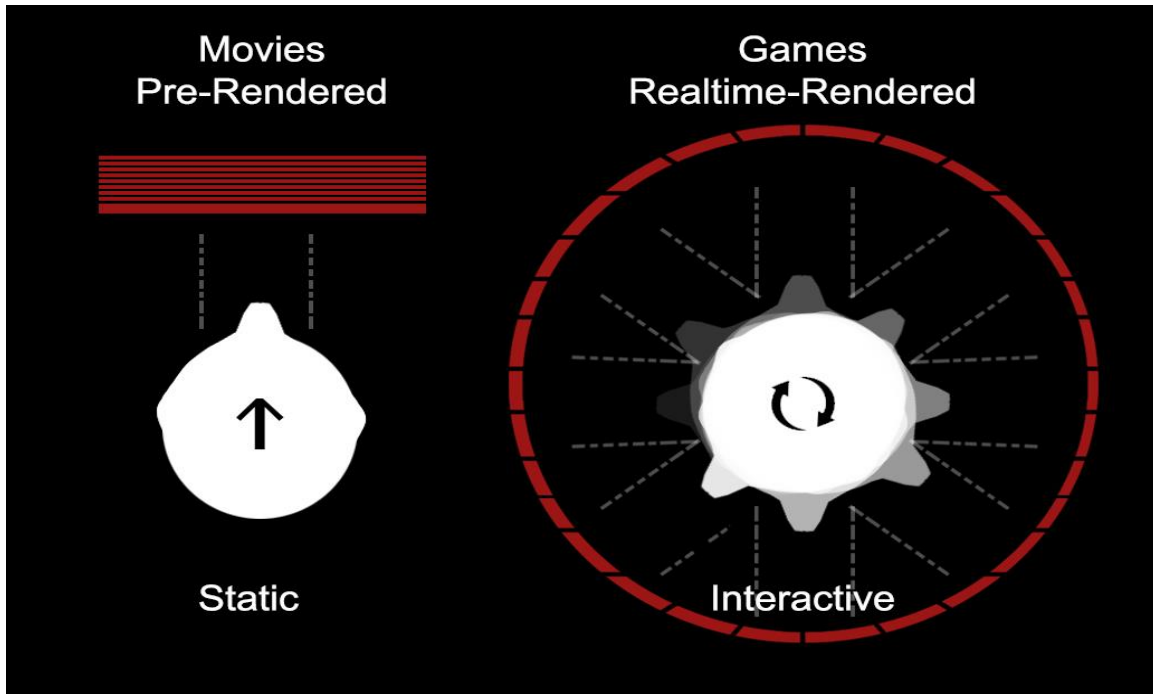


Fig 5. Difference in Movies and Games, (Hagström, 2015)

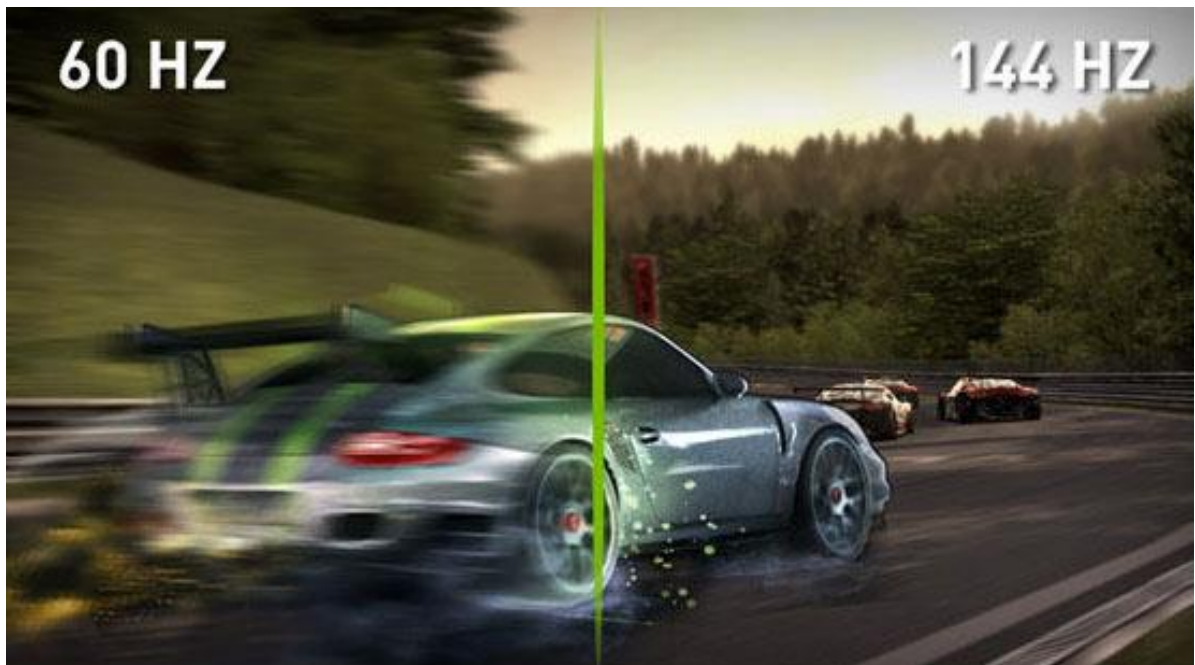


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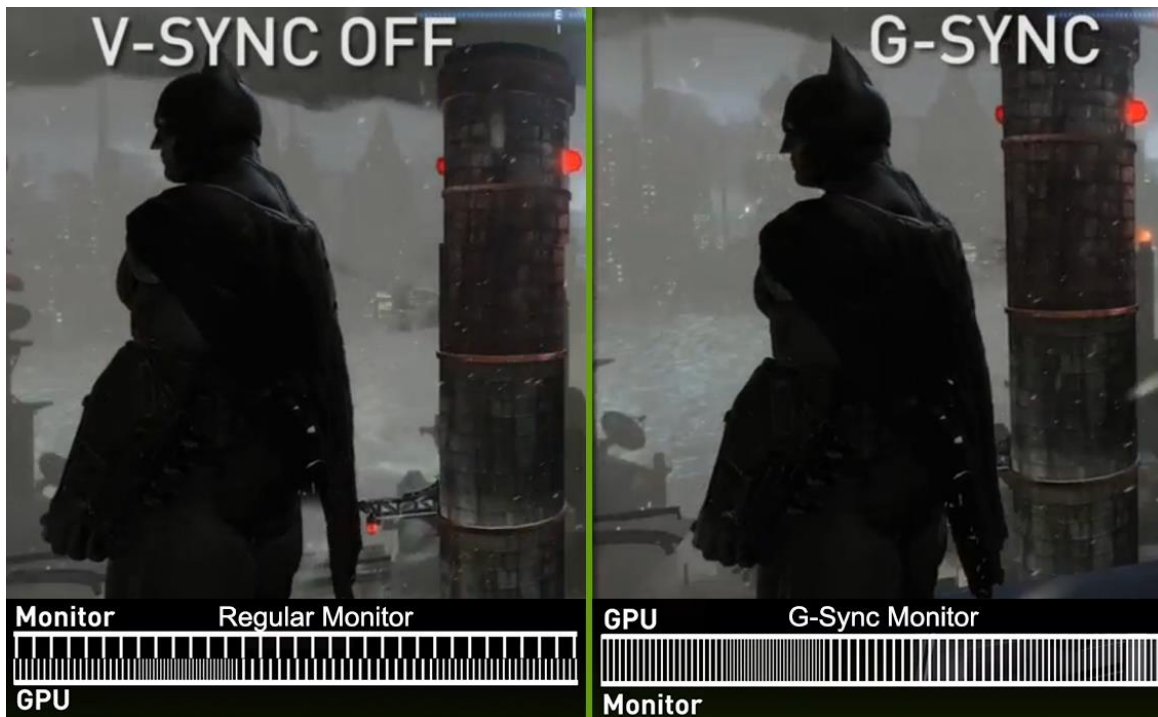


Fig 8. Batman Arkham Knight, G-sync Monitor vs Regular Monitor (Engadget, 2014).

Tables

Table 1. UT Statistics Score & Death, (Hagström, 2015).

FPS		P	L	A	Y	E	R	S	COMBINED	OVERALL
30	Score	44	47	33	33	50	58	45	310	44,28
60		48	39	58	41	56	54	63	359	51,28
120		54	56	46	43	58	55	72	384	54,85
30	Deaths	19	36	33	16	15	17	19	151	21,57
60		22	31	41	21	34	20	20	173	24,71
120		20	31	43	18	29	19	29	169	24,14

Table 2. UT Experience during playthrough, (Hagström, 2015).

	P	L	A	Y	E	R	S	COMBINED	OVERALL
VISUALLY	5	3	5	5	5	5	5	33	4,71 / 5
CONTROLS	4	2	5	1	5	5	4	26	3,71 / 5

Table 3. Which letter felt better to play with, (Hagström, 2015).

	P	L	A	Y	E	R	S	COMBINED	OVERALL
A(30)	2	2	1	1	2	2	1	11	1,57
B(120)	4	3	5	5	3	5	5	30	4,28
C (60)	5	5	3	3	4	4	3	27	3,85

Table 4. UT Assign each letter to a framerate, (Hagström, 2015).

LETTER	PLAYER'S FRAMERATE						
A	30	30	30	30	30	30	30
B	60	120	120	120	60	120	120
C	120	60	60	60	120	60	60

Table 5. TLOU Experience during the playthrough, (Hagström, 2015).

EXPERIANCE ANYTHING STRANGE...					OVERALL
VISSUALLY?	3	1	2	4	2,5
CONTROLS?	3	3	1	1	2

Table 6. TLOU Player Guess Act & Framerate, (Hagström, 2015).

HOW PLAYABLE?					OVERALL
ACT 3	3	4	5	4	4
ACT 4	5	4	5	5	4,75

Table 7. TLOU Assigned Act & framerate, (Hagström, 2015).

ACT	PLAYER'S FRAMERATE			
3	30	60	60	60
4	60	30	30	30

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MORE CINEMATIC WITH 30FPS?	3	3	2	1	2,25
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