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How many frames per second can the human eye see?

This is a tricky question. And much confusion about it is related to the fact, that this question **is NOT the same as**:

How many frames per second do I have to have to make motions look fluid?

And it's **not the same as**

How many frames per second makes the movie stop flickering?

And it's **not the same as**

What is the shortest frame a human eye would notice?

Test 1: Smoothness of motion

Imagine yourself watching movie of an unbelievably slow fog. You don't see edges and sharp borders. Now play the movie with 10fps. It will look fluid. Why? Because the difference from one frame to the other is very low. The extreme would be a totally unmoving wall: Then 1 fps would equal 1000 fps.

Now take your hand and move it slowly in front of your face. Then

move it faster until it's blurry. How many frames per second do you see? It must be little, because you see only a blurred hand without being able to distinguish every change per millisecond, but it must be many, because you see a fluid motion without any interruption or jump. So this is the eye's trick in both examples:
Blurring simulates fluidity, sharpness simulates stuttering.
(It's similar to "rotation simulates gravity".)

Motion blur example1: Capture from a live performance of *The Corrs "What can I do"* at MTV Unpluged

Motion blur example2: Capture from "*Basic Instinct*", where you see a woman plunging an ice pick into a man's body while sitting on him.

The fact is that the human eye perceives the typical cinema film motion as being fluid at about 18fps, because of its blurring.

If you could see your moving hand very clear and crisp, then your eye needed to make more snapshots of it to make it look fluid. If you had a movie with 50 very sharp and crisp images per second, your eye would make out lots of details from time to time and you had the feeling, that the movie is stuttering.

Also 25fps but without motion blur: Footage from BBC's story about Ed Gein, the murderer, who's case inspired Hitchcock to make "*Psycho*" and Jonathan Demme to make "*Silence of the Lambs*". The music is from CNN's "*Marketmakers*" (0.52 MB).

Just think of modern games: Have you ever played Quake with 18fps? There is no motion blur in those games, thus you need a lot of frames per second more.

However, you see the spots and the dirt of single frames in a cinema film, don't you? And those movies are played at 24fps. So there is a difference between seeing motions fluid and seeing that there's something (dirt) at all. Read on.

Test 2: Sensitivity to darkness

Imagine you look at a **shining** white wall. Now this wall turns totally black for 1/25th of a second. Would you notice it? You surely would. 1/50th of a second, well maybe harder. 1/100th of a second? Very difficult. Think of your 100Hz TV sets. They are called flickerfree, because at flicker rates of 100 times per second you stop to notice the blackness of the TV screen, though the TV screen isn't shining all the time, but pulsating 100 times per second. **Brightness eats darkness**.

Take again "Test 1: Smoothness of motion". You have a fluid film with 24 fps. The film roll has to roll thru the projector. To not see it rolling you have to make the picture black while the film rolls on. You would have to blacken the screen 24 times per second. But 24 black moments are too visible. Thus you have smooth motions but

flicker.
The solution is: Show each frame 3 times and make the screen black 3 times per frame. This makes the black moments shorter and more frequent: "Triple the refresh rate". So you see about 72fps in the cinema, where 3 consecutive frames are the same. Strange solution? Solution of an analog world. And an example how "Brightness eats darkness".

Test 3: Sensitivity to brightness

Let's do the opposite test to "Sensitivity to darkness". Let's talk about, how sensitive the eye is to brightness.

Imagine yourself in a very dark room. You have been there for hours and it's totally black. Now light flashes right in front of you. Let's say as bright as the sun. Would you see it, when it's only 1/25th of a second? You surely would. 1/100th of a second? Yes. 1/200th of a second? Yes. Tests with Air force pilots have shown, that they could **identify** the plane on a flashed picture that was flashed only for 1/220th of a second.

That is **identifying**. So it's pretty safe to say, that recognizing, that SOME light was there is possible with 1/300th of a second. Now if you take into consideration, that you have two eyes with different angles and different areas of sensitivity (you probably know, that you see TV flickering best, when you don't look directly into the TV screen, but with the sides of your eyes) and you can move/rotate/shake your head and your eyes to a different position, you probably needed flashes as short as 1/500th of second to make sure, nobody sees them in any case.

Now, what happens if I flashed you 1/500th of a second once in a second for 365 days directly into your eye? Would you feel something strange? Would it feel different than without it? Would you notice that something is wrong?

So, we should add a security value, to make sure nobody sees ANYTHING even **unconsciously** and feels comfortable about it.

Maybe the industry didn't add enough security factor to CDs and that's why many people still feel that analog is sometimes better. It's like in a room full of neon lights. You just know that something isn't right.

The reasons for the results of Test 2 and Test 3 are **afterimages**. Bright light creates an afterimage in the eye. The same way you see light in your eye seconds AFTER the doctor shined a light into it. This afterlight makes it possible to see what was there seconds ago. The brightness of the afterimage of the cinema canvas produces such afterimages and thus helps the movie to be flickerfree.

So the question "How many frames do I need to make the movie flickerfree" = to not see the blackness between the frames (about 70-100 fps) doesn't answer the question "How short can a bright image be to see it?" = the Airforce question and this doesn't answer the question "How short can a (not bright) image be to see it?".

So the conclusion is: To make movies/Virtual Reality perfect, you'd have to know what you want. To have a perfect illusion of everything that can flash, blink and move you shouldn't go below 500 fps.

Think of that, too

1. If your screen refreshes at 85Hz and your game runs at 50Hz (=50fps): Are you sure that you don't need to synchronize them? Are you sure, you don't need to play with a multiple of 85 to enjoy synchronized refresh updates? So the game running at 85fps may better than at 100fps. Maybe even a TFT display was better. It displays only with about 40fps but **progressively**.
2. Even though single eye cells (rods and cones) may have their limitations due to their chemical reaction times and due to the distance to the brain, you cannot be sure how they interact or complement or synchronize. If 1 cell is able to perceive 10fps, 2 cells may be able to perceive 20fps by complementing one another. So don't confuse "The human eye" with "The cell".
3. Some eye cells are reacting only when a stimulus is moving. Some react when it's moving from A to B, some when it's moving from D to Z. This may complicate frame-based simulation of reality.
4. Motion of your body could alter the way how you perceive. Do you get headaches after watching 3 movies in the cinema in a row? Maybe that's because you didn't move with the filmed motion? This is the reason for front-passengers' indispositions (= somebody else moved the car) and seasickness (=the sea moved the ship suddenly). Maybe this is the reason why 3D gaming glasses will never work perfectly. And this has nothing to do with frame rates.

5. When you look straight (= with the center of your eyes) it's not the same as if it was with the sides of your eyes. The sides are more sensitive to brightness and to flickering. The next time you are in the cinema do the following: Look up to the ceiling while the movie is playing. Especially during bright/white scenes you will clearly notice that the movie flickers.
6. Sensitivity to blue is different than to green: You see green best, even when it's dark, e.g. leaves in a forest at night. So "blue frames per second" may differ from "green frames per second"
7. Do you like to play Quake? Do you think "More is better"? Maybe that's why you think 200fps is better than 180fps.
8. Do you think moving in 3D games is stuttering? Maybe your mouse scans motion with too little dpi (Dots Per Inch) or fps (Frames Per Second)?
9. Do you think it is important that a graphics card can display 250 fps in your favourite game, because that's a feature they write about in PC magazines and on covers?
   Now this is just a figure to show how fast the card is, not to show that you need such a high frame rate. It's like with cars: 100km/h in 5 seconds. When will you ever need to go 100km/h in 5 seconds?

So what is "Enough fps"? I don't know, because nobody went there so far. Maybe 120fps is enough, maybe you will get headaches after 3 hours. Seeing framewise is simply not the way how the eye\brain system works. It works with a continuous flow of light\information. (Similar to the effects of cameras' flashlights ("red eyes"): flashing is simply not the way how we see). So there are still questions. Maybe you need as much as 4000fps, maybe less, maybe more.

The same question as for fps will arise for resolution. How many pixels can the human eye see? Does 2000x1000 (=*Star Wars Episode II* resolution) look like reality? Or is it just enough to make a film "cinemable"?

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