Journal of
Design Sciences and Applied Arts

Considerations of Producing Cinematic Films for Viewing on Digital Platforms Taking into Account the Human Eye Resolution Perception

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Submit Date: 2023-01-12 19:58:55 | Revise Date: 2023-02-24 21:25:55 | Accept Date: 2023-05-27 11:39:52

DOI:10.21608/jdsaa.2023.187034.1247

KEYWORDS:
Resolution, Cinema, Netflix, Digital Platforms, Visual Acuity.

ABSTRACT:

The cinematic image is regarded as the portal through which the spectator travels from their reality to a parallel world created by the cinema; the closer the quality of the cinematic image is to the spectator's actual perspective, the more effective it is in creating that world. Furthermore, filmmakers now regard individual variance and integration factors as more critical to the psychological effect of the cinematic image on the spectator and what distinguishes it from other arts, allowing the recipient to live the entire cinematic experience inside their head instead of experiencing it outside. Besides that, as production and display technologies develop, this research compares the physiological limits of the spectator's vision and personal perspectives with the percentage of benefit the spectator derives from the quality of the final image presented to them. A survey was conducted among experts on the resolution of TV screens in relation to human eye perception and the connection between TV size and viewer perception. Include a definition of alternative digital cinema platforms along with the requirements some of these platforms have established for accepting their original works.

1. Introduction

The study of the cinematic image is related to the development of technologies, and the future of the cinematic image depends on the development of the cinema industry in all stages (production, post-production, and projection). To understand the importance of the development of digital technology in the cinematic image, it is necessary to understand how the viewer looks at the cinematic image and how he receives it. The answer to these questions will not only be connected to the psychology of the viewer and his sense of the image, but the matter will take us to a scientific angle, given that the viewing itself is mainly related to the element of the image, which is related to the scientific perspective and the technology that affects them. The perceptual experience of the spectator is formed through the visual system and the image translation by the nervous system. The images surrounding us forms on the retina by the effect of light that capture the colors, movements, and physical relationships in the scenes around it. The digital cinematic image is characterized by high quality, and the development till it reached its current state, with more than 12K, was rapid. The process of displaying visual information fully falls on the human eye, through which the first viewing stage begins from the visual perspective. It moves to the brain to complete the perceptual experience with other highly complex cognitive and mental factors describing the final scene at the end. It is worth mentioning here that the primary goal of imaging technology development lies in the attempt to reach that superior quality of the human eye with its prominent ability to see details and colors with accuracy and high quality.

The research problem can be described in the proliferation of digital display platforms and their unilateral production of films, specifically to be displayed on these platforms. These productions are required to be shot with at least 4K resolution. Hence, there has been a need to study the requirements of the physiological limits of the vision of the spectator. Moreover, the percentage of benefit from the quality of the final image shown to the receiver should be investigated. It aims to assist filmmakers in ensuring that the viewer receives the disposition of the cinematic image presented to them and the extent of their ability to see and determine its quality from all aspects.

The researcher follows the descriptive approach to study the characteristics of the human eye and the limits of its ability to perceive the final quality of the image presented to it. The study of some characteristics of the camera and the image post-production path will also be considered to improve the quality of the final perceptual image for the viewer.

2. Composition of the Human Eye

The vision process involves many factors and organs, each of which plays a vital role in the visual process, so it is one of the most used senses, and most of the information a person receives is visual. The eye collects, focuses, and delivers light to specialized cells that translate the image.

The eye is considered one of the main parts of the human body that participates in the visual process. the first part of the eye is a group of fats and bones surrounding the eye to protect it. The diameter of the eye is usually 1 inch. The eye contains many parts, as shown in Figure 1 (Walls, 1944), each of which has a specific function in the vision process. The cornea,

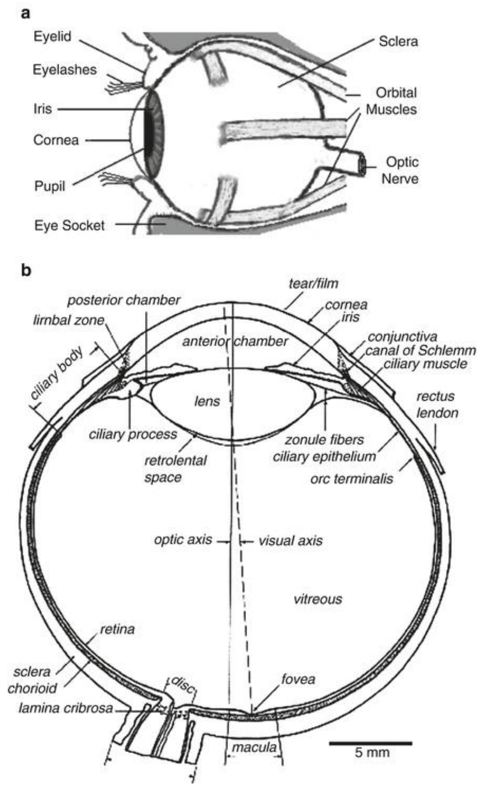

Figure 1: Parts of the eye. **(a)** In its bony orbit, the human eye's extraocular muscles are shown **(b)** an Anatomical cross-section of the eye

lens, iris, retina, and sclera work together to capture images of objects and transmit them through the optic nerve to the parts of the brain involved with vision. A group of photoreceptors that emit nervous signals when exposed to light, and these receptors are divided into two parts (cones and rods). Cones help with color vision, and rods help in seeing black-and-white images. There are also groups of eye muscles that are driven by the optic nerve. These muscles help the eye move up and down or sideways. The eye is the organ responsible for seeing, distinguishing, and detecting shapes by sending electrical signals to the brain through the optic nerve, allowing the brain to identify shapes and interpret them for the eye (*Vision: Processing Information*, n.d.).

3. The Vision Process

Vision forms when light reaches the retina; as the photoreceptor cells are activated when the light reaches the center of the retina and when it reaches the appropriate field of the light wave as follows (*Vision: Processing Information*, n.d.):

- Light passes through the cornea and lens of the eye. The cornea and the lens then work together to produce a sharp, detailed image that is received by the retina, and then the image is reflected. The reflected images are sent to the brain as electrical signals via the optic nerve.
- Visual information travels from the retina to the area responsible for vision at the back of the brain.
- The area responsible for vision in the brain contains layers of nerve cells that respond to electrical signals from the eye.
- During visual processing, the electrical signals are fed into three systems that process information according to shape, color, movement, and location.
- All images are interpreted by the brain based on movement, depth, size, shading, and color gradients.

The retina is one of the most important parts of the human eye, allowing it to see clear images in different conditions and levels of lighting. Its sensitivity to differences between lighting levels is estimated to be at a fraction of a second, and it can adapt to changes in optical energy by expanding and contracting the iris. This change must not exceed the ratio of 16:1, in the best-case scenario (عبد الرحمن, ١٩٧١).

3-1. The Precision of the Human Eye and Light Ratios

The human eye is characterized by its ability to see three-dimensional objects. This is due to the visual system of the human brain, which receives signals from the left and right eyes and interprets them as images. Any cinematographic method still represents vision with one eye, and photographers must create the illusion of dimension, depth, and colors using lighting and technological tools. The space between the cornea and lens is filled with a clear fluid known as corneal water, and the rest of the eyeball is filled with vitreous. The cornea controls the amount of light that reaches the retina through what is known as the pupil, according to the eye's need for light amounts.

The retina is the basis of the visual system that adjusts sensitivity to changes in light ratios, allowing it to catch clear images of objects in different proportions. The high sensitivity of the retina makes its response to this shift very quick, estimated at a fraction of a second, while the eye regains its sensitivity to light at a lower speed in conditions of large differences in lighting. The cornea is responsible for highlighting and focusing the light through the lens of the eye so that it falls on the retina. Adaptation allows the eye to automatically adjust focus from seeing things at a distance and to adjust it to see things in a wide range of light levels (عبد الرحمن, ١٩٧١).

3-2. Visual Receptors of the Eye and Color Translation

The retina contains several layers of arteries, veins, and nerve fibers through which light passes until it reaches sensitive layers containing two types of visual receptors: cones and rods, as shown in Figure 2 (*Why is the retina Back-to-Front?*, n.d.).

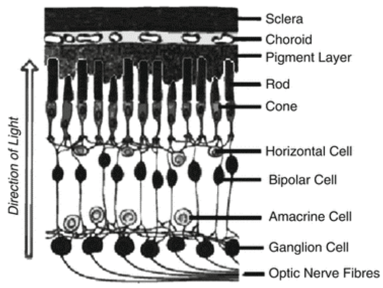

Figure 2: The structure of the retina

Photoreceptors differ in their functional characteristics, with rods controlling the retinal periphery and forming low-quality monochromatic images in the visual process, while cones control the central area and are responsible for high-quality, high-resolution colored images. The human eye can perceive colors the same way as the colors are in nature, accomplished by three receptor systems (cones) that work together to receive color. ,as shown in Figure 3 (Hesham, 2006).

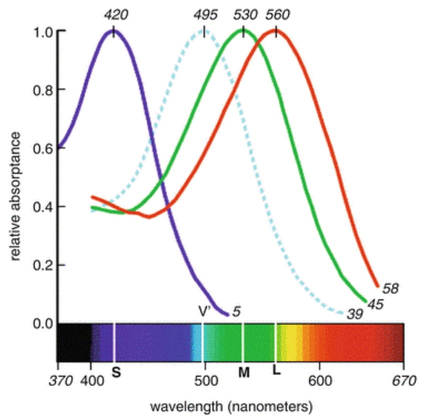

Figure 3: rods and cones sensitivity

Film imaging and display systems must adjust their spectral sensitivity to reach the spectral sensitivity curve of the three-color receiving system of the human eye to obtain images with identical colors and display them with the same accuracy and clarity. Post-production is essential for achieving a complete perceptual experience for the audience.

4. Visual Perception Experience

The process of visual perception takes place through the visual receptors in the retina. It is completed by the nerve fibers responsible for the signals of the visual system through a comprehensive and successive scan of a large area of the visual elements, which plays the role of the processor. This automatic neural scanning, scientifically called unconscious vibration, enables the eye to receive visual elements, and it is as close as possible to the progressive scanning process on which the digital image is based in reading the information and data of the photographed scene and recording it. The nervous system performs a complex process for the eye by calculating the distance from the imaged scene to the center of the retina through the sum of the height of the image multiplied by its width and in optical units of measurement for the lines of the image calculated in millimeters and units of circles' degrees. All of this is done through temporal frequencies, which are unstable neural frequencies that vary according to the levels of luminance of the visible objects, and at times ranging from 0.3 seconds to no more than 0.15 seconds so that the sensory centers of the mind can deduce the details of the movement in the image. As for the mind, it cannot distinguish and feel the fleeting periods between each scan, and the reason for this is the presence of the temporal filter in the eye, which works on integrating the visual information from one image to another, so the retina sees a continuous image of the visual information (Garharta and Lakshminarayananb, 2015).

4-1. Persistence of Vision Theory

From the preceding information, the theory of perseverance of vision emerged, which is the theory of the persistence of the effect of the image on the retina, and it was discovered in 1824 AD by Marc Rouget, who noticed that the eye takes a part of a second to record the image and transmit it to the brain and that the eye keeps the image on its retina for a period ranging from parts of the second. This important theory is what cinematic art relied on and was the basis for discovering the process of cinematography and motion recording (الصبان, ١٩٩٥).

5. Digital Display Physiology

In the process of vision from a physiological point of view, the digital display system operates through a frequency of 48 Hz (Watkinson, 2013), which is the frequency allowed by the field of the nervous system responsible for the automatic scanning process within low vision limits. This does not represent a problem related to the final viewing process, where the brightness level is determined by the screen mainly by the amount of low light, which is very effectively proportional to the human eye's ability to see details clearly in low-light areas. Therefore, the human eye is the main factor in judging the cinematic image quality during playback. By examining the boundaries between the sensory centers in the human brain and the eye, we can tell the difference in the final quality displayed. The objective of the research is to provide an explanation based on this is to make things clear about human vision perception to new technologies displays on a scientific basis.

5-1. The Difference between Pixels and Resolution

It is important to understand that there’s a difference between pixels and resolution. When looking at HD, 4K, and now 8K TVs, the higher you go, the higher the resolution, or the total number of pixels. Pixels are the individual points of light that make up a digital picture. For example, an 8K TV has 33, 177, 600 pixels. To note, the term 8K refers to the number of pixels (about 8000) displayed horizontally per line.

However, in human vision, eyes do not contain pixels. The closest comparison would be the rods and cones in your eyes that help you see. In addition, what the person resolves is the picture they can put together with their eyes and brain, not what necessarily exists in reality (*Can the Human Eye See in 8K?*, n.d.).

5-2. The Resolution of the Human Eye

Since the human eye does not see in pixels at all, it is hard to compare them to a digital display. But if we could compare the two, how many pixels would the human eye likely have? Researchers used complex math and (assuming 20/20 vision) got to 576 megapixels. 576 megapixels is roughly 576,000,000 individual pixels, so at first glance, it would seem that we could see way more than an 8K TV has to offer. But it is not that simple. For instance, we see in 576-megapixel definition when our eyes are moving, but a single glance would only be about 5-15 Megapixels (*What Is The Resolution Of The Eye?*, n.d.).

Moreover, the eyes naturally have a lot of flaws that a camera or digital screen doesn’t. For example, it has a built-in blind spot where the optic nerve meets up with the retina. It might also have a refractive error like nearsightedness or farsightedness. The person might have also been born with (seemingly) super-powered eyes, like tetrachromats: people with four cone cells in their eyes instead of three. This means they can see many more color varieties and therefore, when looking at a TV, could potentially distinguish much more than the average person.

6. Visual Acuity

It is defined as 1/a where a is the response in x/arc-minute. The problem is that various researchers have defined x to be different things. However, when the different definitions are normalized to the same thing, the results agree. Here is the problem:

Usually, a grating test pattern is used, so x is defined as cycles in the pattern. Different researchers have used a line, a line pair, and a full cycle as the definition of x. Thus, they report seemingly different values for visual acuity and resolution. It is easy to recompute the acuity to a common standard when the study defines what was used. So, when we define x to be a line pair, as is normally done in modern optics, the 1/a value is 1.7 under good lighting conditions (Konig, 1897). The acuity is 1.7 when the light level is greater than about 0.1 Lambert. A Lambert is a unit of luminance equal to 1/pi candela per square centimeter. A candela is 1/60 the intensity of one square centimeter of a blackbody at the solidification temperature of platinum. A point source of one candela intensity radiates one lumen into a solid angle of one steradian according to the photonics.

Blackwell is a scientist that derived the eye's resolution, which he called the critical visual angle as a function of brightness and contrast. In bright light (e.g., typical office light to full sunlight), the critical visual angle is 0.7 arc-minute. This number corresponds to the resolution of a spot as a non-point source. You need two pixels to say it is not a point, thus the pixels must be 0.35 arc-minute (or smaller) at the limit of visual acuity, in close agreement with the line pairs. Line pairs are easier to detect than spots, so this too is consistent. In other studies, acuity is measured in cycles per degree, 77 cycles per degree, or 0.78 arc-minute/cycle. You need a minimum of 2 pixels to define a cycle, so the pixel spacing is 0.78/2 = 0.39 arc-minute, close to the above numbers (Roger N Clark, n.d.).

6-1. Megapixels Equivalent to the Eye

The eye is not a single-frame snapshot camera. It is more like a video stream. The eye moves rapidly in small angular amounts and continually updates the image in one's brain to paint the details. We also have two eyes, and our brains combine the signals to increase the resolution further. We also typically move our eyes around the scene to gather more information. Because of these factors, the eye plus brain assembles a higher resolution image than possible with the number of photoreceptors in the retina. So, the megapixel equivalent numbers below refer to the spatial detail in an image that would be required to show what the human eye could see when you view a scene.

Based on the above data for the resolution of the human eye, let's try a small example first. Consider a view in front of you that is 90 degrees by 90 degrees, like looking through an open window at a scene. The number of pixels would be 90 degrees * 60 arc-minutes/degree * 1/0.3 * 90 * 60 * 1/0.3 = 324,000,000 pixels (324 megapixels). At any one moment, you do not perceive that many pixels, but your eye moves around the scene to see all the detail you want. But the human eye sees a larger field of view, close to 180 degrees. Let's be conservative and use 120 degrees for the field of view. Then, we would see 120 * 120 * 60 * 60 / (0.3 * 0.3) = 576 megapixels. The full angle of human vision would require even more megapixels. This kind of image detail requires a large format camera to record (Roger N Clark, n.d.).

6-2. The Sensitivity of the Human Eye (ISO Equivalent)

At low light levels, the human eye integrates for up to about 15 seconds (Blackwell, 1946). The ISO changes with light level by increasing rhodopsin, which is the light receptor in rod photoreceptor cells of the retina, that plays a central role in phototransduction and rod photoreceptor cell health. This process takes a half hour to complete, and that assumes you haven't been exposed to bright sunlight during the day. Assuming you wear sunglasses and adapt well to darkness, you can see faint stars away from the city. Based on that, a reasonable estimate of the darkness-adapted eye can be done.

In an exposure test done with a Canon 10D and 5-inch aperture lens, the DSLR can record magnitude 14 stars in 12 seconds at ISO 400. You can see magnitude 14 stars in a few seconds with the same aperture lens (Clark, 1990). So, we would estimate the darkness-adapted eye to be about ISO 800.

Note that at ISO 800 on a 10D, the gain is 2.7 electrons/pixel which would be like the eye being able to see a couple of photons for a single detection. During the day, the eye is much less sensitive, over 600 times less, which would put the ISO equivalent at about 1 (Roger N. Clark, n.d.).

6-3. The Dynamic Range of the Eye

The Human eye can function in bright sunlight and view faint starlight, a range of more than 100 million to one. In any one view, the eye can see over a 10,000 range in contrast detection, but it depends on the scene brightness, with the range decreasing with lower contrast targets. The eye is a contrast detector, not an absolute detector like the sensor in a digital camera, thus the distinction. The range of the human eye is greater than any film or consumer digital camera.

7. The Analogy between the Human Eye and Digital Resolution of Projection of Cinematic Image

A survey was conducted by asking several experts such as electrical engineers, directors of photography, and ophthalmologists. The conclusion of the knowledge they provided can be summarized in the following points.

7-1. Numbers of Pixels for a Human Eye

On most digital cameras, you have orthogonal pixels: they are in the same distribution across the sensor (nearly perfect grid), and there is a filter (usually the "Bayer" filter, named after Bryce Bayer, the scientist who came up with the usual color array) that delivers red, green, and blue pixels.

So, for the eye, imagine a sensor with a huge number of pixels, about 130 million. There is a higher density of pixels in the center of the sensor, and only about 6 millions of those sensors are filtered to enable color sensitivity, with only about 100,000 senses for blue. This sensor is not made flat but semi-spherical so a very simple lens can be used without distortions. Real camera lenses must project onto a flat surface, which is less natural given the spherical nature of a simple lens, while better lenses usually contain a few aspherical elements.

This is about 22 mm diagonal on average, just a bit larger than a micro four-thirds sensor. But the spherical nature means the surface area is around 1100 mm^2, a bit larger than a full-frame 35 mm camera sensor. The highest pixel resolution on a 35 mm sensor is on the Canon 5Ds, which stuffs 50.6 Megapixels into about 860 mm^2.

But the hardware is not the limiting factor on effective resolution. The eye seems to see "continuously", but it is cyclical, there is kind of a frame rate that is fast. The eye is in constant motion from ocular microtremors that occur at around 70-110 Hz. Your brain is constantly integrating the output of your eye as it's moving around into the image you perceive, and the result is that, unless something is moving too fast, you get an effective resolution boost from 130 Megapixels to about 520 Megapixels, as the image is constructed from multiple samples.

However, your luminance-only rod cells, being sensitive to low light, saturate in bright light. So, in full daylight or bright room light, they are completely switched off. That leaves you about 6 million cone cells alone as your only visual function. With microtremors, you may have about 24 million inputs at best, not the same as 24 Megapixels, per eye, equivalent to 48 Megapixels in comparison.

In the dark, the cones don't detect much, it is all rods at that point. Technically this is more pixels, but your eye and brain are dealing with a low photon flux density, the same thing that causes ugly “shot noise” in low-light photographs. So, your brain is only getting input from rods that detect things.

All the 130 million sensors are wired down to about 1.2 million axions of the ganglion cells that wire the eye to the brain. There is already processing and crunching on your visual data before it gets to the brain.

Our brains can deal with this kind of problem as parallel processors with performance comparable to the fastest supercomputers we have today. When we perceive an image, there is this low-level image processing, plus specialized processes that work on higher-level abstractions. For example, we humans are good at recognizing horizontal and vertical lines, while frogs have specialized processing in their relatively simple brains looking for a small object flying across the visual field. We also do constant pattern matching of what we see back to our memories of things. So, we don't just see an object, we instantly recognize an object and call up a whole library of information on that thing we just saw.

Another interesting aspect of our in-brain image processing is that we don't demand any resolution. As our eyes age and we can't see as well, our effective resolution drops, and yet, we adapt. In the relatively short term, we adapt to what the eye can see, and we can experience this at home. Spending lots of time in front of Standard Definition television is one such experience. Our brain could have adapted to the low quality of NTSC television or PAL television, and then been exposed to VHS, which was even worse than what you could get via broadcast. When digital started, between Video CDs and early DVRs like the TiVo, the quality was low, but if you watched lots of it, you stopped noticing the quality over time. An HDTV viewer of today, going back to those old media, will be disappointed, mostly because their brain moved on to the better video experience and dropped those bad-TV adaptations over time.

For multi-sampled images, in low light, many cameras today can average several different photos on the fly, which boosts the signal and cuts down on noise. Your brain does this too in the dark. We are even doing the microtremor thing in cameras. The recent Olympus OM-D E-M5 Mark II has a "hires" mode that takes 8 shots with 1/2-pixel adjustment, to deliver what is essentially two 16 Megapixels images in full RGB (because full pixel steps ensure every pixel is sampled at R, G, B, G), one offset by 1/2 pixel from the other. Interpolating these interstitial images as a normal pixel grid delivers 64 Megapixels, but the effective resolution is more like 40 Megapixels, still a big jump up from 16 Megapixels. Hasselblad showed a similar thing in 2013 that delivered a 200 Megapixels capture, and Pentax is also releasing a camera with something like this built in.

We are doing simple versions of the higher-level brain functions, too, in our cameras. All kinds of current-model cameras can do face recognition and tracking, follow-focus, etc. They are nowhere near as good at it as our eye/brain combination, but they do well for such weak hardware.

7-2. Comparison between Human Eye and Camera

If the human eye were converted to a camera, how many megapixels would its resolution be? It is 576 Megapixels. By seeing how the human eye compares to digital imaging, the following parameters can be deducted:

Human Eye Specifications (typical):

- Sensor (Retina): 22 mm diameter x 0.5 mm thick (section); 10 layers.
- Resolution: 576 Megapixels equivalent.
- Visual Acuity: ~ 74 Megapixels (printed) to show detail at the limits of human visual acuity.

- ISO: 1 - 800 equivalent.
- Data Rate: 500,000 bits per second without color or around 600,000 bits per second including color.
- Lens: 2 lenses – 16 mm & 24 mm diameter.
- Dynamic Range - Static: contrast ratio of around 100:1 (about 6 1/2 f-stops) (4 seconds).
- Dynamic Range - Dynamic: contrast ratio of about 1,000,000:1 (about 20 f-stops) (30 minutes)
- Focal Length: ~ 3.2 mm - (~ 22 mm 35 mm equivalent).
- Aperture: f2.1 - f8.3 (f3.5 dark-adapted is claimed by the astronomical community).
- FOV Field of View: 95° Out, 75° Down, 60° In, 60° Up.
- Color Space: 3D (non-linear) RGB.
- Color Sensitivity: 10,000,000.
- Color Range: 380 to 740 nm.
- White Balance: Automatic (constant perceived color under different lighting).
- Refresh Rate: foveal vision (high-quality telescopic) - 3-4 fps; peripheral vision (very inaccurate) - up to 90 fps.

Compiling this creates some very big assumptions, as many of these are interrelated to the brain's processing of the eye's signals. While the above statistics are factual, presenting them as a direct apples-for-apples correlation to common camera specifications is probably fraught with inconsistencies.

7-3. The Difference between 4K and 8K and Their Perception by the Human Eye

- This chart below should help you decide if someone with 20/20 vision can tell the difference between a 4K TV and an 8K TV at a particular viewing distance and TV size. Note, this assumes you have 20/20 (or corrected vision).
- It depends on how big the screen is and how close you are to the TV, but in most cases no. 4K is already more detail than most humans can perceive at a reasonable viewing distance.
- The 8K screen would have four times the number of pixels vs. the 4K. Whether this results in a perceptible difference would depend on the screen size and viewing distance. For most typical home situations, it would be unlikely to be a significant difference.
- It is dependent on screen size and viewing distance.

However, there are other things to consider. More pixels allow greater control for not only color reproduction but also contrast, being more important for video content than a still image. In addition, some people have vision better than 20/20. Anytime there is supposed to be a smooth gradient of color, like a sunset. On 1080p, you can easily see transitions in some content, in 4K it is much more difficult to tell. 8K may solve that issue completely.

7-4. Benefits of Increasing Resolution from Human Perspective

Now, the bigger your screen (or the more it fills your field of view) the more likely you are to notice 4K, so many argue that 4K is needed if you have a big screen TV. Well, most movies shown in theatres nowadays are still only shown in 2K, which is just slightly higher resolution than 1080p and less than half the resolution of 4K. (Four of 2022 top 5 biggest grossing blockbusters so far -Beauty and the Beast, Wonder Woman, Spiderman: Homecoming, and It- were all distributed in 2K. Native 4K copies of these movies don’t even exist). With the right content and viewing setup, a resolution increase of over 1080p is noticeable. However, anything beyond 4K would likely make no difference to the human eye in the vast majority of home theatre setups.

The chart in Figure 4 shows the viewing distances relative to TV sizes where most people would be able to perceive the higher resolution.

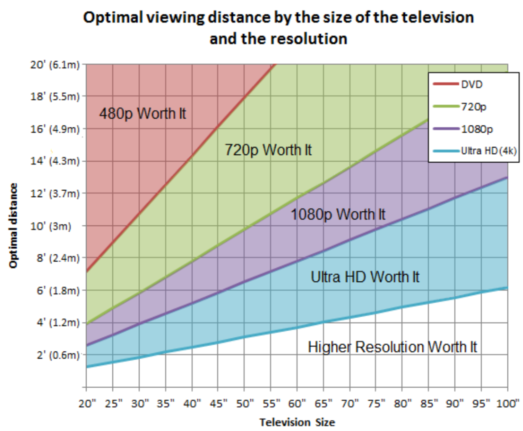

Figure 4: Relation between TV size and distance of the viewer

Taking into consideration only the resolution, 4K's biggest benefit is its color definition. High Dynamic Range (HDR) refers to the expanded color information encoded into the new format. The pixels in a standard 1080p signal can be any one of 16.7 million colors. Humans are capable of seeing more color definitions than that. The new HDR standard for 4K UHD signals allows for over 1 billion colors to be defined, which means that highlights and shadows can have more detail, and colors can generally be more vibrant and/or more accurate. This is where the majority of people will notice the difference; the colors on a 4K HDR TV will look more impressive and life-like, regardless of the viewing distance or screen size.

When watching a 50″ TV from a distance of < 8ft, that 4K content is way more lifelike than 1080p - and this is from compressed videos on streaming platforms (Netflix, Prime Video, etc.).

7-5. The Need for UHD Televisions

There is a need for UHD televisions, in addition to the resolution boost talked about above. The HDTV standard is defined by Rec. 709. All the pieces of technology in the HDTV pipeline follow this spec. UHD is defined by Rec. 2020. The color gamut defined by Rec 709 is small, and most LCDs can get away with 6-bit (18bpp) color, UHD's color gamut requires 12-bit (36bpp). Rec 709 defines frame rates up to 60fps. Rec 2020 defines framerates up to 120fps. (Framerate makes a bigger difference to perceived viewing quality than resolution.) Rec 2020 also gets rid of interlacing, an artifact left over from analog television.

8. Alternative Digital Cinema Platforms

Alternative digital cinema platforms are sites or applications that began to appear in the early 2000s and contain libraries of movies and series, whether these productions were produced by the company that owns the application or the app acquired the rights to display them from the original production companies. The subscriber can, for a monthly or annual subscription, watch these materials without restriction during the validity period of the subscription. These sites are considered an alternative to movie theaters and terrestrial and satellite television channels. At the beginning of 2007, major film production companies began to transfer their work to display and broadcast through their platforms. Some of these platforms set minimum requirements for production for any cinematic work shown Through the platform to ensure a high-quality perceptual experience for the viewer through television screens.

The development is taking place in the technical aspect of the film industry, specifically in the sector of cameras and their supplies and accessories. Also, with the development of presentation and coloring methods and other post-production techniques, broadcasting and display companies needed to determine what is acceptable and what is rejected based on the technical aspect of some filmmakers and studios. Their choice of camera is usually based on the number of pixels without conducting any controlled tests to see if there are any other aspects on which the final image quality of the display depends. Other factors like the quality of the sensor itself, noise, color path, contrast, selection of work resolution, adjustment ratio, and measurement.

Netflix is the first alternative viewing platform widely spread among digital platform viewers by 61%, as shown in Figure 5. According to a conducted survey, Netflix has allocated development laboratories in which cameras and various capture technologies are

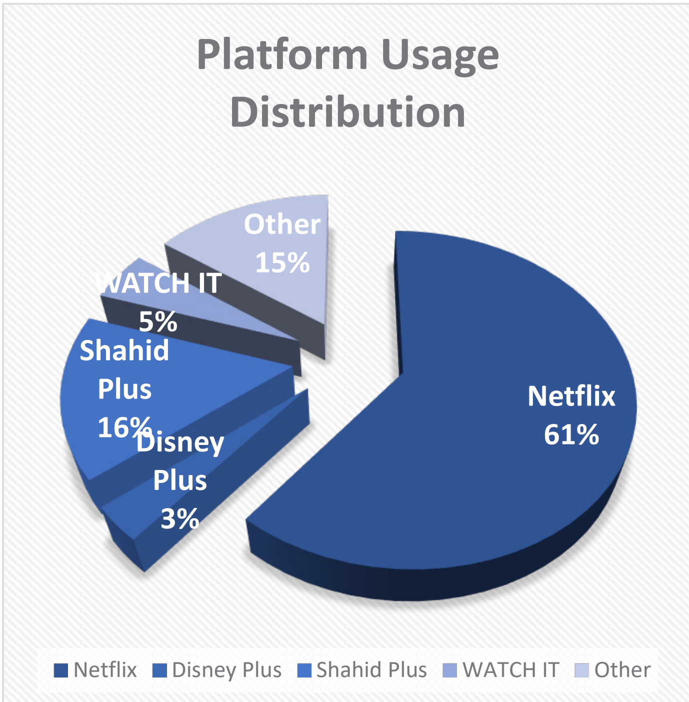

Figure 5: Most used digital platforms in Egypt, according to a survey conducted by the researcher

evaluated for possible inclusion in their list of approved cameras. The development of camera specifications for online platforms and the list of cameras approved by Netflix as a case study for controlling technologies in picture quality intended for viewing on alternative platforms.

9. Netflix

In the Age of Netflix: Critical Essays on Streaming Media, Digital Delivery and Instant Access, Barker and Wiatrowski (2017) note the change in user behavior on digital platforms:

"From the rise of binge-watching and password-sharing to intermittent debates about spoiler etiquette and how critics should cover programs that are released all at once, Netflix is the central force in the contemporary experience of media consumption" (Barker and Wiatrowski, 2017).

One of the most known video-on-demand platforms is Netflix. Founded in 1997, Netflix brought a new form of cinema experience to mass audiences. Once started as a DVD home delivery it is nowadays a preferred viewing system for television programs, movies and documentaries. The experience that Netflix offers which makes it different from other video-on- demand platforms is the "immersion experience". This model brought about a huge change in viewer consumption habits.

Exclusive arrangements with filmmakers were a strategic move for Netflix in order to produce high quality video content. In a break from traditional cinema production, with a common misconception is that explicit capture is the only requirement for cameras to enter the platform's approved camera list. While capturing at a higher resolution is vital to obtaining a higher-quality image, there are other aspects to focus on other than resolution. One of the essential attributes considered is the resolution of the image produced by the camera system and other parameters that are vital to image quality as:

- Dynamic range: the difference between the higher and lower values in an image, the contrast between light and dark. Paying attention to the dynamic range of the camera, whether it is increasing or decreasing, controls the amount of detail displayed in the final image.
- Color reproduction: A term used to describe how the image is managed between the camera and final delivery. Accurate color reproduction of the cinematic image displayed across platforms is difficult due to issues including changing viewing conditions.
- Color management is a term used to describe how an image is managed between camera and rendition. Moreover, appropriate color management means that the color has been captured and preserved with the highest quality and accuracy throughout the production and post-production process, which increases the possibility of preserving the appearance of innovative content during the production process, leading to the service provided by the display platform. Therefore, explicit capture is not the only responsible factor. The final display quality, but rather the path of the color image and the exact color translation during the display, are among the most critical factors responsible for the correct perception of the quality of the image.
- Noise: Image noise is unwanted fluctuations in color or brightness that obscure details in a shot. Knowing its causes and how to identify it can provide final, high-quality images for presentation.
- Compression: It is a type of data compression applied to a digital cinematic image. The compression method affects the visual perception and visual properties of the image data.
- Chroma subsampling: Chroma subsampling is a type of compression that reduces color information in a signal in favor of luminance data. This reduces bandwidth without significantly affecting image quality.
- Bit depth: Bit depth refers to the color information stored in the image. The higher the bit depth of the image, the more colors it can store. The simplest image, a 1-bit image, can only show two colors, black and white. As the bit depth increases, the image quality also increases because more color information is stored for each pixel in the image.

All these parameters are based on years of feedback from filmmakers and users as well. Furthermore, Netflix emphasizes that it's working with the camera manufacturers in order to ensure that every camera is being tested correctly to ensure the high quality of the final image delivery regardless of the display medium. Netflix also states that image quality is not everything. Other not-less-crucial factors are related to the camera's stability, reliability, and robustness to allow intensive usage during professional productions. These factors include proper thermal management (is it going to over-heat on a professional film-set?), the reliability of the media (to prevent data loss), NLEs support of the chosen codecs, file structure, fitting metadata, timecode implementation, and more. All of this information is calculated to determine the approval of the camera (*Cameras & Image Capture: Requirements and Best Practices*, n.d.).

10. Conclusions

The 4K technology does not determine the image's resolution, but only the number of pixels it contains, to determine whether the details in the image will be beyond the ability of the eye to resolve them (that is, its spatial sharpness). The 4K image's size and the distance at which it is displayed should also be specified. The human eye's acuity limit is about 60 cycles/degree, but this is only true in the center of the field of view. In contrast, outside this relatively small area, eye acuity decreases significantly. On digital platforms, the camera system is subjected to high-accuracy tests with specialized equipment to measure image performance and all criteria required to achieve an image quality as close to the theatrical display image as possible. Furthermore, it preserves electronic image data regardless of the display medium, such as television, computer, or telephone.

11. References

1. Barker, C. and Wiatrowski, M. (2017) *The age of Netflix: critical essays on streaming media, digital delivery and instant access*. McFarland.
2. Blackwell, H.R. (1946) 'Contrast thresholds of the human eye', *Josa*, 36(11), pp. 624–643.
3. *Cameras & Image Capture: Requirements and Best Practices* (n.d.). Available at: https://partnerhelp.netflixstudios.com/hc/en-us/articles/360000579527-Cameras-Image-Capture-Requirements-and-Best-Practices (Accessed: 12 January 2023).
4. *Can the Human Eye See in 8K?* (n.d.). Available at: https://www.lasikmd.com/blog/can-the-human-eye-see-in-8k (Accessed: 12 January 2023).
5. Clark, R.N. (1990) *Visual astronomy of the deep sky*. CUP Archive.
6. Clark, Roger N (n.d.) *Notes on the Resolution and Other Details of the Human Eye*. Available at: https://clarkvision.com/imagedetail/eye-resolution.html (Accessed: 12 January 2023).
7. Clark, Roger N. (n.d.) *The Signal-to-Noise of Digital Camera images and Comparison to Film*. Available at: https://clarkvision.com/articles/digital.signal.to.noise/ (Accessed: 12 January 2023).
8. Garharta, C. and Lakshminarayananb, V. (2015) 'Anatomy of the Eye'.
9. Hesham, G. (2006) *التكنولوجيا الرقمية في التصوير السينمائي الحديث: Digital cinematography*. Academy of Arts, Giza.
10. Konig, A. (1897) 'Die Abhangigkeit der Sehscharfe von der Beleuchtungsintensitat', *Acad. Wiss. Sitz*, 35, pp. 559–575.
11. *Vision: Processing Information* (n.d.). Available at: https://www.brainfacts.org/thinking-sensing-and-behaving/vision/2012/vision-processing-information. (Accessed: 12 January 2023).
12. Walls, G.L. (1944) 'The vertebrate eye and its adaptive radiation'. LWW.
13. Watkinson, J. (2013) *The art of digital video*. Routledge.
14. *What Is The Resolution Of The Eye?* (n.d.). Available at: https://www.youtube.com/watch?v=4I5Q3UXkGd0&ab_channel=Vsauce (Accessed: 12 January 2023).
15. *Why is the retina Back-to-Front?* (n.d.). Available at: https://catalase.com/retina.htm (Accessed: 12 January 2023).
16. الصبان, م. (١٩٩٥) *فن المونتاج فى الدراما التليفزيونية*. General Egyptian Book Organization.
17. عبد الرحمن, س. (١٩٧١) *السينما الملونة*. Cairo University Printing Press.