Engineering Psychology

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Week-03

Lecture-06

Visual and tactile displays - 2

Namaskar friends, welcome back to this lecture in the course on engineering psychology. In the previous lecture, we explored an important aspect of engineering psychology known as displays. Displays play a crucial role as they project information to the operator, enabling them to make decisions about future actions. In other words, the operator's ability to take actions in the future relies on the information provided by displays. Displays provide two main types of information.

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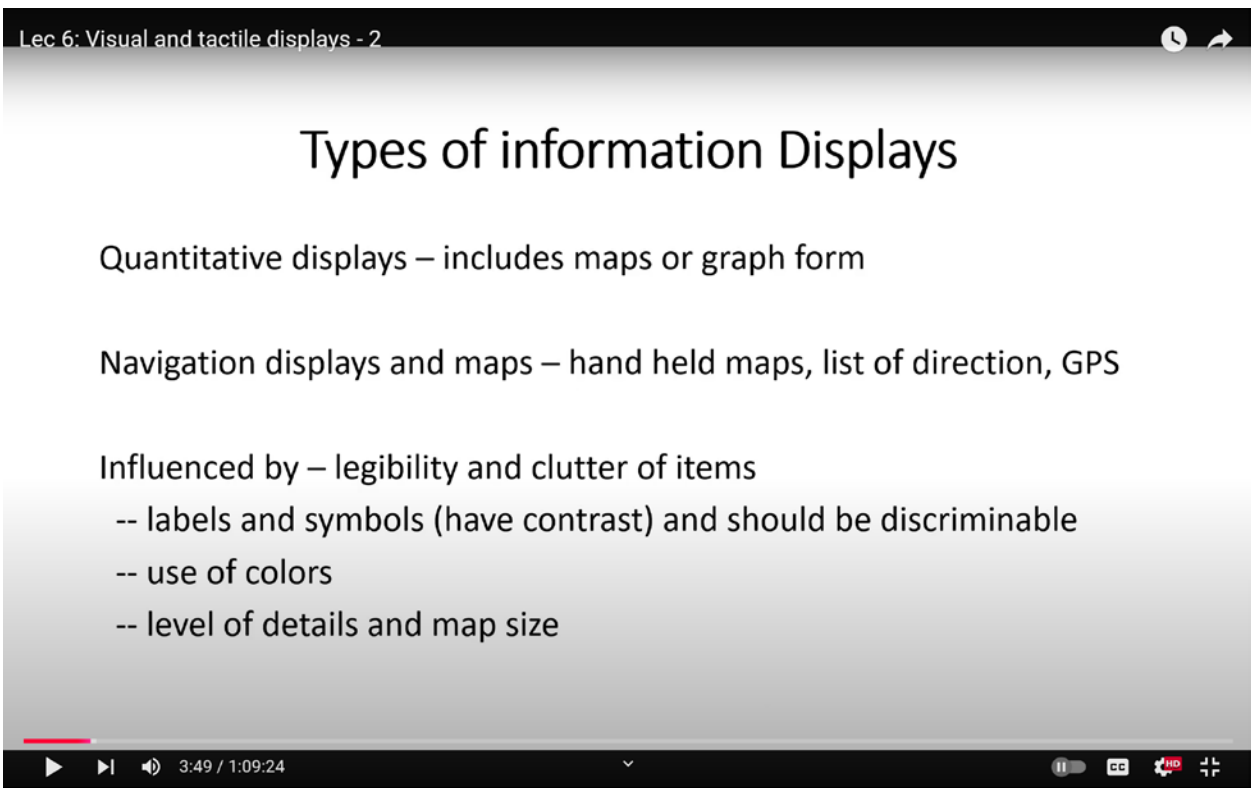

First, they offer insight into the state of a system, indicating whether it is functioning properly, whether there is any deficiency, or if the system requires some form of input. Second, displays offer feedback to the user. For example, if you press the stop button on a printer, it will halt the printing process. But how does the user know what happens after pressing the stop button? Displays are designed to provide this feedback, such as showing the message "job cancelled" or "job terminated" as a response to the button press.

There are various forms of displays. We have discussed digital and analogue displays, as well as static and dynamic displays. We also explored several factors that affect displays, such as conspicuity, readability, and placement. These were some of the topics covered in the previous class. Since this lecture focuses on visual displays, today we will examine the human visual system, its capabilities, and its limitations. We will see how understanding the human visual system can help in designing more effective visual displays. Towards the end of this lecture, we will introduce two more forms of displays: tactile displays, which convey information through vibrations or haptics, and olfactory displays, which engage the sense of smell.

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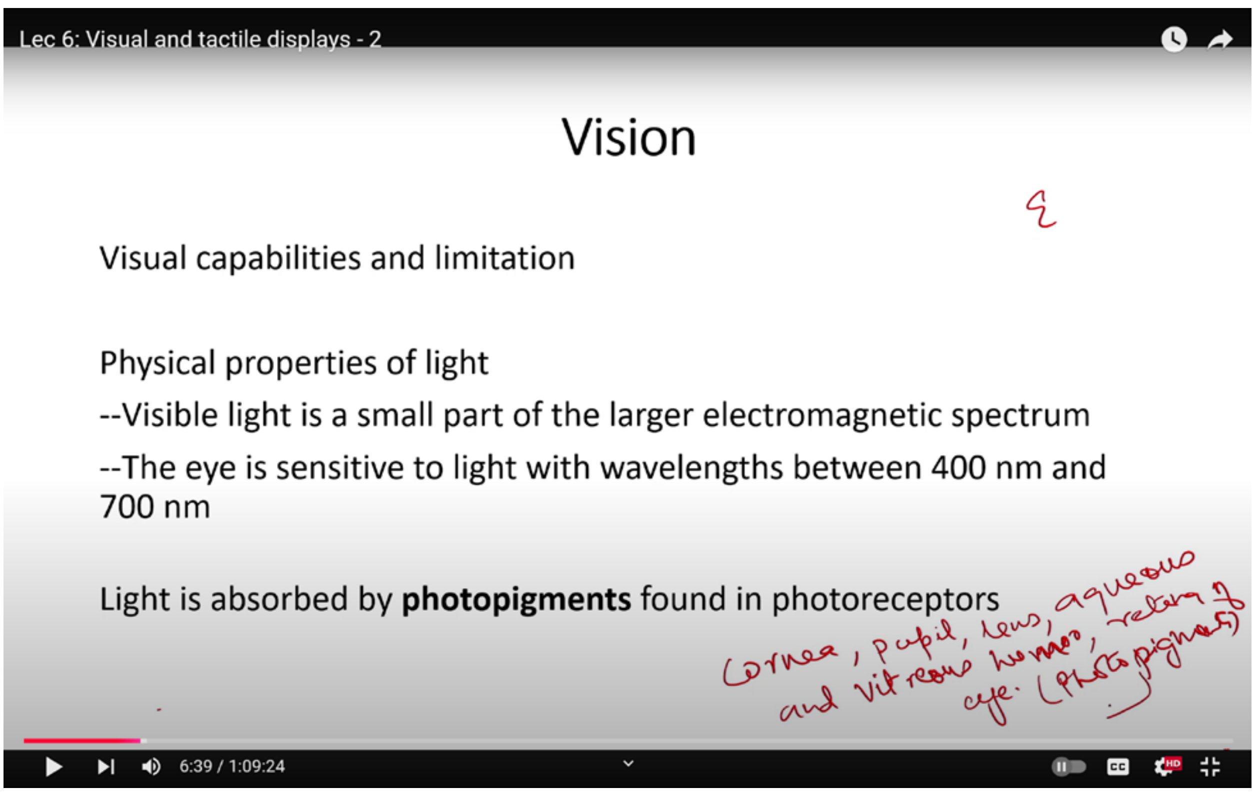

Continuing from where we left off in the previous class, we discussed navigational and quantitative displays, as well as how factors like legibility and clutter can influence them. Since we are primarily focused on visual displays, now is the right time to delve into the human visual system. I will provide a brief overview of the human visual system, covering its components, capabilities, and limitations, which are central to today's lecture.

The human visual sensory organ is the eye. The eye consists of several parts. The outermost surface is the cornea, followed by the pupil, which is regulated by the ciliary muscles that contract or expand to control the amount of light entering the eye. The eye contains two fluid-filled spaces, the vitreous humor and the aqueous humor, which help maintain eye pressure and the spherical shape of the eye. Next is the lens, which refracts and focuses incoming light onto the retina, the part of the eye responsible for processing information. We will also discuss some important features of the retina.

In summary, we will start by exploring the cornea, followed by the pupil, the lens, the aqueous and vitreous humors, and finally the retina, which contains photopigments. These photopigments convert light into electrical signals that are transmitted to the brain via the optic nerve. Don’t worry, we will go through this step by step and explain everything in an easy-to-understand manner.

Let’s begin with the physical properties of light, as vision starts with light. Light is a part of the electromagnetic spectrum and has a broad range of wavelengths. Within this spectrum, there is a specific range called the visible spectrum, where most human vision occurs. The visible light spectrum lies between wavelengths of 400 nanometers and 700 nanometers. As we discussed earlier, this visible range is a small portion of the electromagnetic spectrum. On one side of the visible spectrum, you have ultraviolet light (wavelengths shorter than 400 nm), and on the other side, infrared light (wavelengths longer than 700 nm). Humans cannot see ultraviolet or infrared light, though some animals, such as bats and dogs, can perceive information in these ranges. However, the human eye is sensitive only to the wavelengths between 400 and 700 nanometers.

Now, the process of vision involves light entering the eye and passing through several layers. It starts at the cornea, then moves through the pupil, the vitreous and aqueous humors, and the lens, before finally reaching the retina. The retina contains specialized cells known as photoreceptors or photopigments, which are responsible for converting light into electrical signals. These signals are carried through the optic nerve to the brain's primary and secondary visual areas, where they are processed into the images we perceive.

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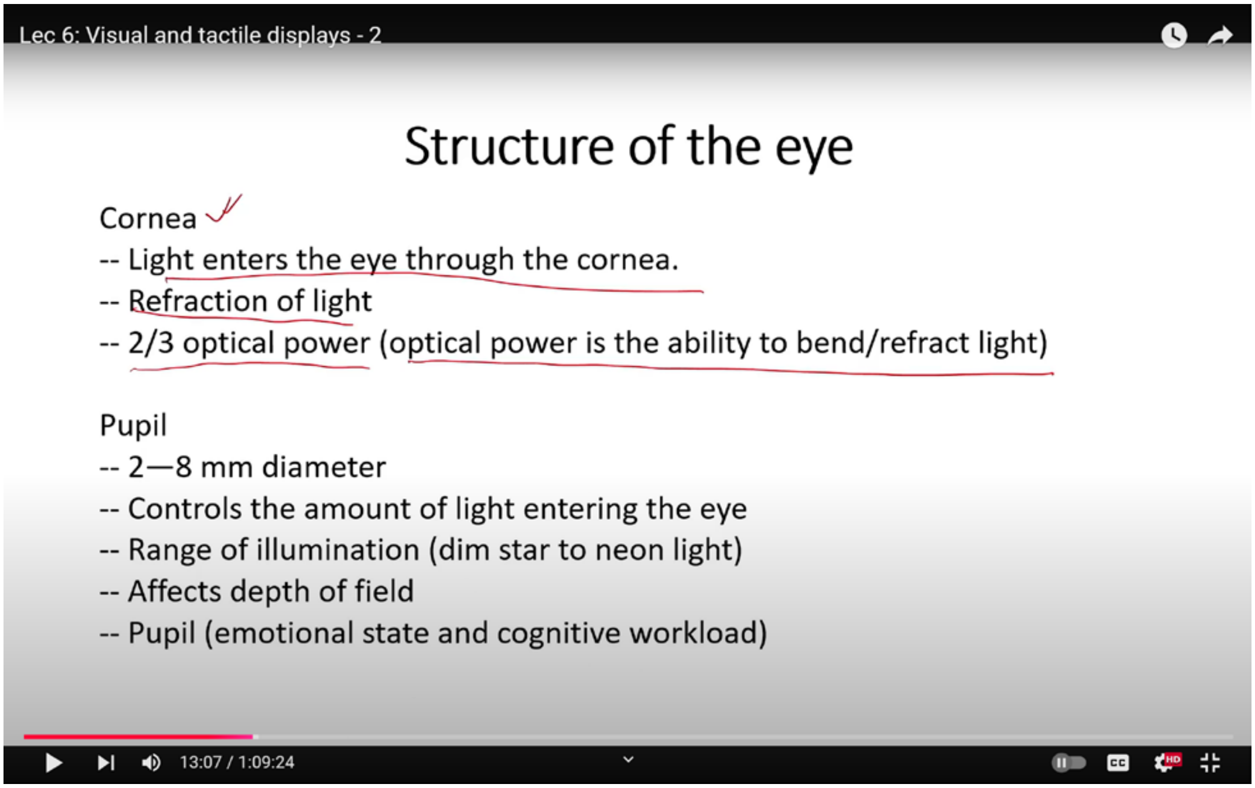

But what exactly are photopigments? Think of them as the photoelectric cells you see in certain devices, like clocks that chime only during the day when light is present. At night, without light, these clocks do not function. This mechanism works thanks to a photoelectric sensor or photovoltaic cell. Similarly, photopigments in the human eye convert light into electrical signals, enabling vision.

What this photoelectric or photovoltaic sensor does is that when light does not fall on it, it breaks the circuit connected to the chime, causing the chime to remain silent. However, when light falls onto the sensor, it converts this light into electrical energy, completing the circuit and allowing the chime to sound. This is how such a sensor functions, and a similar mechanism is present in the human eye. As I explained earlier, the eye consists of several layers: starting with the cornea, followed by the pupil, the aqueous humour, the vitreous humour, the lens, and finally, the retina.

We will now begin discussing these layers, examining the various segments of the eye and their properties. While we will not delve deeply into the specific functionality of each segment, our focus will be on their limitations and capabilities. Let's take a quick look at the features of these segments.

The first segment is the cornea, the part of the eye where light enters from the external environment. The cornea has the property of refraction, bending light as it passes through to transmit it to the inner parts of the eye. The cornea provides two-thirds of the eye's optical power, with the remaining one-third coming from the lens. Optical power refers to the ability to bend or refract light so that it falls on the retina. In fact, two-thirds of this bending or focusing of light onto the retina, which converts it into electrical signals, is accomplished by the cornea.

The next section is the pupil, which regulates the amount of light entering the eye. This is the part that responds when you move from a bright room to a dark theatre. In bright light, the pupil contracts to reduce the amount of light entering the eye, while in darkness, it expands to allow more light to enter so you can see clearly. The diameter of the pupil ranges from 2 to 8 millimeters, adjusting based on light conditions to control the amount of light entering. This extending and contracting ability, known as dilation, also influences the depth of field, how deeply you can perceive your environment. Interestingly, the pupil's response is not only affected by light; it also reacts to emotional states. When you are happy, your pupils dilate, and when you are sad, they contract. Similarly, after intense cognitive work or mental fatigue, the pupil relaxes, reflecting your mental state.

The third part is the lens, responsible for one-third of the eye's optical power. Unlike the lenses you might get from an optometrist, which can vary in power, the natural lens in the eye is fixed in place. It compensates for this by changing its shape, a process called accommodation. Accommodation refers to the lens's ability to alter its thickness in response to different focal points, allowing you to focus on objects at varying distances. This change in shape is made possible by the ciliary muscles, which reshape the lens to adjust its focus. This accommodation is crucial for sharpening the image, much like how a corrective lens prescribed by an eye doctor helps you see clearly. Whether you are near-sighted or far-sighted, the lens's ability to change its shape enables you to focus on objects at different distances, maintaining clarity.

A simple demonstration can help illustrate accommodation: place a finger in front of your nose and gradually move it away. You'll notice that as your finger moves further away, its image becomes blurry, but eventually sharpens again. Similarly, when you bring the finger closer, the image blurs once more but becomes clear after a moment. This correction is a result of the lens's accommodation, allowing you to clearly focus on the finger, regardless of its distance.

Now, we move on to the retina, the layer of the eye where light is converted into electrical signals. The retina is curved, and light refracted by the cornea and lens falls onto it. The outer regions of the retina contain rods, specialized cells responsible for detecting black-and-white images and low light. Rods are not sensitive to color and take longer to adapt. In the center of the retina, however, we have cones, specialized cells that detect color and help you see bright objects.

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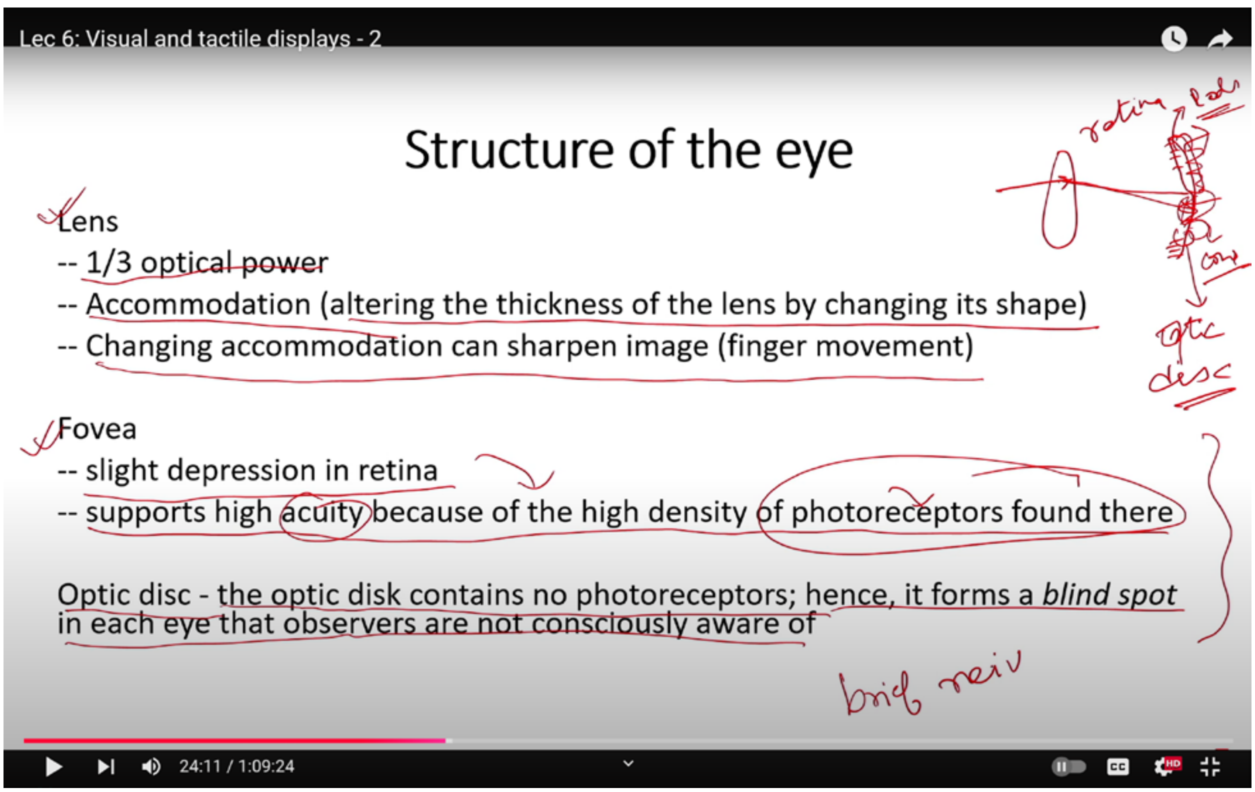

While rods assist in seeing dimmer objects, cones enable the perception of brighter objects. Within the center of the retina lies a region densely populated with cones. When light falls upon this area, it allows for sharper and more colorful images, leading to brighter and clearer visuals. This region of the retina, which enhances image quality, is known as the fovea.

So, what exactly is the fovea? The fovea is a slight depression in the retina, located just below the center of the retina. This area contains a high concentration of cones, making it crucial for seeing accurately and with detail. The fovea supports high acuity due to the dense arrangement of photoreceptors present there. Acuity refers to the eye's ability to distinguish changes in forms, shapes, and patterns, essentially, how clearly one can perceive variations in objects.

We will delve deeper into acuity and discuss why the fovea contributes to clearer vision. The photoreceptors, the cells responsible for converting light energy into electrical signals, are most densely packed in the fovea. Adjacent to the fovea is a region known as the optic disc.

What is the optic disc? The photoreceptors convert light energy into electrical signals, which must be transmitted to the brain via neurons, essentially the “wires” of the nervous system. The optic disc is where these main connections to the retina occur. In this region, the larger axons of neurons gather all the electrical signals from the photoreceptors and transmit them to the brain. The optic disc itself contains no photoreceptors, rendering it a blind spot. If light is directed onto someone’s blind spot, they will be unable to see it due to the absence of photoreceptors in that area.

Thus, the optic disc serves as the connection point for neurons to the retina, lacking photoreceptors and forming the blind spot in each eye. As a result, observers are often unaware of certain visual tricks performed by magicians; these illusions frequently occur in the blind spot, where light falls upon the optic disc and is not detected by photoreceptors.

This overview highlights the capabilities and limitations of the visual system. Our visual system operates based on the duplex method. What is the duplex method? This term refers to our ability to see under both dim light and bright illumination conditions, made possible by the presence of two distinct visual systems.

As mentioned earlier, we can perceive both a dim star and bright noon sunlight, indicating that we have at least two types of photoreceptors. These are the rods, which facilitate dim-light vision, and the cones, which enable bright-light vision. The combination of both types of receptors constitutes the duplex visual system.

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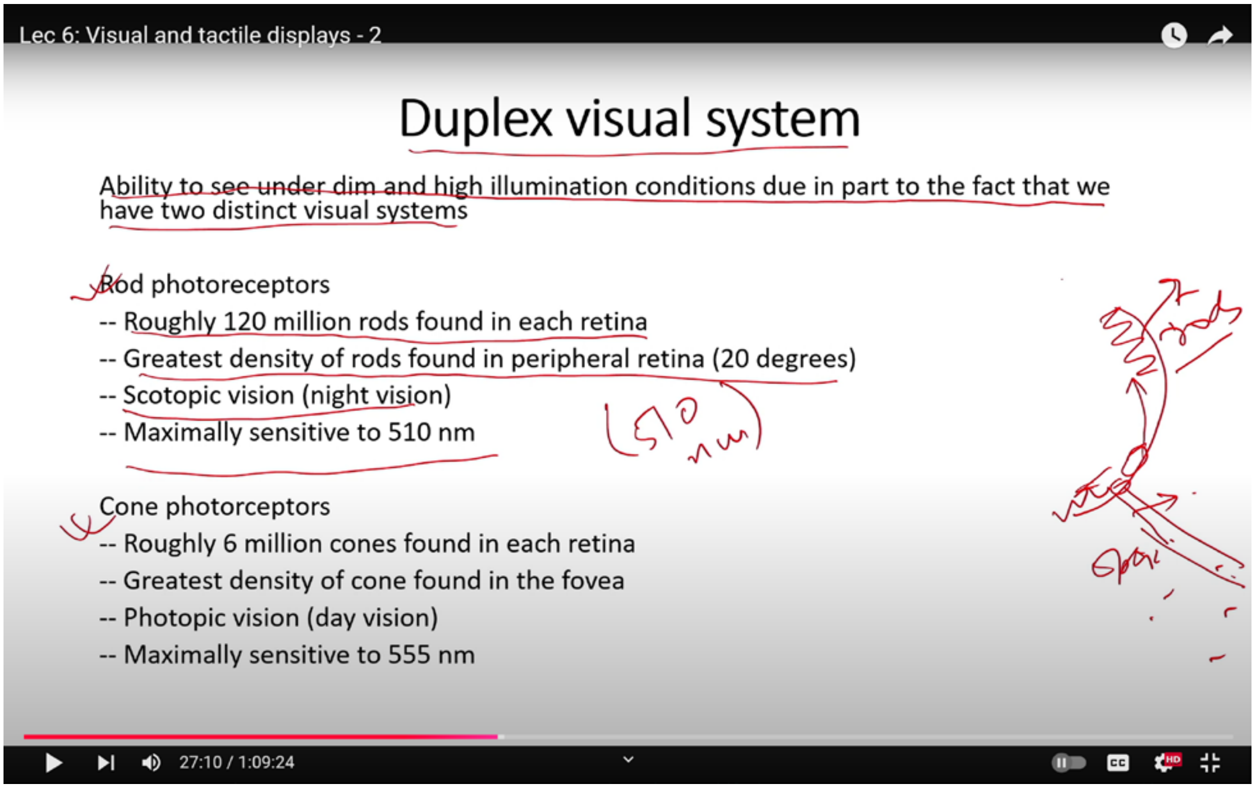

Now, let’s discuss rods. Each retina contains approximately 120 million rods, indicating a significantly higher number compared to cones. The greatest density of rods is found in the periphery of the retina. If we visualize the retina with the fovea at the center and the optic disc where the optic neurons connect, we can identify the shaded region containing the rods, located towards the periphery.

The presence of rods in the peripheral regions can be illustrated by the fact that if objects are placed in dim light, attempting to see them with the center of your vision will be ineffective. The most effective way to observe objects in dim light is to utilize your peripheral vision, as rods excel in low-light conditions. Thus, the highest concentration of rods is found within a 20-degree peripheral zone from the fovea.

Rods facilitate scotopic vision, or night vision. During the night, rods are more active, making them highly sensitive to light wavelengths around 510 nanometers. In contrast, cones, which number around 6 million in each retina, are predominantly located in the fovea. The density of cones is greatest in this central area, enabling color perception and contributing to phototopic vision, or day vision, which is essential for seeing in daylight with maximum accuracy. Cones are most sensitive at 555 nanometers.

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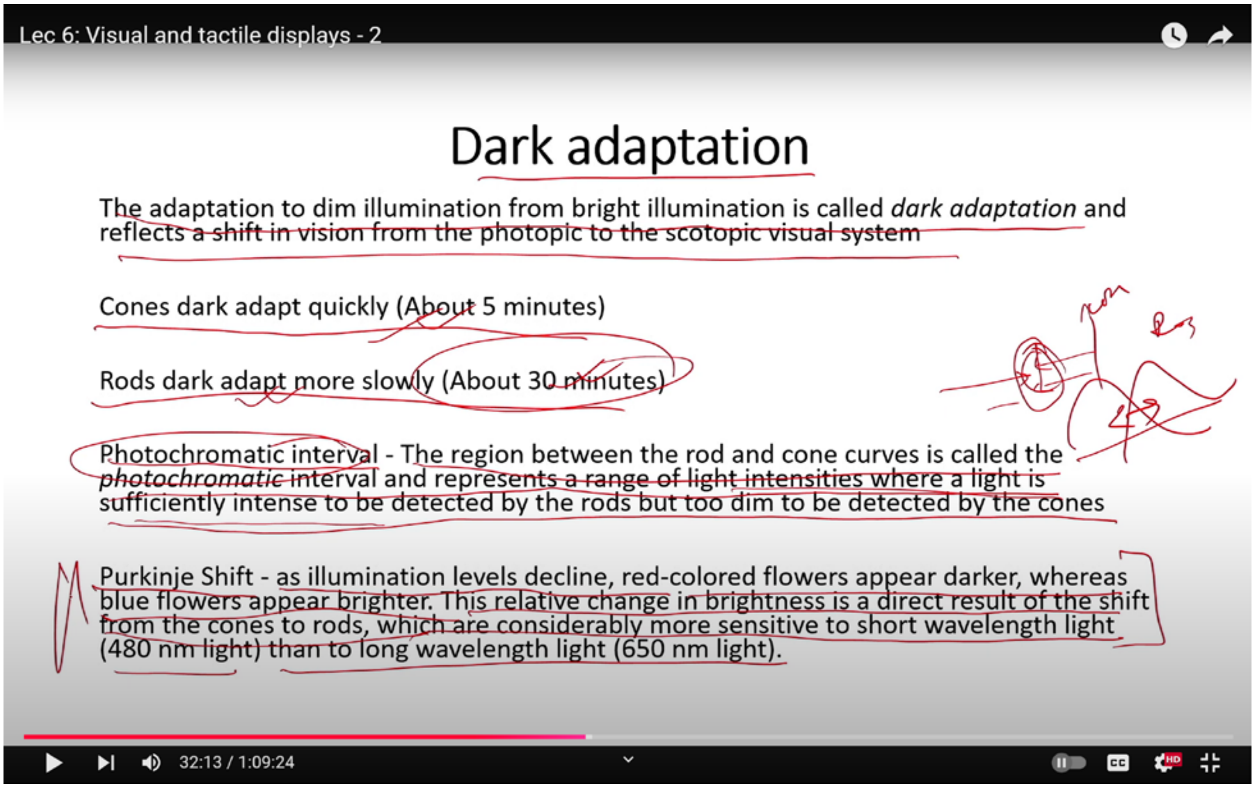

Additionally, there is a phenomenon known as dark adaptation, which refers to the process by which the eye adjusts to lower light levels, enhancing its sensitivity in dim environments.

So, what does this mean? In simple terms, when you exit a completely dark cinema hall, it takes some time for your eyes to adjust to seeing objects in the light. This property of the human eye, which adapts from a dark environment to a lighter one, is known as dark adaptation. You may have noticed that at night, you can perform various tasks, such as navigating and recognizing larger objects around you. But how can you navigate if your eyes receive no light? The ability of the eye to perceive minimal light and assist in navigating around larger objects is a manifestation of dark adaptation.

Dark adaptation reflects a transition from bright illumination to dim lighting. In essence, moving from bright light to darkness is termed dark adaptation, while the reverse process is known as light adaptation. Cones adapt quickly, typically taking around five minutes to adjust from dark to light. Thus, when you come out of a cinema hall, you can start seeing more quickly. Conversely, when moving from bright light into a cinema hall, it takes longer for your eyes to adjust; this slower adjustment is associated with rod-based adaptation, which is part of dark adaptation. Rods adapt more gradually, taking about 30 minutes to fully adjust. Consequently, it will take you longer to start seeing in a dimly lit cinema hall compared to when you move out into a brightly illuminated area, as cones require about five minutes for light adaptation while rods need approximately thirty minutes for dark adaptation.

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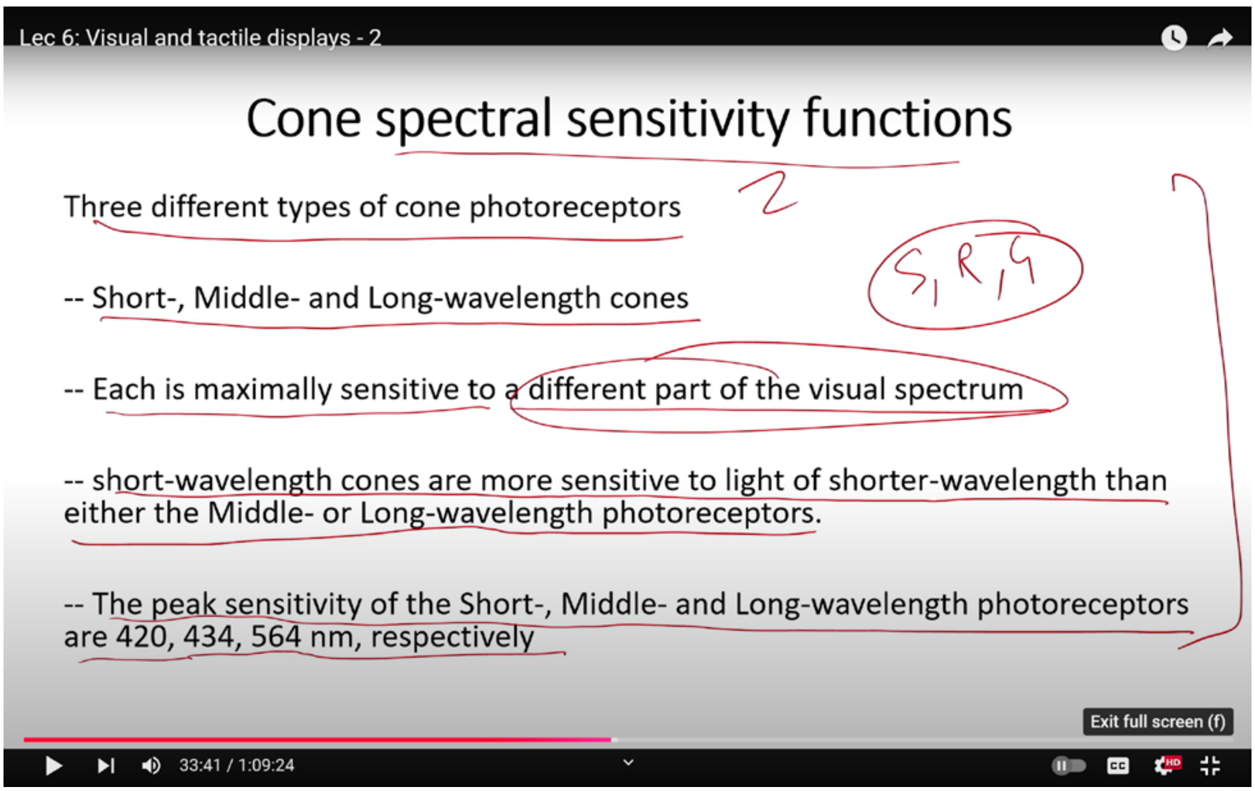

There is also a concept known as the photochromatic interval, which refers to the region between the sensitivity curves of rods and cones. This interval represents a range of light intensities where the light is sufficiently intense to be detected by rods but too dim for cones to perceive. If we visualize the activity of the cones across various bands of the electromagnetic spectrum, we can identify a specific region where light intensities can be detected by rods but cannot be perceived by cones. This region is termed the photochromatic interval, indicating the range of light that rods can detect while cones cannot.

Would you like to know more about this? There is a recommended book for this course that provides additional insights. Additionally, there is a phenomenon known as the Purkinje shift, which is commonly observed. This phenomenon states that as illumination levels decrease, red flowers appear darker while blue flowers appear brighter. This relative change in brightness is a direct consequence of the shift from cones to rods. As you transition from cone vision to rod vision, red objects tend to appear darker, while blue objects become more vibrant. This effect is referred to as the blue shift within the Purkinje effect, which demonstrates that rods are significantly more sensitive to shorter wavelengths of light (around 400 nanometers) compared to longer wavelengths.

The spectral sensitivity function we are discussing reveals that there are three types of cone receptors. While rods consist of only one type, there are three distinct types of cones, each sensitive to different colors: red, blue, and green, often abbreviated as RBG. We refer to these as short, medium, and long-wavelength cones, each of which is maximally sensitive to different portions of the visual spectrum. Thus, the S, M, and L cones respond to varying intensities of light and different colors, as these three colors combine to create the full spectrum of visible colors. In summary, the three types of cones are specifically sensitive to and respond to their respective colors.

Short-wavelength cones are more sensitive to light with shorter wavelengths compared to middle- and long-wavelength photoreceptors. Thus, there are short-wavelength cones, middle-wavelength cones, and long-wavelength cones, each responding to different colors ranging from red to green to yellow. The peak sensitivities of the short, middle, and long-wavelength photoreceptors are 420, 434, and 564 nanometers, respectively. This section discusses the three types of cones and their varying responses to different wavelengths of light, which produce specific colors when light of particular frequencies or wavelengths strikes the corresponding cone.

Now, let us delve into human visual capabilities. We have previously discussed the human visual system, and we will now focus on human visual capabilities. First, we will address a concept known as visual acuity. What exactly is visual acuity? It refers to the eye's ability to resolve fine details. Specifically, visual acuity is defined as the minimal separation between two points that can still be perceived as distinct. For instance, if I illustrate two objects, visual acuity measures the smallest distance between these two objects that you can perceive in order to differentiate their boundaries. This is known as visual acuity. Essentially, it quantifies the smallest difference or gap between two objects that you can discern.

Visual acuity is typically measured using a tool called the Snellen chart. This is the same chart that an optician or ophthalmologist provides during an eye examination. The chart features individual letters of varying sizes arranged in different rows. During the examination, the ophthalmologist asks you to read these letters aloud. As the letters decrease in size, there will come a point where you can no longer distinguish between the letters in a particular row. The results from this exercise indicate your visual acuity, providing insights into the corrective lens power you may require.

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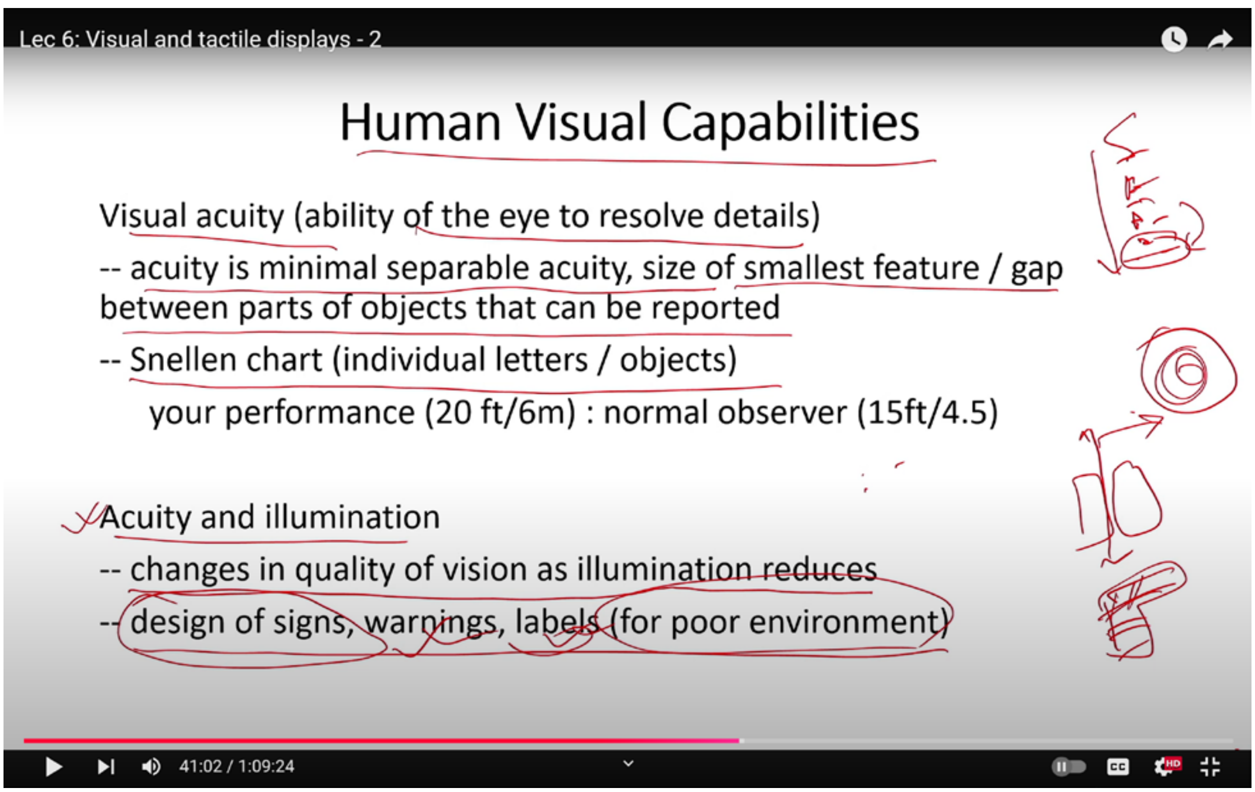

So, how is this lens power determined? The power needed is based on visual acuity and is measured by comparing the performance of the individual in question to that of a normal observer. This is generally expressed as a ratio, such as 20/15. In this notation, 20 represents the individual's ability to clearly differentiate between two objects at a distance of 20 feet, while 15 denotes the standard performance of a normal observer. A person with 20/20 vision can differentiate objects at 20 feet, which is considered the standard for normal vision. If someone has 20/40 vision, it indicates that the normal observer can distinguish objects at 40 feet, while the individual can only do so at 20 feet, suggesting that their vision requires correction.

Thus, this is how lens power is precisely measured, and visual acuity is a critical aspect of designing visual signs and displays.

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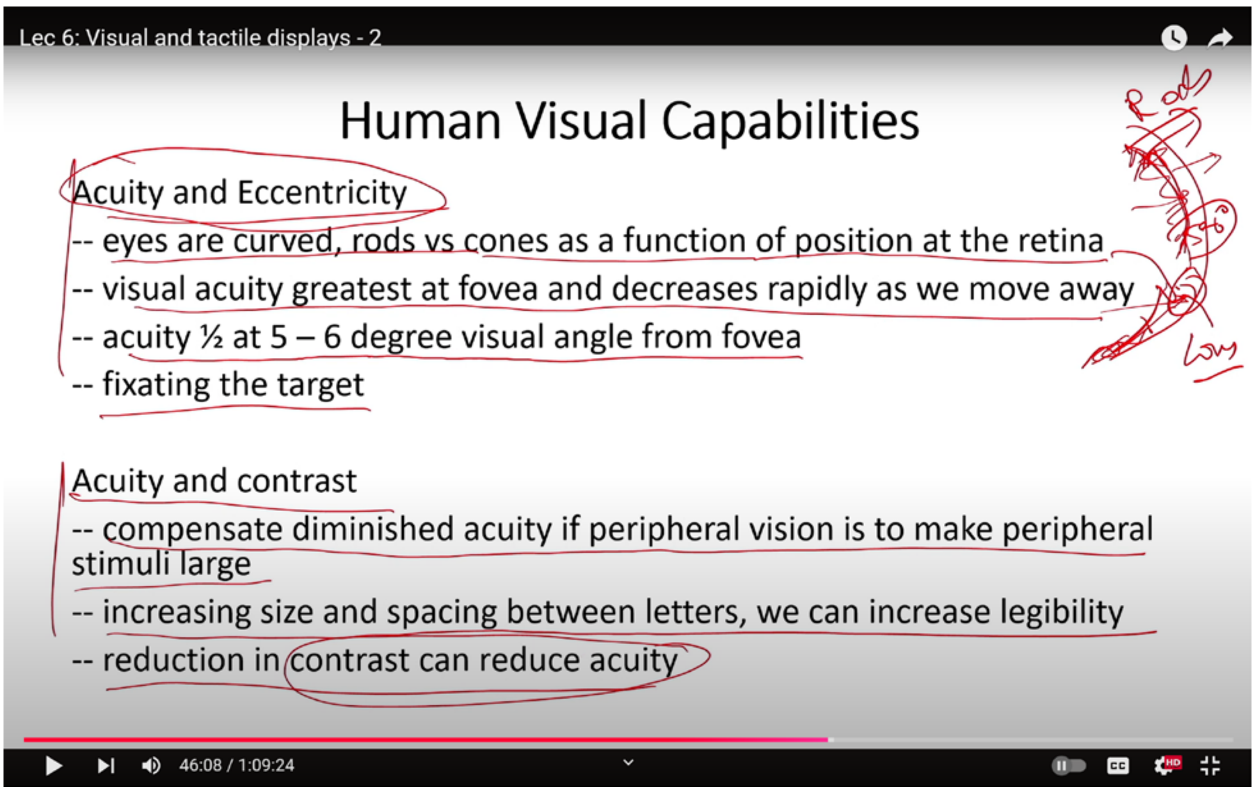

The next feature of the human visual system we will explore relates to illumination and visual acuity. We have just examined the concept of visual acuity, which refers to the smallest distance that allows for the discrimination between two different objects. Now, we must consider whether this discrimination capability is influenced by illumination. Specifically, does the brightness of a display affect your ability to differentiate between two different displays?

Research indicates that as illumination decreases, the ability to distinguish the gap between two objects diminishes. In other words, the minimal gap that separates two objects is dependent on the level of illumination. The brighter the environment, the greater the likelihood of successfully discriminating the boundary between objects. Conversely, in poorly illuminated settings, discrimination becomes challenging. This is why navigating in a dark environment can be difficult when dealing with small objects.

When navigating your home, you can easily walk around larger obstacles like chairs and tables; however, smaller objects can pose challenges. This difficulty arises because, in dim light, distinguishing gaps between objects or discerning the clarity between two objects becomes challenging. Understanding this issue is crucial for sign design. It raises questions about the optimal placement of signs, the type of illumination they should have, the nature of the text used, and how it should be formatted. All these factors significantly influence the effectiveness of sign design.

Similarly, the design of warnings and labels also depends on visual acuity. For example, consider road signs intended for traffic management. These signs are subjected to various weather conditions, which may include darkness and rain, potentially degrading their readability. Therefore, sign and display designers must consider how to effectively illuminate these signs. One approach could involve incorporating motion or artificial movement into the design, such as using visual illusions that create lines appearing to show motion. This technique could enhance the visibility of a sign, even in adverse conditions.

Additionally, the use of color and different textures can further improve the design of signs, ensuring that individuals can notice warning labels and signs even when driving in poor visibility. Another essential aspect of the human visual system is visual acuity and its relationship with eccentricity. Eccentricity refers to the positioning of objects in relation to the center of the visual field. The human eye is curved, and rods and cones are distributed in varying intensities and ratios across this curved region.

Visual acuity is highest at the fovea, the center of the retina, and decreases rapidly as one moves away from this point. As we move peripherally, the number of rods increases, and we have already established that acuity is dependent on illumination. The fovea, containing a high concentration of cones, is the region with the brightest illumination, resulting in optimal acuity. However, moving away from the fovea means encountering areas dominated by rods, which function better in lower light conditions, resulting in decreased acuity.

Acuity can diminish significantly when moving just 5 to 6 degrees away from the fovea. Fixation on a target is influenced by where the light is focused; it is challenging to maintain fixation at the periphery of the retina, while fixation is easier at the fovea. In dim lighting conditions, however, fixation becomes easier at the periphery due to the higher activity of rods. Conversely, focusing on objects at the fovea becomes difficult in low illumination.

One method to improve acuity in dim environments is by increasing the size of objects. Larger objects can be better discriminated by rods to some extent. Another important concept to consider is contrast. Contrast refers to the ratio of brightness between the foreground and background. If the foreground is significantly brighter than the background, it stands out; conversely, if it is much dimmer, it may fade into the background. This ratio, defined by the luminance of both foreground and background, is critical for visibility.

The ability of individuals to discriminate between two objects varies as a function of contrast. Enhancing contrast can compensate for diminished acuity, particularly in peripheral vision, by making peripheral stimuli larger. Thus, to improve object perception in low light or when utilizing peripheral vision, enlarging these objects can be an effective strategy, as we previously discussed.

By increasing the size and spacing between letters, we can enhance legibility. To effectively utilize both the foveal and peripheral vision, it is beneficial to increase the letter spacing and the size of the letters. Doing so aids in understanding the content with greater clarity. This improvement in comprehension occurs only when one can effectively distinguish the spacing between letters. The better we can read the letters, the more meaning we can extract from the text and understand what the sign conveys.

Thus, the legibility of letters is significantly influenced by their size. Another crucial aspect to consider is that a reduction in contrast can impair visual acuity. If the foreground and background have minimal differences in brightness or luminosity, the ability of individuals to perceive gaps or distinguish between two objects or letters diminishes. Consequently, a certain level of contrast is necessary for humans to function effectively and to differentiate between objects or letters.

The use of color plays an essential role in designing displays and information projection systems. Colors assist in segregating a target from its background. Employing brighter and lighter colors enhances contrast, enabling easier differentiation between text that needs to be read and the surrounding elements. For instance, a black-on-white background or gold-on-black lettering are effective methods for improving the visibility of targets against their backgrounds.

Colors can also facilitate grouping; objects of similar colors tend to be grouped together, while those of different colors are categorized separately. By employing various colors for both the background and foreground, individuals can more easily distinguish and group the elements.

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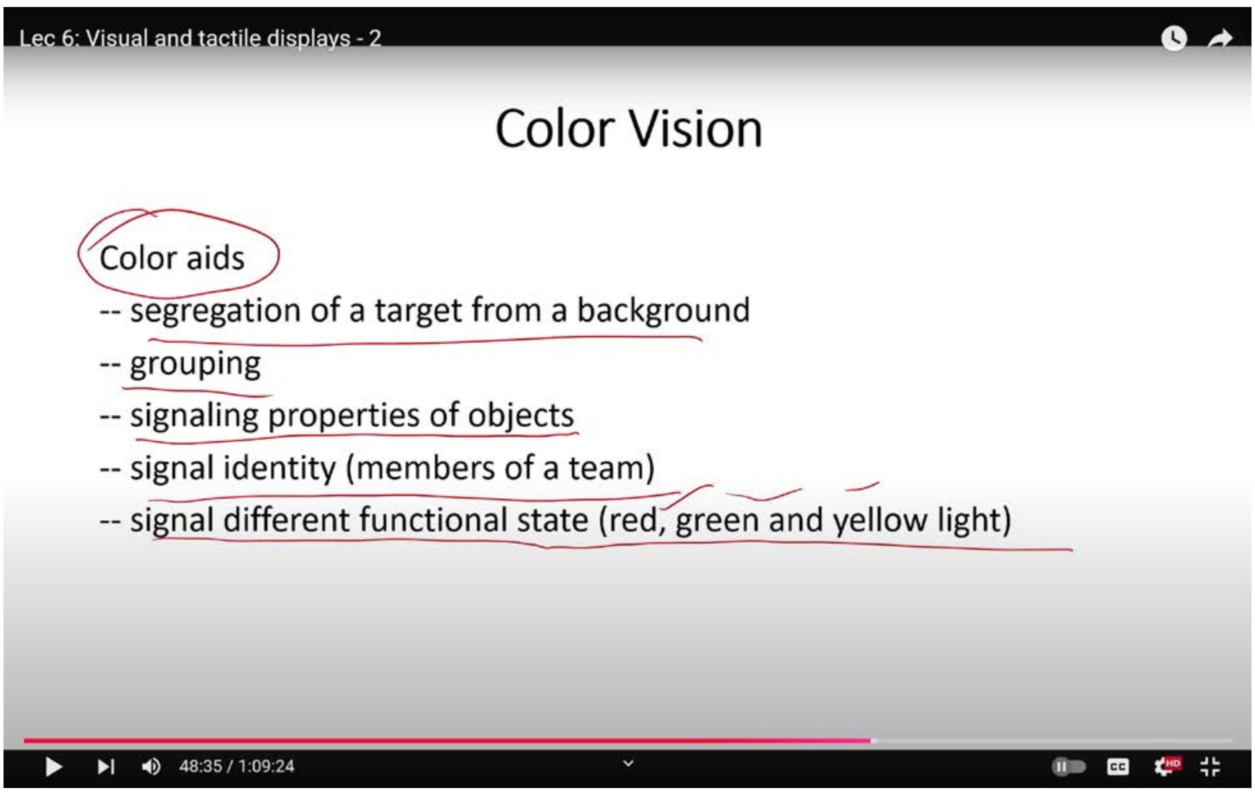

Additionally, colors convey signaling properties of objects. For example, a red object often indicates that it should not be touched, while a green object suggests that it is safe to handle. The signaling properties of an object can influence actions, such as whether to press or not press something. The identity of signals is also relevant in contexts like sports; for example, in football matches, a specific color worn by a team signifies its members, differentiating them from members of opposing teams.

Colors also signal different functional states; for instance, red indicates "stop," green indicates "go," and yellow signals "proceed with caution." This color system is widely used in traffic lights, facilitating immediate understanding and appropriate action by observers.

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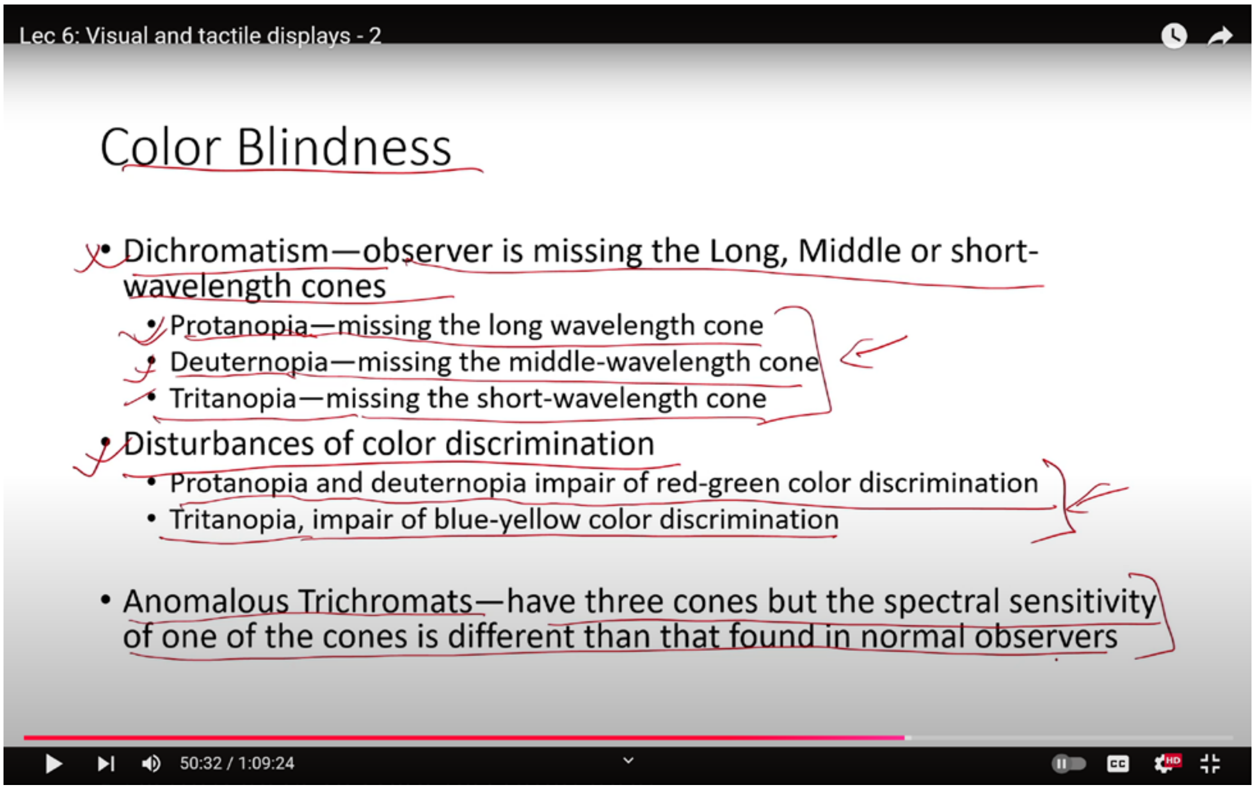

Now, let us briefly discuss color blindness. A condition known as dichromatism occurs when an observer is missing one of the cone types responsible for color vision, long, middle, or short wavelengths. There are three forms of dichromatism: protanopia, which involves the absence of long wavelength cones; deuteranopia, which entails the absence of middle wavelength cones; and tritanopia, characterized by the absence of short wavelength cones. The absence of any of these cones means that the individual will not be able to perceive certain colors or color contrasts.

These cones exhibit dual-end sensitivity, which means that if one end becomes overly sensitive, the contrasting color that one begins to perceive is known as the color aftereffect. For instance, if an individual looks at a red object and then shifts their focus to a white screen, a contrasting color may become visible. This phenomenon is linked to the theory of color vision, which posits that an alternating color will be perceived more sensitively as a result of the aftereffect.

Disruptions in color discrimination occur in cases such as protanopia and deuteranopia, which impair red-green color discrimination, while tritanopia affects blue-yellow color discrimination. Individuals with normal trichromatic vision possess three types of cones; however, the spectral sensitivity of one of these cones may differ from that of typical observers. As a result, one cone may become more active, causing colors in that particular wavelength to be perceived more vividly than those in other wavelengths.

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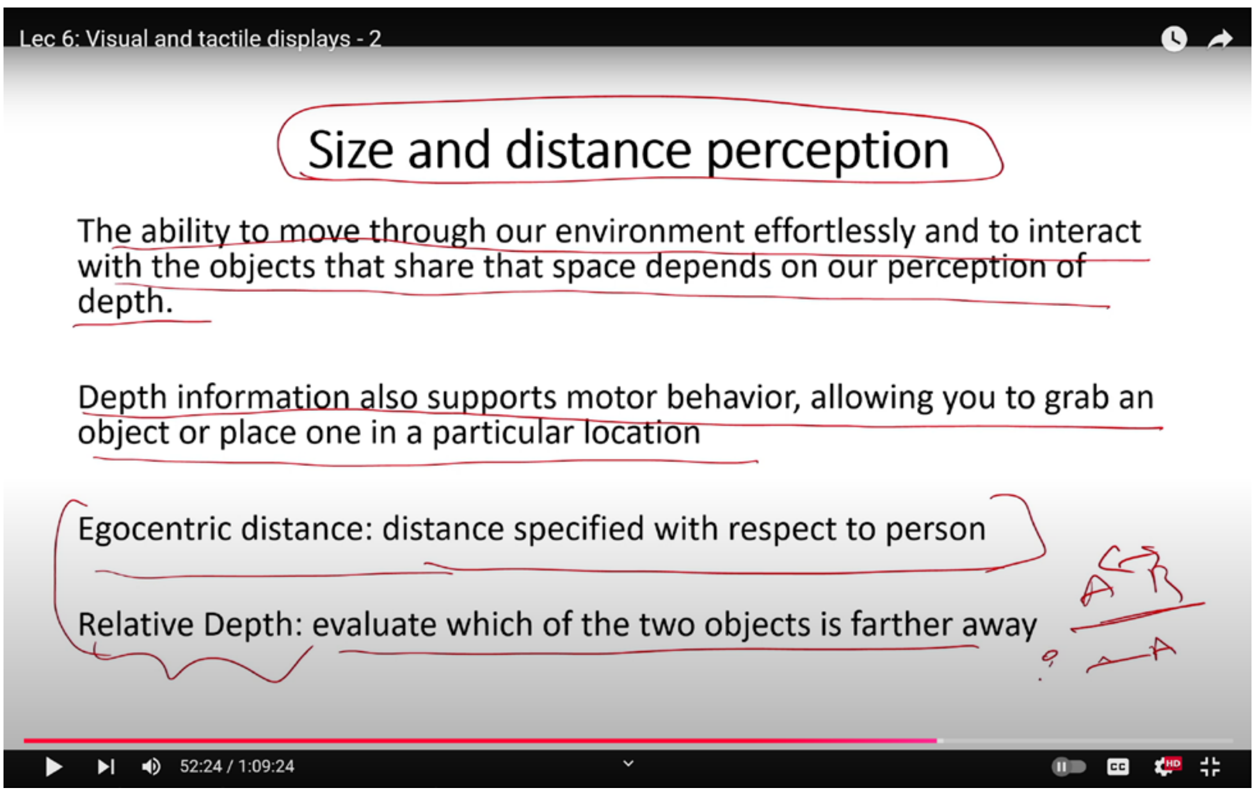

Next, we will explore the relationship between size and distance perception. Does the perception of different distances get influenced by the size of an object? Specifically, does the apparent size of an object impact distance perception? Ultimately, our focus is on how size affects human perception and our understanding of three-dimensional space. The ability to navigate our environment effortlessly and interact with objects within that space relies heavily on our depth perception. Depth perception refers to how our two-dimensional visual input creates a sense of depth, which is the key concept we aim to elucidate here.

Depth information also supports motor behavior, allowing individuals to grasp an object and place it in a specific location. But why is depth perception necessary? Because interacting with objects in the environment, whether grasping something from the environment or placing something into it, requires knowledge of the object's exact location. Therefore, visual perception is essential for accurately reaching for objects.

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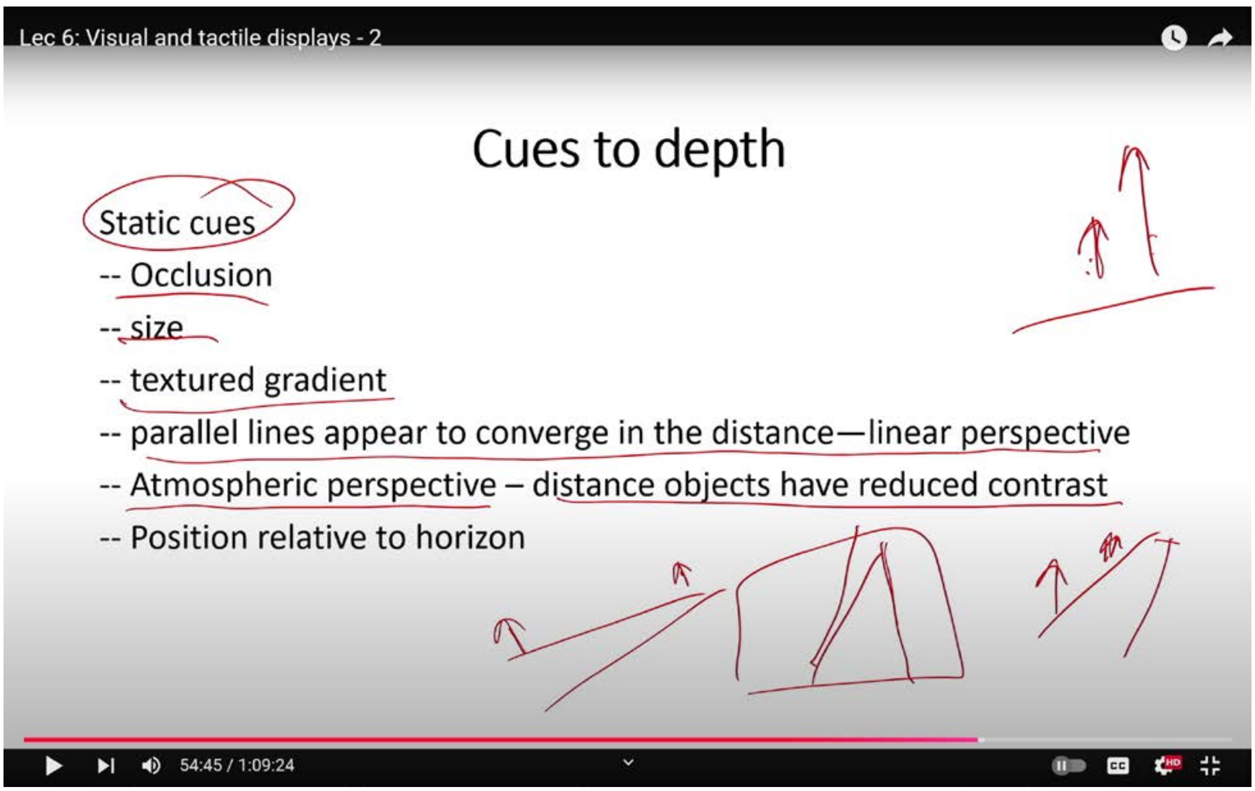

There are two types of distance measurements. The first is known as egocentric distance, which refers to how far an object is from oneself. This approach measures depth in terms of personal distance: "How far is something from me?" The second type is called relative depth, which assesses the distance between two objects. For example, how far is object A from object B? This inquiry exemplifies relative depth. When considering the distance between two objects, A and B, the calculation used here represents relative depth, while the question of how far object A is from me pertains to egocentric depth. Both types of information are utilized for measuring depth.

Several cues, or signals, help individuals measure depth. One category of these cues is called static cues.

Occlusion is one such cue, referring to the obstruction or hiding of one object by another. When one object obscures part of another, we tend to believe that the obscured object is larger than the object doing the hiding. For instance, if two buildings are present and one building casts a shadow on part of the other, we might conclude that the obscured building is larger than the one casting the shadow.

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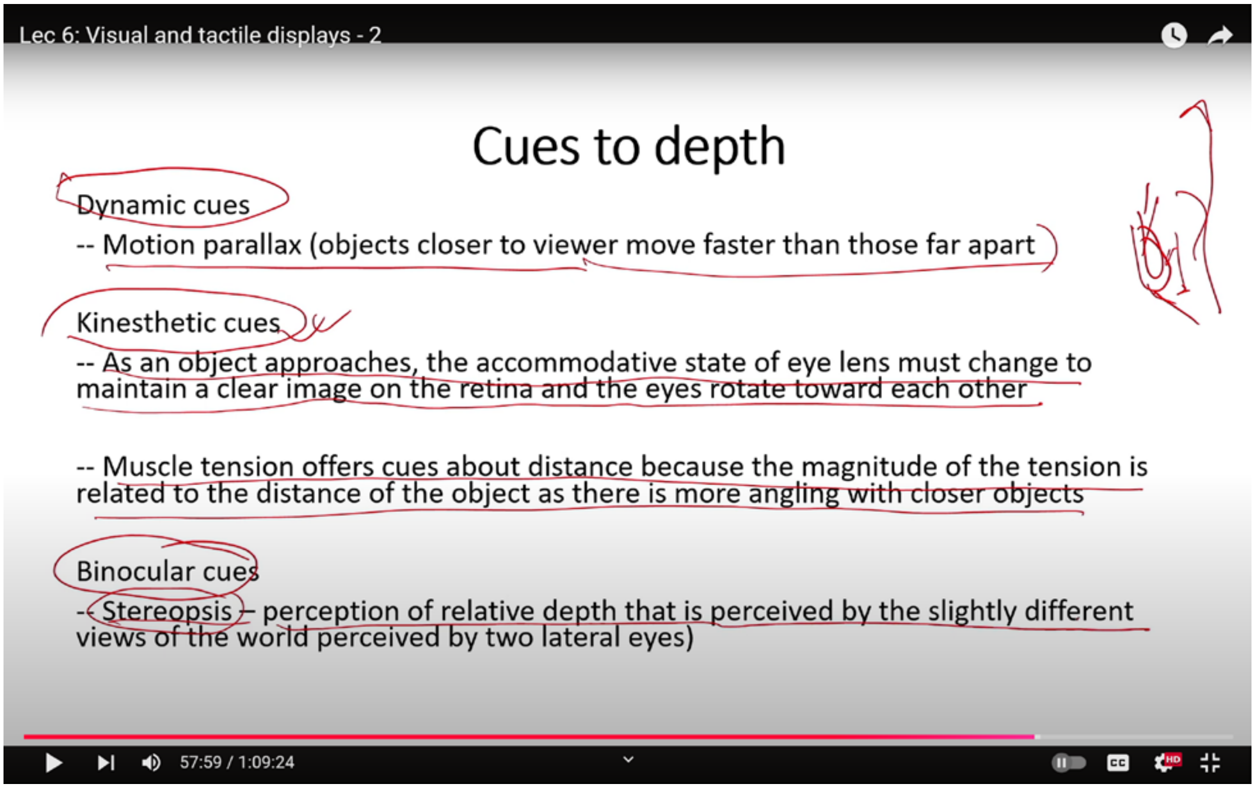

Another static cue is size comparison in a 2D space. For example, when comparing two objects, we might perceive one as being larger or closer than the other. If I draw two arrows, the comparative size of these arrows will indicate their relative distances in the environment.

Texture gradient also aids in depth perception. As we move further away, textured objects, such as cobblestones, lose their distinct boundaries and appear to cluster together. This clustering effect leads us to perceive these objects as being more distant.

Parallel lines can also indicate depth through linear perspective. When lines converge within an image, they suggest depth, with objects at the far end of the line appearing more distant than those at the near end.

Atmospheric perspective is another cue; distant objects tend to exhibit reduced contrast. For example, an object with lower contrast appears less bright than a brighter object. We interpret this brightness as a result of light scattering, which indicates that the brighter object is farther away.

The position of objects in relation to the horizon also informs our perception of depth. We initially look at the horizon, and the relative distance or size of objects compared to it can provide cues about their positions. Objects situated closer to the horizon tend to appear smaller and further away than objects positioned higher in our visual field.

Dynamic cues are also employed in depth perception. One such cue is motion parallax. If you have ever traveled in a car, you may have noticed that objects nearer to you appear to move faster than those that are further away; this phenomenon is known as motion parallax.

Additionally, when focusing on objects, a fixation point is established. Objects that are farther from the fixation point appear to move toward you, while objects closer to the fixation point move in the opposite direction. This characteristic of movement provides insight into the spatial relationships of objects.

There are also kinesthetic cues involved in perceiving depth. As an object approaches, the accommodative state of the eye and lens must adjust to maintain a clear image on the retina, causing the eyes to rotate inward. When an object comes close, the length of the eye adjusts its accommodation to increase its focusing power, allowing for a sharp image of the approaching object. The greater the bending of the eye, the more muscle tension occurs in the ciliary muscle. This muscle tension is interpreted by the brain as an indication of how close or far an object is, serving as an internal mechanism for observing and perceiving motion.

Muscle tension provides cues regarding distance because the magnitude of the tension is related to the distance of an object, with greater angling for closer objects. If an object is near, the lens of the eye becomes shorter; conversely, if the object is farther away, the lens elongates. This motion affects the ciliary muscles. The ciliary muscle works to bend the lens, and as it bends more, the ciliary muscle contracts further, creating tension. This tension is then interpreted by the brain as an indication of distance.

There is a specific type of cue known as a binocular cue, which includes a feature called stereopsis. A simple experiment can demonstrate this effect: hold your finger in front of you and observe it first with your left eye while closing your right eye, and then repeat the observation with your right eye closed. You will notice that the finger appears to move and seems to occupy different distances, demonstrating a relative shift.

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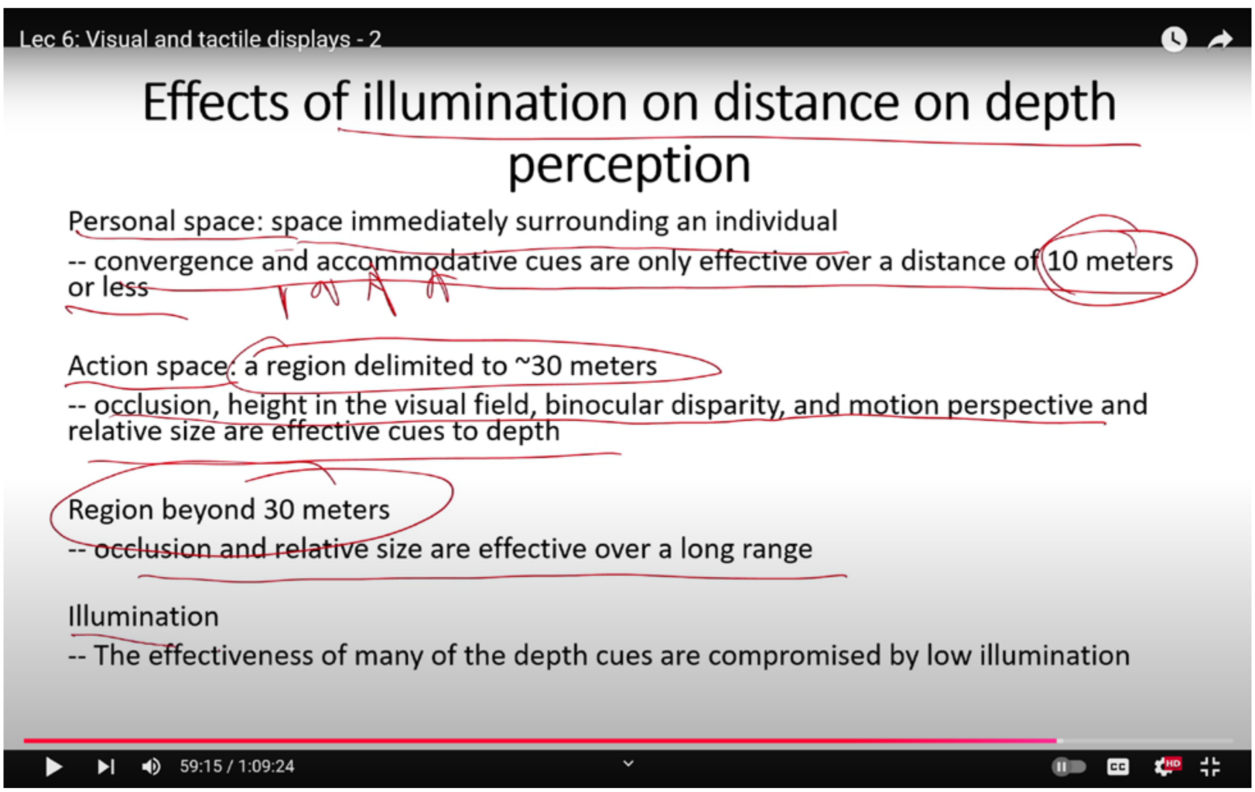

This phenomenon helps you understand depth perception through the slightly different views provided by each lateral eye. For instance, take your hand, extend your finger, and place it in front of your nose. Look at it first with one eye, then with the other, closing the alternate eye. You will observe a relative shift in the position of the finger, which illustrates the concept of binocular cues.

Now, does illumination affect distance and depth perception? There are three types of spaces that individuals occupy, and each is affected differently by illumination. The first is personal space, which extends for approximately 10 meters around an individual. In this space, only convergence and accommodation cues are effective. Accommodation refers to the lens's ability to bend light.

The second space is known as action space, which extends to around 30 meters. Within this region, various cues, such as occlusion, height in the visual field, binocular disparity, motion perspective, and relative size, are effective for depth perception. Beyond 30 meters, occlusion and relative size become the primary cues used to perceive depth.

The effectiveness of many depth cues can be compromised by low illumination. As the level of illumination decreases, the efficacy of these depth cues also diminishes. This concludes the discussion on visual displays.

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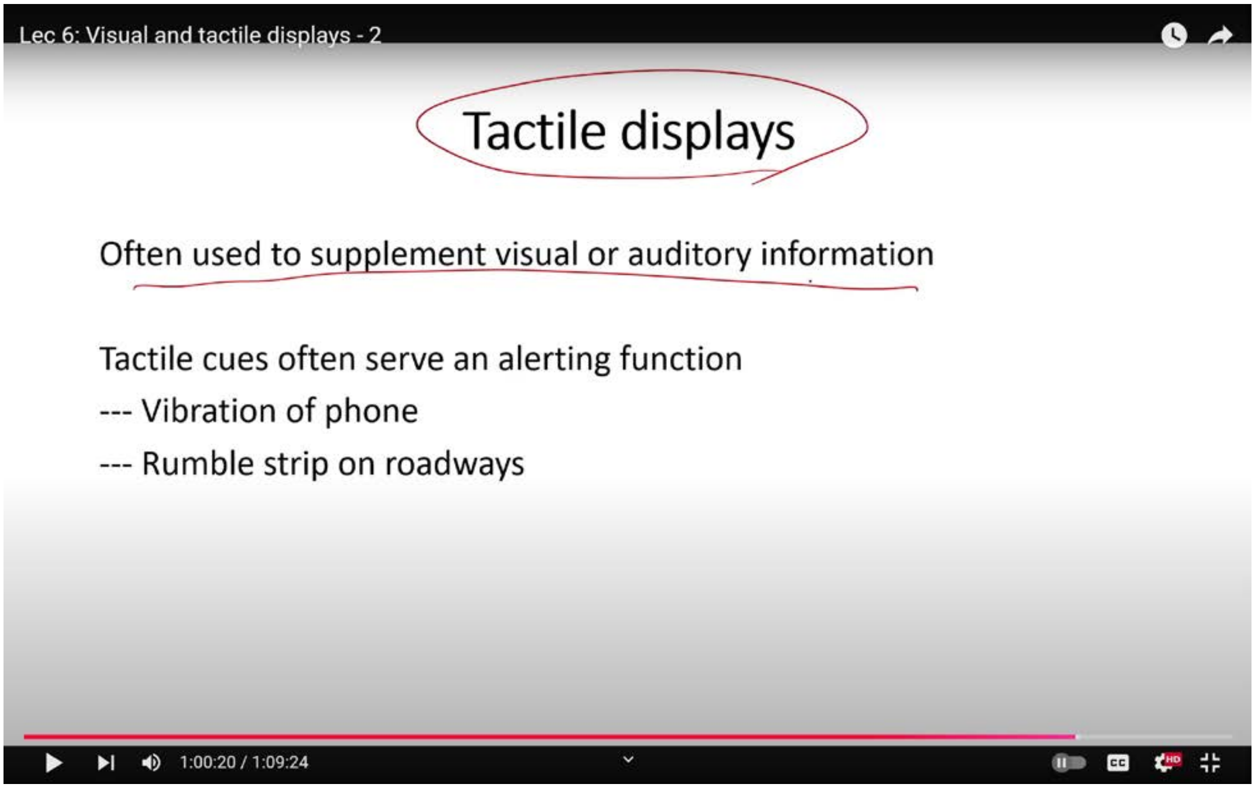

We will now briefly examine two types of displays: one is called the tactile display, which relates to the sense of touch. Tactile displays are always used to supplement visual and auditory information. For example, the vibration of your phone acts as a tactile display, providing additional information that a call is incoming. This tactile feedback works in conjunction with visual cues to help you understand what is happening.

There is only one situation where the tactile display functions independently, which is in the case of Braille. Individuals who are visually impaired can read Braille by touching the surface, allowing them to understand what is written. In most instances, tactile displays are used alongside visual and auditory information.

Tactile cues often serve as alerting functions. For instance, the vibration of a phone or a rumble stick may indicate that you need to slow down your vehicle, while the phone's vibration alerts you to an incoming message or call. Within the tactile display, there are two types of cues: kinesthetic cues and proprioceptive cues.

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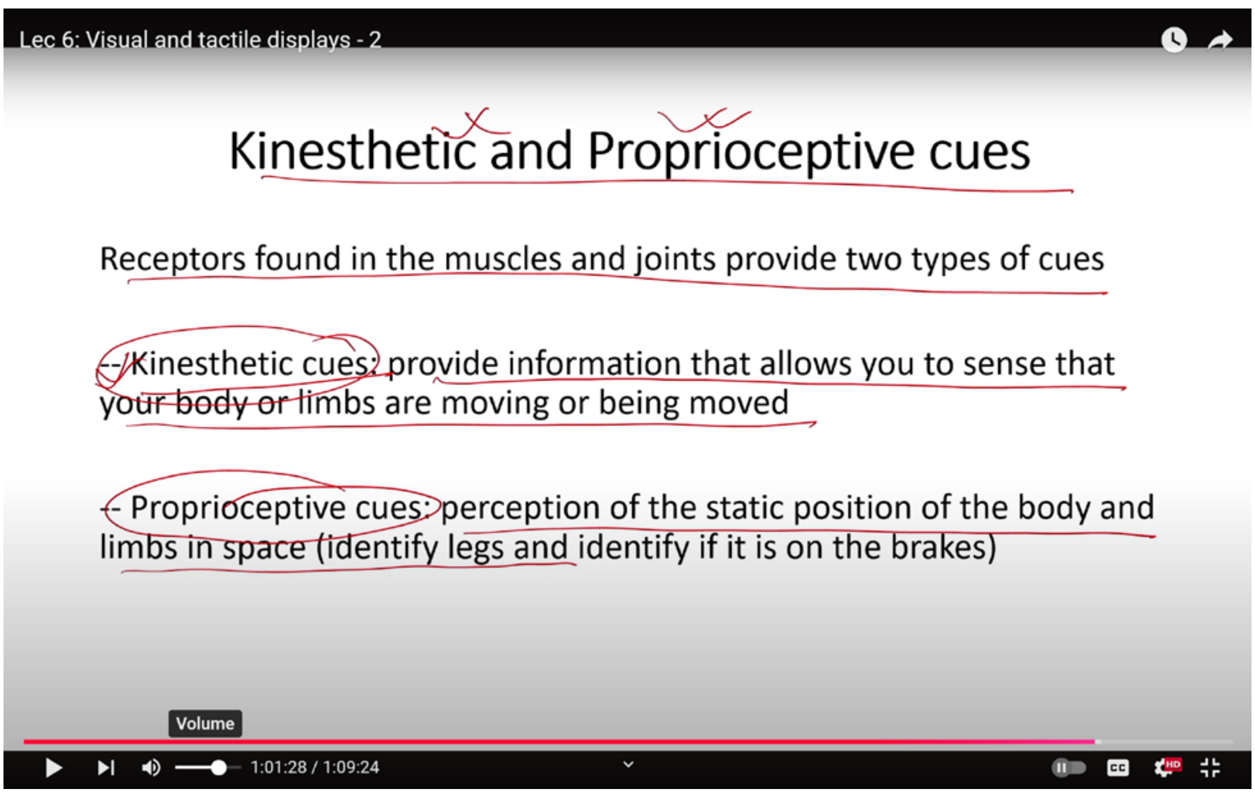

Kinesthetic cues provide information that allows you to sense the movement of your body and limbs. As your body and limbs move, an internal queuing system informs you of these movements, allowing you to recognize that a specific part of your body has moved.

Proprioceptive cues, on the other hand, refer to the perception of the static position of your body and limbs in space. For example, using these cues enables you to know the location of your legs, whether they are on the brake pedal, or the position of your hand.

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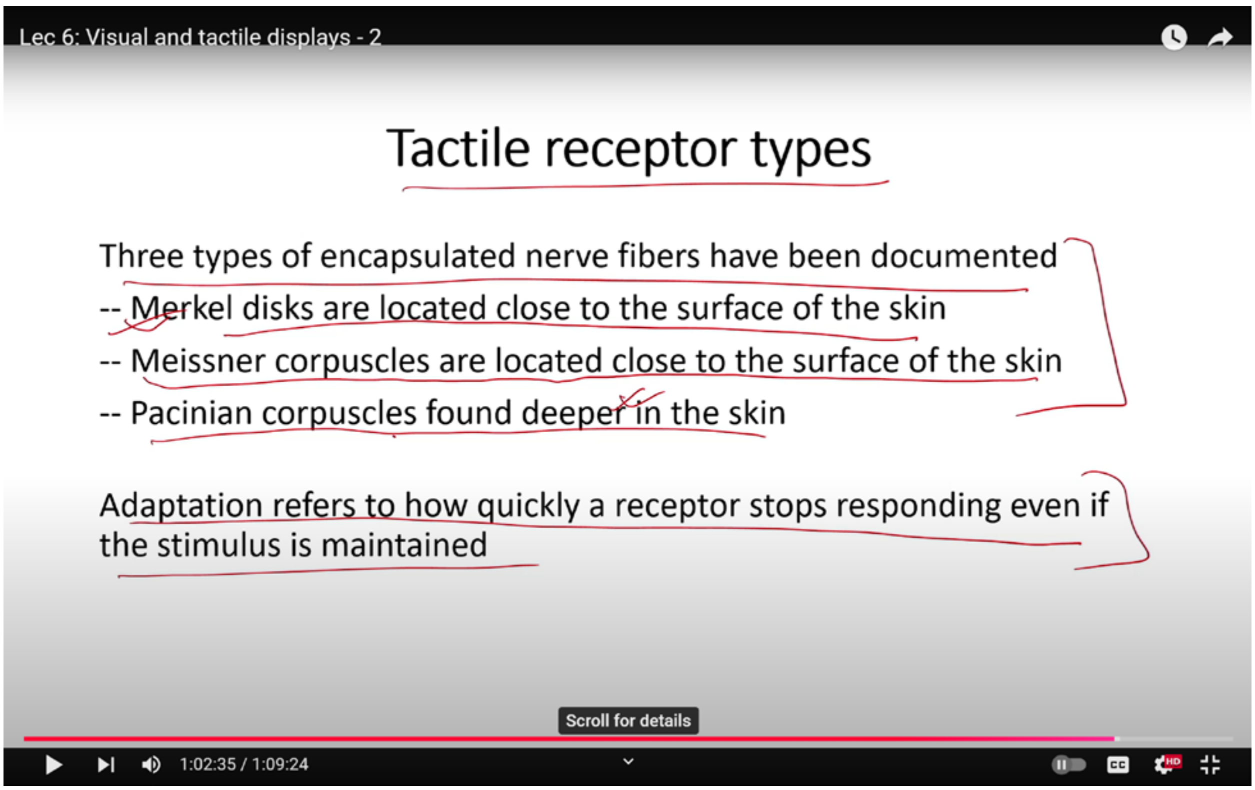

Regarding tactile receptors, there are three main types of receptors, which are nerve endings. Some are free nerve endings, while others are encapsulated nerve endings. The three types of tactile receptors include Merkel disks, located close to the surface of the skin; Meissner corpuscles, also situated near the skin's surface; and Pacinian corpuscles, which are found deeper in the skin. These receptors assist in providing tactile displays related to pressure.

Adaptation refers to how quickly a receptor stops responding even when the stimulus remains constant. This property enables individuals to stop responding to a stimulus after some time. For example, consider a room with a ticking clock. Upon entering for the first time, you may notice the ticking sound, but over time, you may become unaware of it, even though the clock continues to tick. This phenomenon is called adaptation, which serves as a protective mechanism for the nervous system, preventing overindulgence or overstimulation of a particular sensory system.

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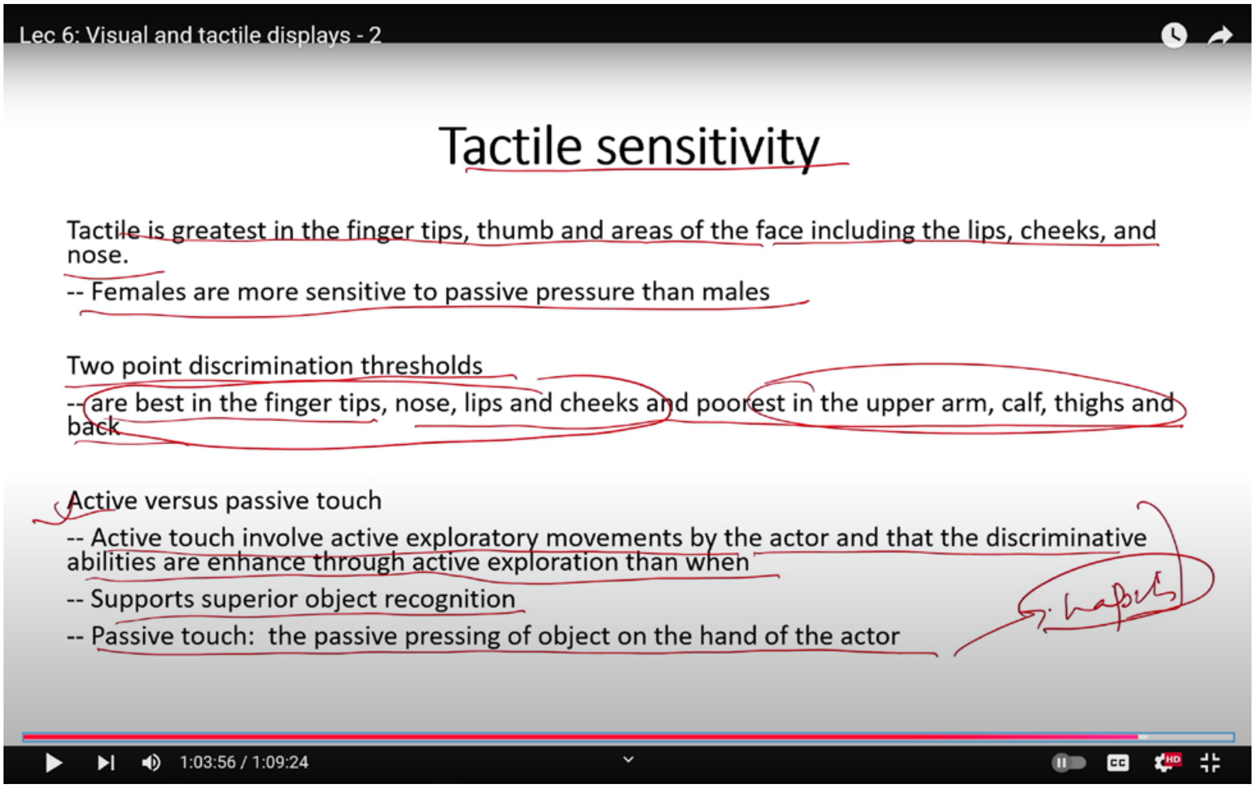

Tactile sensitivity is greatest at the fingertips, thumbs, and areas of the face, including the lips, cheeks, and nose. Research indicates that females tend to be more sensitive to passive pressure than males. Lastly, there is the two-point discrimination threshold, which refers to the ability to perceive two closely spaced stimuli as distinct points rather than one.

You may have observed three-point and four-point touch on screens. Two points refer to two different pressure sensations or two distinct objects creating pressure. The areas where sensitivity is greatest include the fingertips, nose, lips, and cheeks, while sensitivity is poorest in the upper arm, calf, thighs, and back. Therefore, when two objects or two hands make contact, perception is most accurate in these sensitive areas and least accurate in the less sensitive regions.

Active versus passive touch: Active touch involves voluntary movement by the individual, enhancing discriminative ability through active exploration. This process supports superior object recognition. In contrast, passive touch refers to the passive pressing of an object. These factors contribute to the development of a concept known as haptics. Thus, active touch focuses on exploration, while passive touch involves simply making contact with an object.

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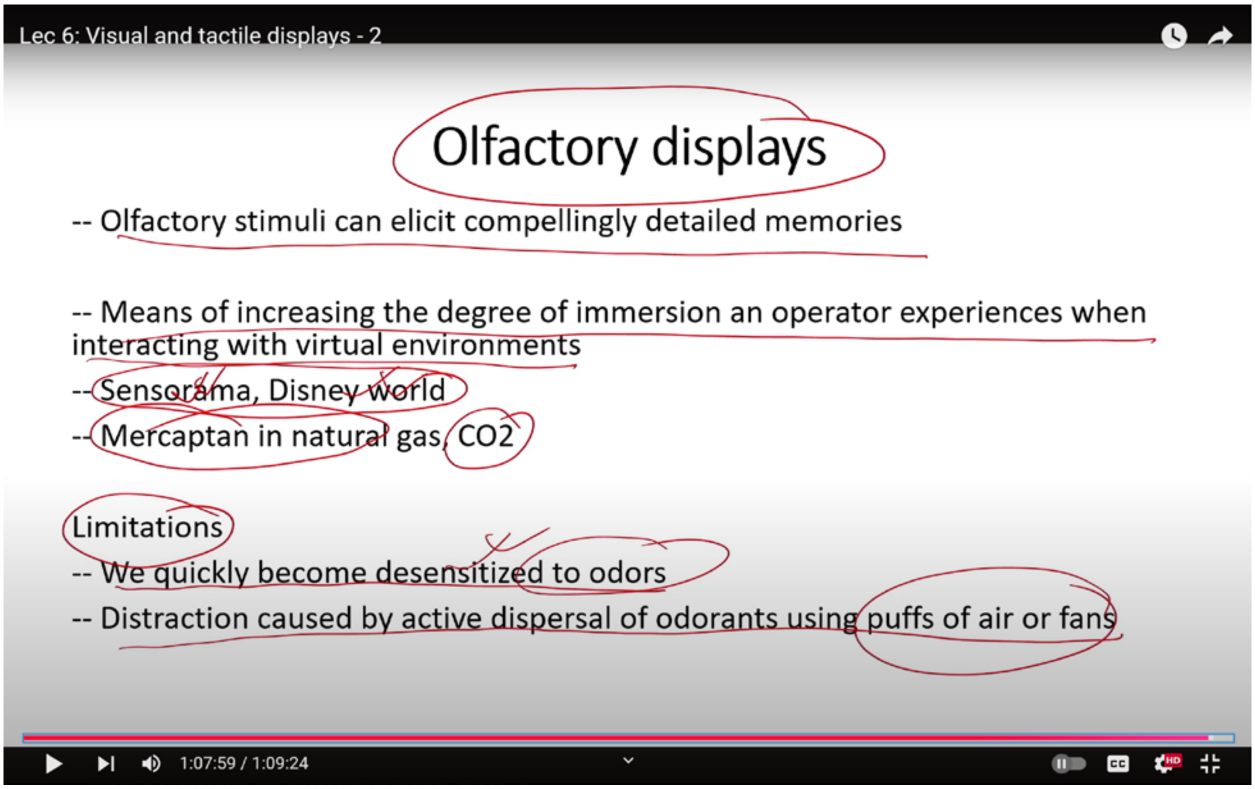

The last type of display we will discuss is the olfactory display. The olfactory system in our body assists us in discriminating between objects or conveying certain types of information. A notable example is natural gas. When a gas leak occurs, such as with cooking gas, a pungent odor is detected. This pungent smell is not the scent of the gas itself but rather a chemical called mercaptan, which is added to the gas for safety purposes. This application of the olfactory system to provide warnings is termed an olfactory display.

Olfactory stimuli can evoke vivid, detailed memories. For instance, the smell of freshly baked bread or a specific scent from your childhood can trigger certain memories. When that smell reappears, those memories may resurface. The olfactory senses are among the most active and compelling senses, providing detailed recall of past experiences.

To enhance the degree of immersion in operator experiences while interacting with virtual environments, the olfactory senses play a significant role. One historical example of utilizing the olfactory sense as a display system is Sensorema, a game developed in the late 2000s. In this game, participants sat in a box that simulated bike riding through New York City, where various scents enhanced the experience while they held bike handles and navigated the streets. This virtual environment provided an enjoyable and immersive experience.

Another example can be seen at Disney World, where specific scents are used to create an immersive experience, transporting visitors into a whimsical world. Such olfactory cues are designed to elicit detailed memories and craft unique experiences. We previously mentioned mercaptan, which is added to natural gas to indicate leaks, and the oil of wintergreen, which is used in fire extinguishers to suggest the presence of carbon dioxide gas.

However, it is important to consider the limitations of the olfactory system. Despite its effectiveness, there are several challenges that prevent its more frequent use. First, we rapidly become desensitized to odors. For instance, after applying several perfumes to your palm, you may find it difficult to distinguish between them. This desensitization occurs because the olfactory nerve is the largest sensory nerve and bypasses the thalamus, allowing it to carry only limited information. As a result, it struggles to differentiate between numerous stimuli or various types of stimuli, making olfactory displays less effective in situations requiring precise discrimination.

The second limitation involves distractions caused by the active dispersal of odors using props, air, or fans. Consider the experience of having perfume sprayed onto your face, this can be unpleasant. Such dispersal takes time, leading to uneven concentrations of scent; some areas may have a strong odor while others have none, depending on air flow dynamics. Consequently, this type of display system is not suitable for warning systems or labeling.

In today's session, we examined the visual system, focusing on the capabilities and limitations of human vision. We explored how the properties of the human visual system can inform display design. Additionally, we discussed tactile displays, their benefits, and their applications in creating warning signs, labels, and display systems. Finally, we covered olfactory displays and their role in generating active warning sign systems. We will conclude this class here. Thank you for your participation.

Namaskar, and goodbye from the MOOC studio.