X – The Man with the X-Ray Eyes
or
X-Rayted Roger Corman

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Submitted for your approval

Brief synopsis
In this 1963 American International Pictures film by Roger Corman, Dr. James Xavier develops a reagent that can expand the range of human vision and he uses it on himself. This gives him the ability to see through objects and to make non-invasive medical diagnoses. His brain cannot properly process the visual overstimulation which drives him mad and he eventually plucks his eyes out.

The screenplay is by Robert Dillon and Ray Russel with the story by Ray Russel. This movie is filmed in what the producer calls “spectarama” to suggest enhanced visual effects which in reality amounted to blurry images of off-color registers. At the core of this film are the electromagnetic spectrum, vision, and how sight can be expanded.

Eye tests
At the beginning of the film Dr. James Xavier (Ray Milland) undergoes an eye exam and the results appear to be normal. A colleague, Dr. Sam Brant (Harold Stone), asks, “What makes you think your eyes have changed in three months?” Xavier replies, “Nothing. Nothing yet.” Brant sensing what comes next says, “You’re planning to experiment on yourself.”

Ride the wave
Xavier asks, “Sam, what is the range of human vision?” Sam responds, “Between 4,000 angstrom units and 7800 angstrom units.” [note: an angstrom is one ten-billionth of a meter]. Xavier replies, “Less that one tenth of the actual wave spectrum…What would we really see if we had access to the other 90%?...we are virtually blind, all of us…I’m blind to all but a tenth of the universe.” Sam responds, “Only the gods see everything” to which Xavier reveals, “I’m closing in on the gods.”

The electromagnetic spectrum (see below) is measured in logarithmic scale and is 25 logs from low to high so “less than one tenth” would be about 2 logs of the spectrum. The visible light spectrum, a small portion of the entire electromagnetic spectrum, represents no more than 2/5ths of *one* log so Xavier’s comment is essentially off by over 2 logs! Also, the “other 90%” represents about 23 logs of the spectrum so a significant portion is indeed missed.

Lab layout

Xavier's lab is well equipped. There are tile walls for easy cleaning, several cluttered benches with many instruments, copious glassware, monkey bar set ups holding flasks of multi-colored liquids (all fake), animal cages for rabbits and monkeys, the proverbial lit Bunsen burner (in one scene Xavier uses it to light a cigarette; unforgiveable, smoking in the lab!!), and an overly simple underserved monocular microscope. All in all a busy and reasonably cluttered biomedical lab.

In Xavier's lab in one foretelling scene he and a colleague, Dr. Fairfax, were discussing various ways to interpret x-ray images noting the relative guess work involved in seeing what the images are and what they reveal. They commented on the short comings of x-rays since front and side images can reveal different information and therefore different interpretations. All of this is true.

In further describing his work to Fairfax, Xavier comments, "Light. Waves of energy that excite the eye. And the nerve cells transmit this energy to the brain. And with the brain, we see. There are other forms of energy with different wavelengths." Then Xavier continues, "Dr. Fairfax, I'm developing a way to sensitize the human eye so it sees radiation up to and including gamma rays and the meson ray." This means Xavier is focusing on the high frequency, short wavelength region of the electromagnetic spectrum (see below).

[Note: mesons are subatomic particles composed of one quark and one antiquark bound together and about 1.2 times the size of a proton. Mesons are very unstable and last only a few hundredths of a microsecond. Mesons decay to form electrons and neutrinos (charged) or photons (uncharged). Mesons appear in nature when cosmic rays of very high energy collide with ordinary matter. As such there is no such thing as a 'meson ray'.]

Eye dropped it

The purpose of eye drops is to deliver a liquid medication to the *outside* of the eye, typically to the cornea, iris, and/or lens. Most eye drops are used for redness, allergies and itching, dryness, infections, glaucoma, and inflammation. Large molecules like proteins cannot penetrate the eye. Other molecules, like steroids, also poorly penetrate the eye surface so if administered they would, like proteins, simply wash down your cheeks. The inside of the eye where the retina is located is a privileged site meaning very limited biological access so most drugs, even those in eye drops, will not affect the retina surface.

In the lab Xavier has an eye dropper bottle of his reagent commenting, "These are hormones, enzymes, their molecular structures have been slightly altered…This compound, when used in the eye, increases receptivity. The sensitivity is enormously increased." We have to ask which hormones (protein? steroid?) and which enzymes? What is the function of the enzymes? "Slightly altered" can mean many things, functional or structural or both, so this too is

unclear. How are the hormones and enzymes prepared? Are they synthesized, manufactured, obtained commercially, or needed to be made or extracted from biological sources? Does the reagent have a shelf life? And since the drops go onto the eye then sterility of the reagent is important to prevent any eye problems or diseases. Lastly, how does Xavier know his reagent can significantly increase vision receptivity. What tests did he perform to establish this?

Monkey see, monkey do

To test his reagent Xavier places a drop in each eye of a monkey. What this means is the same "hormones and enzymes" would also work in a monkey. Therefore, the biological molecules that are in the reagent are generic and able to work on species other than human.

After the monkey receives the eye drops his vision is tested. At first the drops allow the monkey to see through a cardboard shield. Xavier comments. "He sees through them (cardboard shield) as if they were glass." Soon after the monkey dies and the subsequent autopsy is normal. Regarding the death of the monkey Xavier theorizes, "Heart failure…shock…It couldn't comprehend or adjust to what it saw or saw through."

Eye-mazing results

Fairfax asks Xavier, "How can you use your new vision?" Xavier responds, "There are thousands of ways…in this hospital there are people I can help. Help by seeing inside them as if they were windows. By seeing their sicknesses with a clarity that would make x-rays a tool only fit for witchdoctors."

It should be noted that the current non-invasive, non-radioactive technology of ultrasound, magnetic resonance imaging (MRI), and Positron Emission Tomography (PET) are just as good as what Xavier can do in ability to see internally.

Not a dry eye in the house

Xavier decides to try his reagent on himself so his colleague, Brant, places one drop into each of Xavier's eyes. It is noted that some of the liquid washes down Xavier's cheeks so the actual delivered biological dose is unknown. After about 10 seconds he opens his eyes. Already his vision has changed to "spectarama" mode suggesting an immediate response. Xavier comments, "It's like a splitting of the world. Vision is fragmented. More light than I have ever seen. Filled with light."

Xavier sees a report under a piece of paper and comments, "I can see through it…right through it…It works!...I have still just penetrated the surface. My eyes have not conditioned yet." Xavier then adds another drop to each eye which subsequently made him unconscious.

The report Xavier sees through the paper is about his eye drops and is titled, "The exact combination of hormones and enzymes is to be determined by analysis" with a subheading of "Report of Multicellular non-Chordates". Under that on the same page are the first biochemical reactions of glycolysis, the metabolic process that breaks down glucose to use and store as cellular energy. The first step of glycolysis is the "activation" of glucose which is shown by the first line of the subsequent text on that report:

Glucose + ATP --------> glucose-6-phosphate + ADP
(hexokinase)

Note: Chordate is a large animal phylum containing all vertebrates, including humans. Non-chordates, as stated in the above report, are just about everything else in the animal world and are noted for not having a spinal cord (e.g., worms & insects) so what this has to do with Xavier's eye drops is not clear. Furthermore, the metabolic steps of glycolysis are in all life forms, from bacteria to humans, so what this has to do with Xavier's eye drop reagent is also unclear.

Eye see you

After some time Xavier can now see through cloth and therefore clothes. "It works! It works!", shouts Xavier and further observes, "My eyes are still not conditioned yet", meaning his brain has yet to fully process all the extra visual input of information. He continues the medication and places one more drop in each eye when he then experiences pain and becomes unconscious. His brain shut down from the over stimulation.

In the hospital recovering from being unconscious Xavier has his eyes covered. When mentioned, Xavier comments, "Bandages (over eyes)? Hardly noticed them at all", demonstrating he can easily see through cloth.

The eyes have it

The effects of the eye drops appears to be slow acting and accumulative. Biology takes time and Xavier's brain is continuously readjusting to the input of new wavelengths. His eyes 'see' but his brain cannot yet fully assimilate, process, and comprehend what he is seeing. At one point as a result of the over active brain processing, Xavier comments, "Just a temporary headache."

Early on Xavier's x-ray ability is unsteady and appears to change. Sometimes he can see through skin and see through clothes. Other times he cannot. He now calls his ability the 'X-effect'. To help protect his X-effect vision Xavier wears sunglasses the purpose of which must to be to eliminate some visible or UV light

wavelengths since such sunglasses will not block out higher frequency radiation like x-rays or gamma rays.

Wrong diagnosis

To prove the usefulness of his new eye sight Xavier approaches a young girl who was diagnosed with a cardiac stenosis and uses his x-ray capabilities in an attempt to confirm the diagnosis. After focusing his concentration Xavier realizes the original diagnosis of stenosis is wrong and comments, “a tumor directly in the oracle attached to the valve”, as the new diagnosis. Apparently, Xavier has some control and has the ability to “turn on” x-ray sight at will so he can use it on the girl.

As a result of Xavier’s ability to see inside the girl the operation was changed. “I can see the heart, lungs, the internal structures (of the girl) quite clearly”, says Xavier. The operation is a success. “You see, no stenosis”, boasts Xavier.

[Note: A stenosis is an abnormal narrowing in a blood vessel usually caused by a lesion that restricts blood flow such as that seen with atherosclerosis. The term, stenosis, is from Ancient Greek στενός, "narrow". Restenosis is the recurrence of stenosis after a procedure.]

Dangerous X-periment

Fairfax tells Brant, “He’s been using the drug again.” Xavier says, “It persists. The effect is accumulative. I see veins, organs, the blood rushing through your heart.” Then he says, “the vision comes and goes” which suggests he does not yet have full control of the effect. Fairfax expresses concern saying, “There must be some way to regulate it.”

Xavier’s mind is also affected and has new found mental energy. He yearns with, “Power to learn, to create”. Brant is also concerned and questions, “Who knows what other parts of your mind are affected by this thing.” Brant and Xavier quarrel and by accident, Brant falls out a window to his death. Fairfax, who observed the accident says, “They (the authorities) will think you insane.”

Mentalo the Healer

Xavier escapes the hospital and ends up at a carnival where he is disguised as a mind reading act titled, “Mentalo”. Fellow carny worker, Crane (Don Rickles), describes Mentalo as, “the man with the miraculous mind’.

At the carnival Xavier reports, “I use only the smallest amounts (of the drops) now but the affect seems to be accumulative.” He can now see through tissue to bone. To demonstrate his abilities he examines a woman who fell off a carnival ride and sees a broken leg and two broken ribs. The comment is made that Xavier “Has power to see inside.” Crane says, “You are a healer of the sick”. Xavier tersely responds, “I can’t heal. I only look. I tell what I see.” Therefore, like he did with the young girl above Xavier has the ability to make an internal

diagnosis based on what he sees. Crane eventually convinces Xavier to use his abilities to diagnose people's health issues.

Eye didn't do it

Xavier talks into a tape recorder: "The effects of the compound are still unpredictable. At times I can see through walls, through stone, just as easily as I can see through the air. At other times I can hardly penetrate the first layer of a man's skin." With his eyelids open or closed it no longer matters with Xavier's constant use of his eye drops since he can easily see through his thin eyelids. It should be noted that with eyelids closed then incident visible light wavelengths will most likely be blocked. However, for shorter wavelengths such as x-rays and perhaps gamma rays it would not be a problem for eyelids since, open or closed, the rays would penetrate.

Eye don't believe it

Crane arranges for Xavier to see many people to make a diagnosis about their health. Patients are astonished that Xavier can see inside them. As Xavier further describes from seeing patients, "The X-effect is intermittent, comes and goes…sometimes double, sometimes triple…I close my eyes and I can still see through my eyes." To further support this, when Xavier takes off his sunglasses, he says, "makes it worse". Then, "I'd give anything to see dark."

Through the constant use of the eye drops Xavier's range of vision greatly expands and he now sees through wood and metal. He describes the skeletal structures of buildings as "fingers of metal". He continues with, "Flesh dissolved in flashes of light", further demonstrating his expanded range of vision.

Beating the Odds

Xavier decides he needs a lot of money to help fund his research and perhaps find a way to fix his eyes. He and Fairfax go to Las Vegas and he uses his x-ray ability to win at gambling. While in Las Vegas all the bright multi-colored marquee lights cause him pain since his brain cannot effectively process all the incoming information. Via spectarama we see many blurry images with multi-colored off-registered hues. Due to the increase of vision range Xavier has difficulty focusing and establishing a depth of field. Light color has certain wavelengths and the lights he sees are all blurry with no plane of focus suggesting the wavelengths randomly come and go. This implies his brain cannot yet effectively process all the new incoming visual imput so everything is out of focus.

As a countermeasure Xavier now wears apparently stronger wraparound sunglasses. These sunglasses are intended to block all incident light filtered by their lenses which begs the question which wavelengths do they block?

Xavier keeps adding more drops to his eyes which suggests the drops no longer have the original results and maybe Xavier is becoming addicted and needs a

bigger “fix” to continue the effects. Fairfax says, “You’ve taken the drug again.” Xavier replies, “I had to. The effect of the drug is wearing down.”

To win money Xavier first approaches slot machines and “sees” one ready to pay off. With the winnings he goes to a card table and can easily see through the cards to win more money. For the cards he would need to be able to control selective depth that penetrates just enough to see behind just one card instead of several (or completely through to the floor!). This suggests that Xavier now has some control of his extra vision range meaning his brain can now effectively process the incoming visual stimulation.

Due to the overuse of the eye drops Xavier has a mental breakdown. In a scuffle his sunglasses are knocked off revealing a black cornea and the pupil has a metallic look. Therefore, the cumulative effect of the eye drops is to alter the surface of the cornea, as well as the structure of the iris, pupil, and possibly the lens.

Revival meeting. Seeking Salvation.
As a result of his mental breakdown Xavier steals a car, eventually crashes it while escaping Las Vegas, and ends up at a revival meeting. From the pulpit the Minister quotes from the Bible, “Said Matthew in Chapter 5, ‘If thine eye offends thee, pluck it out’”. From that biblical reference (Matthew 5) the actual quote is, “And if thy right eye offend thee, pluck it out” (Matthew 5: 29-30). The actual quote used by the Minister in the film, “And if thine eye offends thee, pluck it out”, is from Matthew 18:9.

Due to the constant use of the eye drops Xavier’s eyes have kept changing and at the end of the film his eyes are completely black with no visible iris. Heeding the words of the Minister Xavier does indeed pluck his eyes out.

Electromagnetic spectrum
The electromagnetic spectrum is the range of frequencies of electromagnetic radiation and their wavelengths and photon (light particle) energies. This spectrum encompasses frequencies ranging from below one hertz to above 10^{25} hertz. This incredible 25 logarithmic range includes wavelengths from thousands of kilometers long down to a fraction the size of an atomic nucleus. This frequency range, from low to high, is broadly divided into separate bands each given different names:

1. Gamma radiation
2. X-ray radiation
3. Ultraviolet radiation
4. Visible radiation
5. Infrared radiation
6. Terahertz radiation

7. Microwave radiation
8. Radio waves

This classification goes in the increasing order of wavelength, which is characteristic of the type of radiation so the shortest wavelength, highest frequency, is gamma radiation whereas the longest wavelength, shortest frequency, is radio waves.

When electromagnetic waves interact with any matter the wavelength is decreased which can then be measured. Electromagnetic waves are produced whenever any charged particles are accelerated and these waves can then interact with other charged particles. Quanta of electromagnetic waves are called photons which are bits of light.

Eye-o-nizing radiation

Each one of the separate electromagnetic spectrum bands has different characteristics which influences how they interact with matter. Gamma rays, x-rays, and high ultraviolet are classified as ionizing radiation since their photons have enough energy to ionize atoms which in turn can cause chemical reactions. Over exposure to these rays can result in health issues such as radiation sickness and cancer. Lower wavelengths, such as visible light and radio waves are non-ionizing radiation and have no health risks. Gamma ray photons have the highest energy while radio wave photons have the lowest. On Earth life exists in an aquatic environment and water blocks out most of the windows of the electromagnetic spectrum which does limit sight.

There are many techniques that can separate the various wavelengths along the electromagnetic spectrum. The most common is called spectroscopy that can physically separate waves of different frequencies. Since the behavior of electromagnetic radiation depends on its wavelength then spectroscopy can be used to measure this difference.

Optical density

The optical density of any substance is a ratio of transmitted light to the incident light passing through the substance. When any type of electromagnetic radiation hits the surface of any material there is also some reflected in addition to that which penetrates. Another word for optical density is index of refraction. Simply stated, what gets absorbed and what passes through. Refraction is the bending of light as it passes through any substance whereas absorbance is a measure of the capacity of a substance to absorb light of a specified wavelength.

What factors affect visible light as it passes through any substance? On a molecular scale atoms absorb electromagnetic wave energy in the form of vibrating electrons so the more optically dense any substance is the slower the wave will move through the substance (compare light passing through optically dense steel and light passing through opaque water). The optical depth of

penetration of any incident electromagnetic wave through a substance depends upon the frequency of the radiation. How dense any substance is will determine the ability and amount of electromagnetic wave frequency that passes through or is reflected. The relative density of matter will determine the object's ability to absorb light and what does not get absorbed gets reflected. All of this is important for Xavier's enhanced vision range.

The measure of how deep light or any other electromagnetic spectrum radiation can penetrate any material is called depth penetration. The nature of the material will determine how far or deep the penetration goes, some may travel deep and others not at all. Materials that are more dense will absorb less radiation than those materials less dense which will absorb more.

X-ray-ted science

X-rays, a form of ionizing electromagnetic radiation invisible to the naked eye, are high frequency energetic photons with most having a wavelength ranging from 0.01 to 10 nanometers. Simply stated, x-rays are photons of x-ray electromagnetic radiation. X-ray photon wavelengths are shorter than UV rays and longer than gamma rays.

There are two types of x-rays, those with photon energies below 0.2 to 0.1 nanometer wavelengths, called hard x-rays, and those with higher wavelengths, called soft x-rays which are easily absorbed in air. Hard x-rays penetrate better without being absorbed or scattered and are primarily used in medial radiography and airport security to see inside visually opaque objects.

X-rays are primarily generated by a vacuum tube that converts electrical energy into x-rays. X-rays are produced as long as the x-ray tube is active. X-ray photons ionize atoms and break chemical bonds thereby making high exposure harmful to living tissues. This capability has been used in certain forms of cancer treatment as radiation therapy to kill malignant cells.

Generation of x-rays

To artificially make x-rays generators are used to produce a high voltage between an anode and a cathode. Since electrons are made in the filaments of these generators the tube current can flow from the filament to the target only. As x-rays pass through a patient they are attenuated depending upon the tissues and/or bone they pass through or reflect off of and cast a shadow. This is what is detected. It should be noted that x-ray images are static non-moving images.

Detector Gadget

Without a detector there is no way to image x-rays. These specialized detectors measure the flux, spatial distribution, and spectrum properties of x-rays. There are imaging detectors such as those used in x-ray photographic film and dose measurement detectors such as Geiger counters and dosimeters.

X-ray detectors are designed to collect individual x-rays and count the number of photons collected (intensity), the energy (0.12 to 120 keV) of the photons collected, wavelength (~0.008 to 8 nm), or how fast the photons are detected (counts per hour).

For medical x-rays the patient is placed between the x-ray source and the image detector to produce a shadow of the internal structure of the particular body part. The actual x-rays are somewhat blocked by dense tissues and bone and easily pass through soft tissues. X-rays can readily pass through tissues with various radiodensities and for visualization are converted by an electronic sensor into an electric signal that is computer controlled and converted into a visible-light image. Current technologies for imaging use high contrast reagents such as amorphous selenium or ultrasound to scan internal body parts.

Surface orientation and scene illumination are important for x-rays (this was noted above in the discussion between Xavier and Fairfax in his lab). For image detectors boundary distinctions are essential and edge detectors are used that locate discontinuities such as brightness changes in surface orientation. This helps with resolution to distinguish one body part from another. Edge detection is necessary for image processing. Based on Xavier's spectarama vision he has no edge detection capabilities or adequate resolution.

It should also be noted that high doses of x-rays do cause biological damage, including the eye retina, so there must be some sort of natural long term protection against such harmful rays. Maybe this is why Xavier's cornea changes during the film from normal, to metallic, to completely black, to better block out the enhanced electromagnetic radiation images. Maybe "nature's sunglasses"?

Fluoroscope

A fluoroscope is an instrument that uses x-rays to obtain real-time moving images of the internal structure and function of patients and converts this information into visible light. In this way, swallowing or the pumping of the heart can be visualized in real time. Fluoroscopes are useful for diagnosis, therapy, and image-guided surgery. For fluoroscopy the patient is placed between an x-ray generator and a fluorescent screen, the detector. Fluoroscopy is inherently more dangerous than an x-ray because of the constant continuous exposure to x-rays instead of a brief pulse as with typical x-rays films. Fluoroscopy is what is used in most airport security scanners.

Gamma rays

The main difference between x-rays and gamma rays has to do with the radiation source. The photons generated from nuclear decay are always termed gamma rays whereas X-rays are generated by electronic transitions involving highly energetic inner atomic electrons. In general, nuclear transitions are much more

energetic than electronic transitions, so gamma-rays are more energetic than X-rays.

Background radiation

We are all constantly being bombarded by radiation from outer space. Most of this is absorbed by Earth's atmosphere. The ionizing radiation all around us and naturally present in the environment is called background radiation. From background radiation comes incident radiation which is really an adjective used to describe radiation that is acting on something.

This background and incident radiation primarily consists of positively charged ions from protons of larger atoms, like iron outside our solar system, that interact with Earth's atmospheric atoms to create secondary radiation that include x-rays, muons, protons, alpha particles, pions, electrons, and neutrons. Of these, the largest dose comes from muons, neutrons, and electrons. This dose is also dependent upon altitude and the geomagnetic field of Earth (e.g., mile-high Denver receives more cosmic rays than sea level San Diego). Also, astronauts are exposed to the most cosmic radiation since they are outside Earth's atmosphere and magnetic field.

The source of this background radiation is both natural, such as cosmic radiation and that from naturally occurring radioactive materials including radon and radium, as well as artificial fallout from nuclear incidents that have globally spread around the world. All of this can be inhaled and ingested. Combining worldwide natural and artificial radiation then the average human is exposed to about 3 millisieverts (mSv; a defined unit of ionizing radiation) per year; 2.4mSv from natural exposure and about 0.5mSv from artificial exposure.

X-ray astronomy

Though x-rays do come from the cosmos, including our own solar corona, they are not energetic enough to be practically useful. Cosmic x-rays come from black holes, gamma ray bursts (transient events), and neutron stars from the formation and evolution of stars and galaxies. Material falling into a black hole may emit x-rays. Most cosmic x-rays are absorbed by Earth's atmosphere so to detect them one must be above the atmosphere such as with high altitude balloons or satellites. X-rays have been observed emanating from the sun (solar x-rays vs extra-solar x-rays) since the 1940s and the discovery of the first cosmic x-ray source was made in 1962. From celestial objects many thousands of x-ray sources are now known.

Sunlight

The light given off by the Sun, infrared, visible, and ultraviolet light, is just a portion, about 5 logs (20%), of the 25 log electromagnetic spectrum. This sunlight is filtered by Earth's atmosphere and does not penetrate most objects, mostly translucent ones. For humans the ultraviolet radiation from the sun helps generate vitamin D but can also acts as a mutagen and can change DNA and in

extreme cases lead to cancer. Sunlight is necessary for plant photosynthesis, a process in which plants convert light energy into chemical energy.

Eye see it

The visible spectrum is that small portion of the electromagnetic spectrum that is visible to the human eye. The typical human eye can detect wavelengths from about 370 to about 750 nm (similar to Dr. Brant's "4000 angstrom units to 7800 angstrom units"). Colors of one wavelength are pure colors. Due to the ability to mix multiple wavelengths the human eye can distinguish colors not in the spectrum such as unsaturated colors like pink, purple, or magenta variations. Near infrared lies just outside of typical human vision though other animals may have this ability such as snakes that "see" infrared. The ability to interpret visible spectrum light is called visual perception, commonly called eyesight or vision, and is part of the human visual system.

Visual system

The largest system in the human brain is the visual cortex which processes visual images. Anatomically, the visual cortex lies at the rear of the brain above the cerebellum. Both color and motion are processed by the visual cortex.

The visual system is part of the central nervous system and allows information from the surroundings to be assimilated and assessed. The ability to see starts when the eye cornea and lens focus light to the retina which is actually a part of the brain that converts light to neuronal signals. The lens focuses light on the photoreceptive cells of the retina known as rods and cones. These rod and cone cells detect photons of light that produce neural images that are sent to the central ganglia in the brain.

Visual perception

Visual perception is the brain's ability to interpret surroundings using visible spectrum light reflected off objects. Due to having two eyes then stereo vision is possible which allows the ability to assess the distance to and between objects and to track the movement or motion of these objects. Lack of visual perception is called blindness.

The ability of an organism to distinguish lights of different spectra is called color vision which in reality encompasses a small range of the electromagnetic spectrum. Visual acuity is resolving power of the visual system. The ability to distinguish fine detail or one object from another is resolution which is determined by the shape of the retina.

Eye yi-yi

The organ of the visual system is the eye. Eyes provide vision and function as a transducer. Eyes detect light and convert it to electrochemical impulses in neurons. Eyes are a complex optical system that collects light (incident electromagnetic radiation), regulates its intensity through a diaphragm (iris and

pupil), focuses it into a smaller image through the lens, then absorbed by the molecules in the retina, transduces the image to a set of electrical signals, and transmits these signals to the brain through a complex network of neural pathways that connect the eye via the optic nerve to the visual cortex. After reaching the optic chiasm in the brain the nerve fibers decussate (left becomes right). Specifically, the retina fibers then branch and terminate in three places though most end in the lateral geniculate nucleus, the visual cortex of the brain.

Retina

The retina is the inner lining of the eye containing an array of light-sensitive cells composed of several layers of neurons interconnected by synapses. Images of the visual world are created by the optics of the eye (cornea and lens) which strike the light-sensitive retinal cells thereby initiating a cascade of chemical and electrical events sent to the brain via the optic nerve for processing. Precisely, retinal photosensitive ganglion cells send signals along the retinohypothalamic tract to the suprachiasmatic nuclei to control pupil light reflex.

The photoreceptor cells in the retina contain proteins called opsins. In humans there are two types of opsins involved in vision, rod opsins and cone opsins (see below). The protein opsins absorb photons and transmits a signal that hyper-polarizes the photoreceptor synapse directly onto nerve fibers connected to the brain. About 130 million retinal photo-receptors absorb light that gets visually processed to about 1.2 million ganglion cells to transfer to the brain. As a result of all this visual processing five different populations of ganglion cells send both image-forming and non-image forming information to the brain. It has been estimated that the approximate bandwidth of human retinas to be about 8960 kilobits per second.

Rods and Cones

As mentioned the retina contains two major types of light-sensitive cells, rods and cones. Rod cells cannot distinguish colors but can detect low-light monochrome (black and white) vision because they contain the light-sensitive pigment protein, rhodopsin. Rod cell density is greater in the peripheral area of the retina rather than the central area. Rods function mainly in dim light and provide black-and-white vision. Changes in light are detected by rod cells.

Cones are responsible for color vision and to function properly require bright light. In humans, there are three types of cone cells that differ in the wavelength of light they absorb, those sensitive to long-wavelength (red), medium-wavelength (green), and short-wavelength light (blue). Colors ‘seen’ are due to a combined effect of all three types of cone cells. With the ability to detect color also comes the ability to detect low level ultraviolet light. Most cone cells are located in the fovea (center) area of the retina with only a few present at the retinal sides.

Rho Adopt Sin

Rhodopsin is a light-sensitive protein involved in phototransduction and primarily found in rod cells. When rhodopsin is exposed to light it immediately photo bleaches. In the dark, the protein, retinal, a part of rhodopsin, has a normal bent shape (called cis-retinal) and when light hits it the shape changes to a straight form (called trans-retinal) and breaks away from the opsin protein; this is called bleaching. Simply stated, in the presence of light the retinal protein changes configuration and as a result a nerve impulse is generated. This is the core of sight. Proper color vision requires a range of pigment cells containing these biomolecules which are sensitive to small changes of the visible light spectrum.

Optic nerve

Information obtained by the eye is transmitted to the brain via the optic nerve. About 90% of the axons in the optic nerve are connected directly to the lateral geniculate nucleus in the thalamus area of the brain. The inferior temporal gyrus recognizes complex shapes, objects, and faces. Other optic nerve axons are connected to the superior colliculus in the midbrain which help control eye movements. Parallel processing by each optic nerve is necessary for complete stereoscopic visual perception and sight. Photoreceptive ganglion cells are also involved in both conscious and unconscious vision as rudimentary brightness detectors.

Eye-mazing Summary

For Xavier to 'see' x-rays would require an alteration of the cells, tissues, and molecules in the retina of his eye; the cornea, pupil, and lens can remain the same. After the molecular alterations to see broader wavelengths Xavier's brain had to adjust to properly process the visual input which would require new visual perception cognitive skills. These changes in Xavier's eyes were initially temporary but then became permanent.

With the aid of the eye drops Xavier's vision broadens from the visible spectrum to encompass UV and X-rays so those of shorter wavelengths and increasing frequency. No mention is made of longer wavelengths (decreasing frequency) like infrared and radio waves. The visible spectrum is reflected radiation whereas X-rays are penetrating radiation so Xavier's vision greatly expanded to accommodate the physically different radiation sources. What Xavier 'sees', via spectarama, is totally lacking in visual acuity with no resolving power and an inability to focus. All images appear blurry.

Unlike Superman who has "x-ray vision", meaning the ability to emit x-rays to see through objects (except, famously, lead), Xavier does not emit x-rays but rather through his eye drops developed the ability to *detect* x-rays. That being said then there must be a source of x-rays for Xavier to detect. The nature of this x-ray source must be incident or background radiation, possibly coming from the cosmos. The eye drops gave Xavier the ability to acutely detect even this smallest level of incident cosmic x-ray radiation thereby causing his brain to be overstimulated with all the extra visual input.

For Xavier's eyes to see x-rays would mean his retinas have developed 'detectors' for these highly energetic photons. All forms of incoming electromagnetic radiation, from whatever source, sun or cosmos (cosmic rays), would pass through the cornea, iris, and lens and directly hit the cells and molecules in Xavier's retina thereby activating them. This means there would be some sort of protein like rhodopsin in the retina that can change from a cis-like structure to a trans-like structure once activated by an x-ray photon. And once activated a signal would then be sent along the optic nerve to the brain for processing of the image.

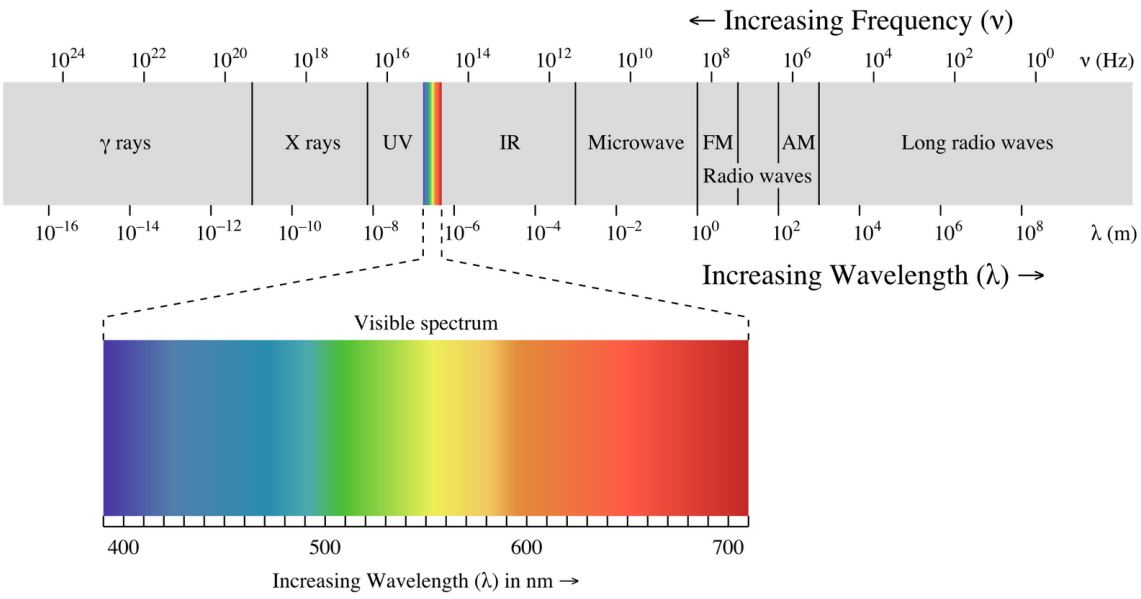
All forms of cosmic rays enter the eye and hit the retina but are not processed or recognized by the brain; only visible spectrum wavelengths are recognized so humans are naturally blind to everything else. Humans are exposed to about 3mSv of ionizing radiation per year and assuming the same applies to Xavier then his eye drops changed his vision system to accommodate this low level of radiation, meaning his vision system became much more sensitive to be able to have x-ray detection and therefore enhanced vision capabilities.

Rays from an external source and hitting Xavier's retina are then processed by the visual cortex of the brain. Though the eyes can detect incoming radiation it is the interpretation (or brain processing) of detection elements that is key. The inability of the brain to effectively process a wider range of radiation means humans are indeed "blind" to the vast majority of the electromagnetic spectrum (over 98%!).

Important for Xavier's x-ray sight are anatomic eye structure, eye development throughout the time of eye drop administration, nerve compression trauma, optic nerve blood flow, excitatory neurotransmitter release, trophic factors, retinal ganglion cell/axon degeneration, glial support cells, immune system, aging mechanisms of neuron loss, and possible severing of the nerve fibers at the scleral edge.

The eye drop reagent Xavier uses most likely dilated his pupils thereby letting in more light, not necessarily the high energy photons of x-rays which would easily penetrate the cornea, iris, pupil, and lens, with his eyelids open or closed, and not needing to be focused through eye optics like visible light. All of which is ultimately processed by the brain. Xavier's brain has a difficult time effectively processing the input information for his new range of vision and a mental breakdown occurs resulting in him literally plucking out his eyes.

Thank you for reading. It's back to the lab for me. Stay healthy and eat right.


← Increasing Frequency (ν)
10^{24} 10^{22} 10^{20} 10^{18} 10^{16} 10^{14} 10^{12} 10^{10} 10^{8} 10^{6} 10^{4} 10^{2} 10^{0} ν (Hz)
γ rays
X rays
UV
IR
Microwave
FM
AM
Radio waves
Long radio waves
10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 10^{0} 10^{2} 10^{4} 10^{6} 10^{8} λ (m)
Increasing Wavelength (λ) →
Visible spectrum
400
500
600
700
Increasing Wavelength (λ) in nm →