

Ergonomics in Automotive Design
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Module - 05
In-vehicle and external visibility of the driver
Lecture – 07
Human Fields of View and Driver's Fields of View

Welcome to the course Ergonomics in Automotive Design.

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Massive Open Online Course (MOOC)
The Ministry of Human Resource Development (MHRD)

Module-5:
In-vehicle and external visibility of the driver

- o Human fields of view
- o Driver's fields of view (in side vehicle and outside vehicle)
- o Field-of-view through windshield and windows
- o Field of View through mirrors (side and rear view)

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Now, we are going to discuss our 5th module that is in-vehicle and external visibility of the driver. So, under this module, we will discuss four topics; first one - human field of view, second – driver's field of view inside vehicle and outside vehicle, third one - field of view through windshield and windows, and fourth one - field of view through mirrors; side mirrors as well as rear-view mirror.

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Human fields of view

Field of View (FoV): defined as the region or extent of the external world/ space which is visible at an instant during steady fixation of gaze in one direction.

(SAE J985) Extent of visual field

Horizontal (left part) and vertical (right part) plane of the human field of view (Dukic 2006)

- ✓ Monocular (FoV by left or right eye),
- ✓ Binocular (FoV common by both eyes)
- ✓ Ambinocular (sum of FoV of both eyes)

Binocular field of view as 60° vertically, 25° up and 35° down (Henson, 1993).

Now, first, we should know; what is field of view? So, while we are discussing about the human field of view. So, we need to understand; that what is field of view? So, as per the definition, we can define field of view as the region or extent of the external world or space which is visible at an instant during steady fixation of gaze in one direction.

So, when we are looking at a particular direction, at that time, the extent of the external world which we are perceiving through our eyes, that is the field of view. Now, according to Society of Automotive Engineers (SAE), J standard, J985, the extent of visual field; if we look at this figure; then for the left eye. If we consider the left eye, the monocular field of view, means, only by left eye, we can see 150 degrees. So, starting from one side; left side, up to 90 degrees, that is the mid-line, straight forward line, and across the nose, we can see another 60 degrees. So, this side 90 degrees, and so, the first portion, this is 90 degree and after that another 60 degrees. So, total 150 degree, this is the monocular field of view for left eye.

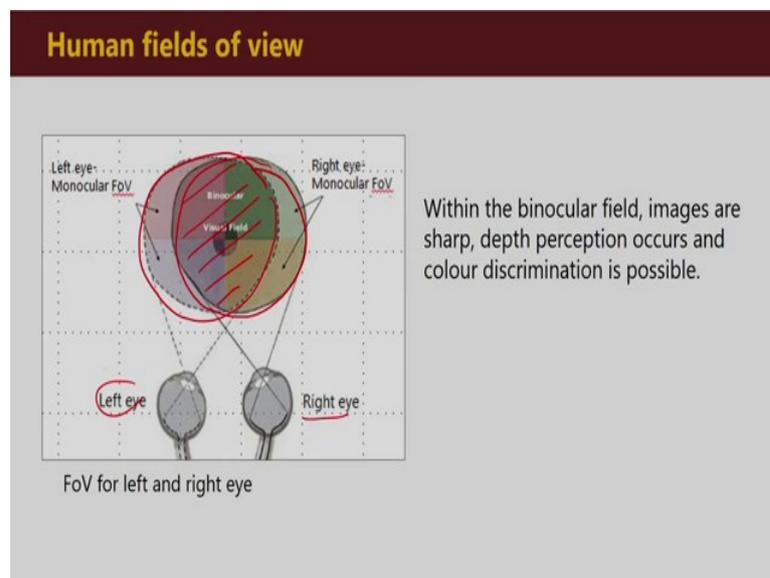
Similarly, for the right eye, from the side-line, we can see up to 90 degrees on the same side; right side and across the nose, we can see another 60 degrees. So, total 150 degrees. So, this is the monocular field of view for the left eye, and this is a monocular field of view for right eye. Then, the overlapping area. So, this middle portion, this is the overlapping zone. So, the size of the overlapping zone, that is the binocular field of view, that is 120 degree. So, whereas, monocular field of view for both the eyes is about 150

degree, but the binocular field of view is 120 degree. Now, the one aspect is monocular field of view while we are visualizing the external world by either left eye or right eye.

While we are looking at the external world; the common zone for both eyes; right and left that is called binocular field of view. The third area; that is the ambinocular field of view, that is actually the sum of field of view, for both eyes. So, for both left eye and right eye; total how much area we can see, that is from this point to up to this much, means, 180 degree; where there is only by the left eye, only by the right eye; at the same time both left eye and right eye. So, monocular field of view, binocular field of view and then again monocular field of view for the right eye. So, this total zone is defined as the ambinocular field of view.

Now, binocular field of view; vertically if we consider, then it is 50 to 55 degree upward and 60 to 70 degree downward. So, the downward field of view is more. Binocular field of view; as defined by the Henson (1993), it is 60 degree vertically, 25 degrees up and 35 degree down.

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Now, if we see the perspective view of the binocular field of view, earlier we were discussing the horizontal field of view, but if we consider both; horizontal field of view as well as vertical field of view, then how much is the binocular field of view? So, if we look at this image. So, this is the left eye, and this is the right eye. For left eye; this is the monocular field of view for the left eye.

Similarly, for the right eye; this is the monocular field of view, then the middle portion, this common zone, that is called the binocular field of view for both eyes. So, binocular field of view is; this zone. So, within binocular field of view; images are sharp, depth perception occurs, and color discrimination is possible. So, this binocular field of view is very important for our visualization of the external world.

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Human fields of view

Range of human neck movement

During viewing, either both eyes and/or neck move to focus the object on the retina.

Horizontal (left part) and vertical (right part) range of human head/neck movements (Dukic 2006)

- ✓ **Stationary field** : Visual targets within a visual angle of $< 30^\circ$, there are rarely eye movements . ✓
- ✓ **Eye field** : Targets presented between 30° and 80° view cone, there are supplementary eye movements;
- ✓ **Head field** : Targets beyond 80° there are requirement of complementary head movements ✓

Now, while we visualize the external world or we are looking at the object in our external world or perceiving visual information or light rays are coming and entering through our eyes, then we perceive different information.

This visualization is not only eye dependent, that is actually, depends on the movement of eye as well as neck. Sometimes, we see only using our eyes; left eye, right eye and sometimes we move our neck to visualize the object and there is also another situation, where we move both our neck as well as eye. So, only eye movement is possible, only neck movement is possible, at the same time neck and eye both moves together to visualize object. So, now, here we are discussing the range of motion of the neck or range of movement of the neck.

So, generally, maximum and easy reach. So, easy neck movement reach, easy head movement or neck movement, all these are possible. If we see the lateral view, means, 45 degree left and 45-degree right. Similarly, maximum head movement or neck movement may happen, that is 60 degrees left and 60-degree right. On the other hand, if we

consider the up-down movement of the neck, then easy neck movement or head movement, it is 30 degree up and 30 degrees down whereas maximum neck movement is 50 degree up and 50 degrees down. During viewing; either both eyes and/or neck movement occurs, as we discussed earlier, to project the image on the retina.

So, in this image, what is shown? As we already mentioned, that is horizontal movement, that is the left part, and this is the vertical range of head and neck movement. Now, we can categorize our field of view, like a stationary field of view, eye field, and head field. So, now, what is stationary field? So, visual targets within a visual angle less than 30 degrees; when we are looking at a particular point, around that line of sight, within a 30-degree view cone, whatever information is presented, that we can visualize without significant eye movement. So, significant eye movement is not required. Although eye always moves, dwell always happens, but significant eye movement is not happening within a view cone of 30 degrees.

So, without significant eye movement, we can visualize the information presented within a view cone of 30 degrees, that zone is defined as the stationary field of view, where significant eye movement not required. Next point is eye field. In case of eye field; target presented within an angle of 30 degrees to 80-degree view cone, then what happens? Supplementary eye movement is required, while we are looking at a particular point, without eye movement, it is not possible to visualize any object or any information or any visuals presented within a view cone of 30 to 80 degree. So, there the eye movement is required, that is why that field of view, that zone is called eye field.

The third area is the head field. While we are looking at a particular point, around that line of sight, if any information, visuals are beyond the 80-degree view cone, then head movement is required. So, that field is called head field. So, while we are pointing at a particular object, say for example, for any human being, while he or she is pointing at a particular location, around that line of sight, up to 30 degree, there is no significant eye movement, that is called stationary field; after that, if he or she wants to see, then there is requirement of eye movement. So, up to 80 degrees, he can see with the help of eye movement, that is an eye field, and beyond that, if he or she wants to see, then he or she has to move the neck.

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Human fields of view

Vancott and Kinkade (1972):

- ❑ 15° angle -- most comfortable viewing (for placement of most required displays)
- ❑ 30° angle -- frequently used for comfortable viewing where frequent changes of gaze between two equally important visual targets are equally critical.

Grandjean 1987: common reading distance of approximately 50.0 cm, character height should be between 3.0-4.3 mm

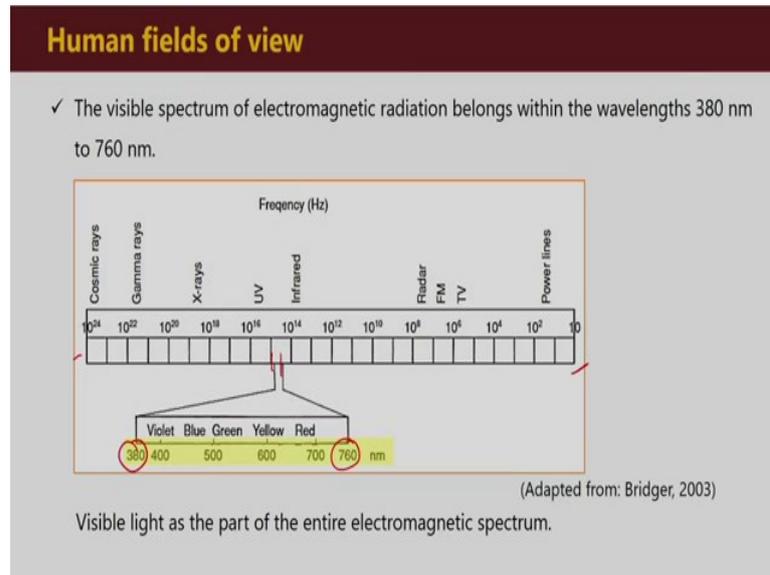
CDC 2000 : comfortable viewing distance of 46.0-76.0 cm away from eyes for VDU work.

Vancott and Kinkade (1972) mentioned the comfortable viewing angle. So, 15 degree is a comfortable viewing angle for positioning the most important display or most frequently used display. So, our laptop, monitor or display screen should be positioned within an angle of 15 degrees below the horizontal eye level.

Similarly, if the number of displays are more or there is requirement, that for frequently used comfortable viewing, where frequent changes of gaze between two or equally important visual targets, where number of visual targets is more, we have to shift our eye from one point to another point or from one display to another display, then the display should be positioned within an angle of 30 degree, so, that we can comfortably visualize those displays.

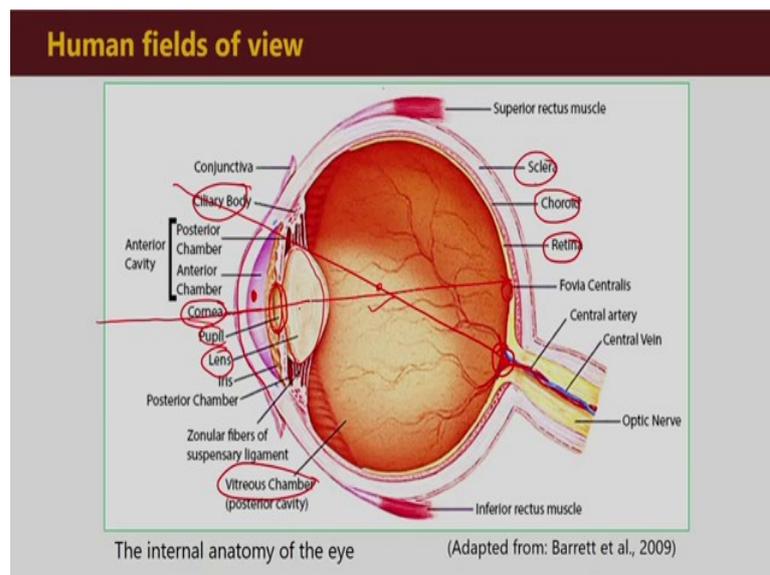
Grandjean (1987) mentioned about the comfortable viewing distance. So, what is comfortable viewing distance? Comfortable viewing distance is approximately 50 centimeters, while the character height or the font size is 3 to 4.3 millimeter. Centre for Disease Control, USA in 2000, prescribed that comfortable viewing distance ranges between 46 centimeters to 76 centimeters away from the eyes for visual display unit workstation.

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Now, we are moving to the human field of view; the visible spectrum of electromagnetic radiation. From this image, we can see the electromagnetic spectrum. Out of this, only this zone, that is starting from 380 nanometers to 760 nanometers, within this range of electromagnetic radiation human can see object. So, human eye is sensitive within this electromagnetic wavelength. So, that is 380 to 760.

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Now, to understand the human field of view, it is very important to understand the anatomy of eye, different parts of the eye, that how light enters inside the eye and image

is formed. So, for that purpose, now, we are going to discuss about the anatomy of eye. So, if we take the cross-section of eyeball, then what we can see? There are mainly three layers. So, the innermost layer, you can see in yellow color, here, that is the retina. Next, there is another layer called choroid; then the third layer is the Sclera. So, when we see from the outside, that white portion of the eye, that is actually the Sclera.

Now, from the front portion, the outermost layer of the eye, which is visible from the outside, that portion is actually, this is that one, so, that is called Cornea. So, the first one is the cornea, after that there is another, this zone is called Pupil. So, how Pupil is formed? There are actually Iris muscles; two types of Iris muscles are there. So, one is a radially arranged and another is concentrically arranged. So, Iris muscles, at the center of this Iris muscle arrangement, there is a hole, that hole is called Pupil.

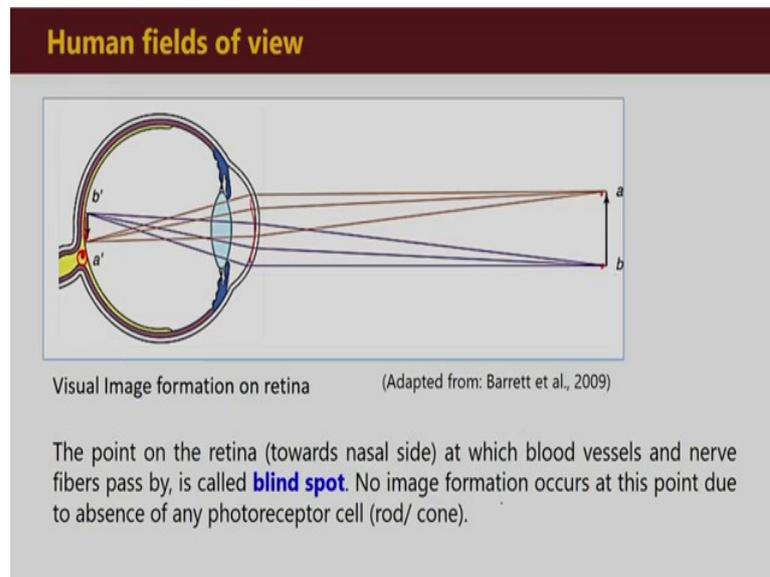
So, the diameter of the Pupil is maintained by the muscle tone of the Iris muscles. So, while the radial Iris muscles constrict, then the diameter of the Pupil increases, whereas, concentric Iris muscles contract, then the diameter of the Pupil reduces. So, behind the Pupil, there is a Lens and Lens is actually suspended through suspensory ligament and attached with this ciliary body.

So, ciliary body and ciliary ligaments actually hold the Lens. So, from outside; first portion is the Cornea, then there is a chamber; liquid field chamber, that liquid is called aqueous humor; after that there is a hole, that hole is called Pupil, then there is the Lens, and after the Lens, there is another chamber, that chamber is filled with jelly-like material that is called vitreous humor.

So, outside chamber that is filled with aqueous humor and inside chamber is filled with vitreous humor. Now, when light rays enter from the outside, then it actually passes through; first, cornea, then enters to the Pupil, then from Pupil, it enters through the Lens, and then vitreous humor and ultimately falls on the Retina. And while the light rays are falling on the Retina, then there are some electrochemical changes, then it leads to electrical potential and that information goes to brain and perception about the image happens.

So, on the Retina, there are different types of photoreceptor cell; generally, two types of photoreceptor cells are there; these are called rod cells and cone cells. We will discuss those in subsequent slides.

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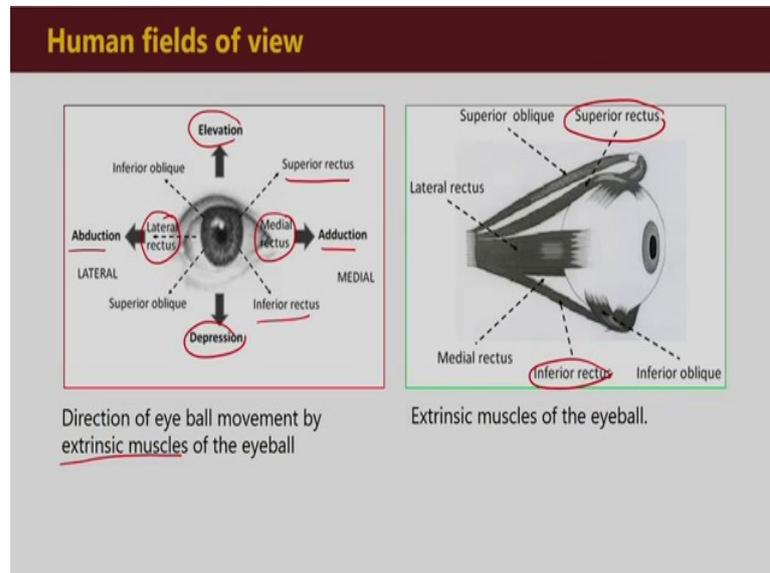
Now, as I mentioned in the earlier slide. So, from any object, say, for example, one object is presented, its top portion is 'a' and bottom portion is 'b.' So, from that object, light rays enter through the Cornea, then pass through the Pupil, then through the Lens, and ultimately fall on the Retina and on the Retina an inverted image is formed. So, 'a' was up, and 'b' was down; here 'b dash' and 'a dash.' So, it is one inverted image for me. So, light rays enter and are passing through different segments, and ultimately fall on the Retina and in the Retina, there are photoreceptor cells, where there are photoreceptor cells, there is generation of electrical potential and that impulse is transmitted towards the brain.

And now, an important aspect is this zone. The point on the Retina, towards the nasal side, at which blood vessels and nerve fibers pass by, it is called Blindspot. No image formation occurs in this particular zone. So, again, we are going back to the earlier image. So, this particular area, this area is called Blindspot because the nerve fibers and blood vessels are passing by through this area, and there are no photoreceptor cells.

As there are no photoreceptor cells, so, there is, for example, if light rays come like this, and fall on this particular area, then there is no formation of image because there is a lack of photoreceptor cells. So, that is mentioned here. So, what is Blindspot? So, Blindspot is the point or is the area on the Retina, where there is no rod and cone cells and the

through that particular area blood vessels and nerve fibers are passing by, and that area is mentioned as Blindspot.

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Now, there are various intrinsic muscle inside the eye. Apart from that, there are extrinsic muscles, which actually regulates the eye movement. So, if we look at these two images. So, eye have different types of movements. So, one is abduction; another is adduction. So, adduction and abduction, means, this, towards lateral side or medial side; these types of lateral or medial movement of the eye happens with the help of medial rectus and lateral rectus muscles.

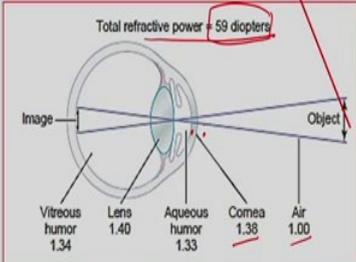
On the other hand, up-down movement of the eye, that is the elevation and depression, it happens with the help of these two muscles. So, one is called superior rectus, and another is inferior rectus. So, superior and inferior rectus, here it is also mentioned; superior or inferior rectus, when superior or inferior rectus muscles contract, then what happens? The eye moves upward and downward.

On the other hand, rotation of eye happens, when there is the constriction or contraction of superior oblique muscle as well as inferior oblique muscle. Superior or inferior oblique muscle is attached with the eyeball in such a way, when this muscles contract, then eye actually rotate.

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Human fields of view

- ✓ The cornea, the humours and the lens are main the refractive apparatus of the eye. The **refractive power** of the eye is measured in **diopeters**.
- ✓ The eye has a single lens **17 mm** in front of the retina. It has a refractive power of 59 diopeters for focusing a distant object. **About 48 diopeters** of the eye's total refractive power is due to the cornea, rather than the lens (Bridger, 2003).



The diagram illustrates the refractive indices of various parts of the eye. It shows a cross-section of the eye with light rays from an object being focused onto the retina to form an image. The refractive indices are listed as follows:

| Part of the Eye | Refractive Index |
|-----------------|------------------|
| Vitreous humor | 1.34 |
| Lens | 1.40 |
| Aqueous humor | 1.33 |
| Cornea | 1.38 |
| Air | 1.00 |

Total refractive power = 59 diopeters

(Adapted from: Guyton and Hall, 2006)

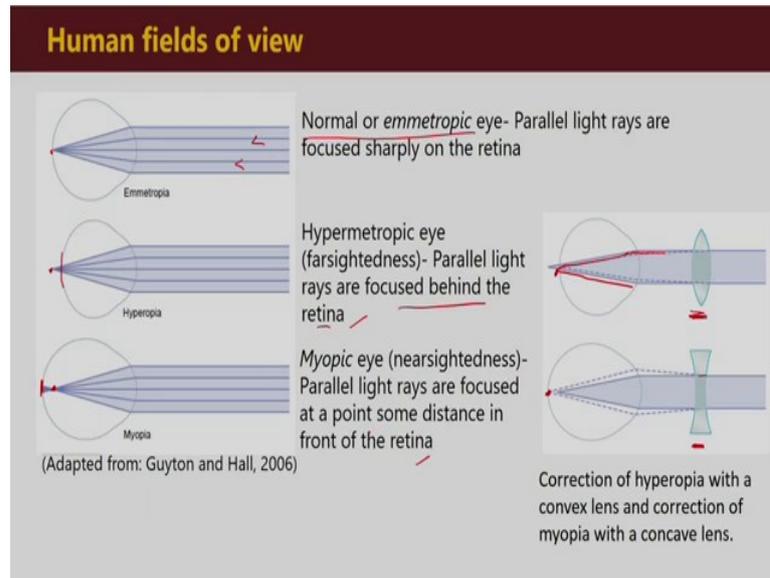
Refractive indices of various parts of eye.

So, understanding of the eye movement is also important for understanding the human field of view as well as in this automobile design, the driver's field of view. The Cornea, the humours, as we mentioned, the first chamber, the first outside chamber, where this liquid is filled, is called aqueous humor. So, this portion, the Cornea, the humours and the Lens are the main refractive apparatus of the eye. So, these are the main refractive apparatus.

The refractive power of the eye is measured in terms of diopeters; this is the unit of the refraction capability of the eyes. The eye has a single lens of 17 millimeters in front of the retina. It has refractive power of 59 diopeters. So, the eye has total refractive power of 59 diopeters. About 48 diopeters of the eyes, total refractive power is due to the cornea. So, only due to the cornea, the refractive power of the eye is 48 diopeters rather than the lens because the outside air, its refractive index is 1, then the cornea's refractive index 1.38. So, there is a huge change in the refractive index between these two mediums; air and the cornea.

So, at this point, maximum refraction occurs. So, that is why the total refractive power of the eye that is 59 diopeters; out of this 48 diopeters refraction happens only due to cornea. So, in this image, various parts of the eye and their refractive index are mentioned.

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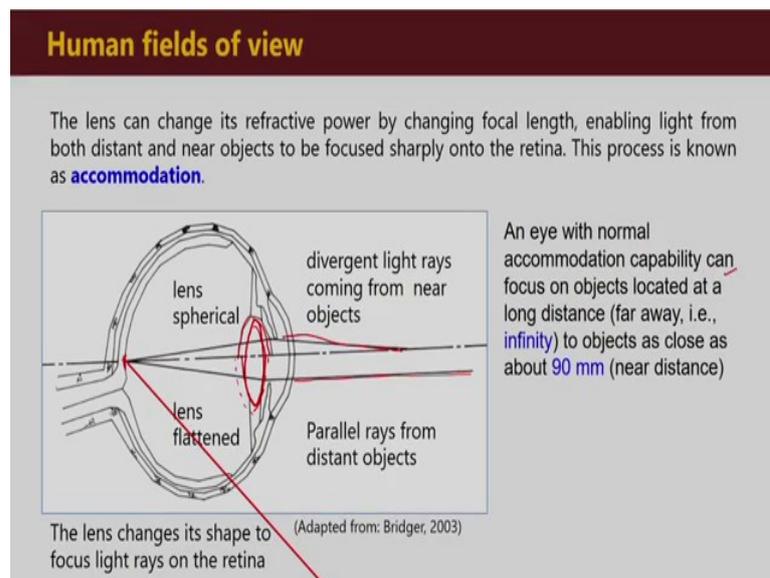
Now, due to the variation in the refractive capabilities of the eyes, different scenarios or different situations happen, like, if the eye condition is normal, so, that is called normal or emmetropic eye, where parallel light rays are focused sharply on the retina. So, while parallel light rays are coming and entering through the cornea, then pupil, then lens, and ultimately it is falling on the retina, so exactly, it is falling on the retina. So, this type of situation; if it is properly happening; that parallel light rays are coming, and it is ultimately projected on the retina, then that type of our eye is called normal or emmetropic eye.

Next category is the hypermetropic eye or farsightedness; in this case, what happens? Parallel light rays enter inside the eye but form the image or focus behind the retina. So, this is the retinal surface; it is forming the image behind the retina. So, this type of situation is called hypermetropia; another condition, we call it myopia and the eye is called myopic eye; it is also known as nearsightedness. When parallel light rays are focused at a point, at some distance, in front of the retina. So, this is the retina surface but actually the parallel light rays are focused to some extent forward of the retinal surface. So, this type of phenomena is called myopia, and that eye is called myopic eye.

Now, for this type of condition; how it can be corrected? So, for that purpose, different types of lens are used. So, one; we can correct this type of hypermetropic eye with the use of a convex lens. While we are using convex lens, then convex lens direct the

parallel light rays in such a way, so, that it can form the image on the retinal surface. On the other hand, in case of myopic eye; what is happening? The image is actually forming in front of the retinal surface. So, in that case, if we use concave lens; in an earlier case it was convex lens; now, if we use concave lens, then what is happening? That parallel light rays are actually focusing on this retinal surface. So, this type of hypermetropic eye or myopic eye can be corrected with the help of different types of lenses.

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Now, we will discuss about the accommodation; what is the accommodation for the eye? The lens can change its refractive power. So, lens has the capability; it can change the refractive power; how? By changing its shape or the focal length. The lens can change its refractive power by changing the focal length; enabling light from both distant object as well as from the nearer object; it can focus sharply on the retina; this process is known as accommodation.

So, lens has the capability to change its focal length and focusing the light rays; either parallel light rays or divergent light rays, it can focus in such a way, so, that the image is formed on the retinal surface or the light is properly focused on the retinal surface and particularly in the foveal area, while eye movement is happening.

Now, in this accommodation process; how lens actually reacts? So, while divergent light rays are coming from the near object. So, this type of light rays are coming, then how is the lens shape? Lens is in the spherical shape; at that time lens is spherical. Due to

spherical shape, that divergent light is refracted more and is falling on the retinal surface. On the other hand, while parallel light rays are coming from the object at longer distance, then lens changes its shape to a flatter one; the flat shape. Then, the light rays are focused on the retinal surface.

So, in this way, the lens can change its shape and helps in focusing the light rays on the retinal surface. So, an eye with normal accommodation capability can focus on object located at a long distance, that is far away or infinity to objects as close as 90 millimeters; means, 9 centimeters. So, for far distance; we can see infinity distance. On the other hand, as the near distance, we can see as close as 90 millimeters or 9 centimeters.

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Human fields of view

- Photopic vision by cones: above 3 cd/m² (during day light)
- Mesopic vision by both cones and rods: 10⁻³-3 cd/m² (during dusk or dawn)
- Scotopic vision: rods: 10⁻⁶-10⁻³ cd/m² (during night) (Konz and Johnson, 2004)

(Adapted from: Barrett et al., 2009)
Schematic diagram of a rod and a cone

- About 125 million rods scattered over the retina except the fovea
- About 7 million cones are densely packed in the fovea (density:140,000 cones/mm²)
- Fovea with greater temporal and spatial resolution capabilities (due to cone cells) acquire information faster than in the peripheral parts of the visual field.

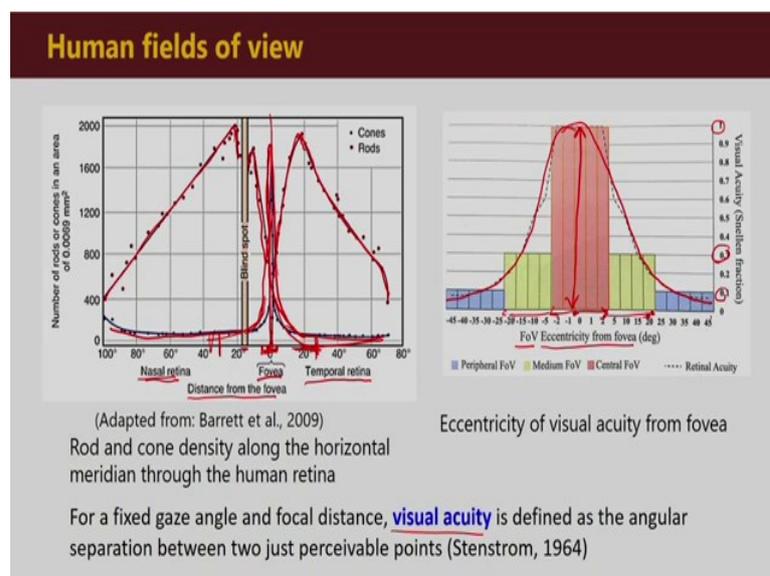
Now, on the retina, there are different types of photoreceptor cells; one is a rod cell; another is cone cell. So, this is the schematic representation of rod and cone cells. Based on the intensity of light, the activity of rod and cone cells changes. So, during daylight, or bright light condition, that is called photopic vision, mainly cone cells become active.

On the other hand, while there is a low level of illumination, during night, then that type of vision is called scotopic vision, and that vision is actually perceived by rod cells. So, for photopic vision or daylight vision or bright light vision it is actually done by cone cells. On the other hand, night vision or dim light vision happens using rod cells, that is called scotopic vision.

But in between, there is another period, during dusk or dawn, when there is relatively low illumination level, then we call that vision as mesopic vision and during mesopic vision; both cone cells as well as rod cell participate. In our eye, on the retina, there are about 125 million rod cells scattered across the different parts of the retina, except foveal region, that foveal region is the specific region on the retina, so, that is very important; again, we are going back to this image. So, if we look at this particular image, then this area; little bit depressed area on the retinal surface which is on the visual axis. So, when light rays enter this visual axis, actually light comes on this particular depressed area on the retinal surface.

This point is called fovea centralis or foveal zone, where there is a maximum number of or most densely packed cone cells and this is the most clear vision zone, and maximum visual clarity is possible in this area, that is called foveal area. Now, about 70 million cones are densely packed in foveal region. So, the densities 140,000 cones per millimeter square. Now, fovea with greater temporal and spatial resolution due to its cone cells; acquire information faster than the peripheral parts of the visual field. So, as in the foveal region, cone cells are densely packed. So, it has the greatest temporal and spatial resolution, and it has the capability to process visual information faster.

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Now, if we consider the visual acuity; but first, we should know, what is Visual acuity? For a fixed gaze angle and a focus distance, visual acuity is defined as the angular

separation between two just perceivable points. So, while we are looking at a particular point or fixing our eyes at a particular focal distance, then visual acuity is defined as the angular separation between two just perceivable points, as defined by Stenstrom (1964). Now, in details, if we try to understand; what is visual acuity? So, as we mentioned; the foveal region with cone cell it has the maximum visual acuity. So, now, if we consider this region. So, this is the distance from the fovea. So, this is the center point; these 0 degrees, it is a foveal region.

From the foveal region, if we move towards the periphery, that is towards the temporal retina, means, and another is the nasal retina; either towards nasal side or towards the temporal side. If we move, with the increase of the angle; view cone angle; what is happening? The density of the cone cells at the foveal region; 0 degrees, this is the straightforward line, or that is the visual axis. So, around that visual axis, near the 0 degree, the concentration or density of the cone cell is the maximum. So, at this point density is the maximum. As we mentioned earlier, 140,000 cone cells per millimeter square region. (Refer Time: 27:24).

After that, drastically, the density of the cone cells reduces towards the periphery, but in case of rod cells, the density is maximum, in this zone. There are no rod cells at the foveal area, but after that, the density of the rod cells gradually increases, and it is maximum in the area of 20 to 30 degree, and then gradually it reduces towards the periphery. And towards that nasal retina, what is happening?

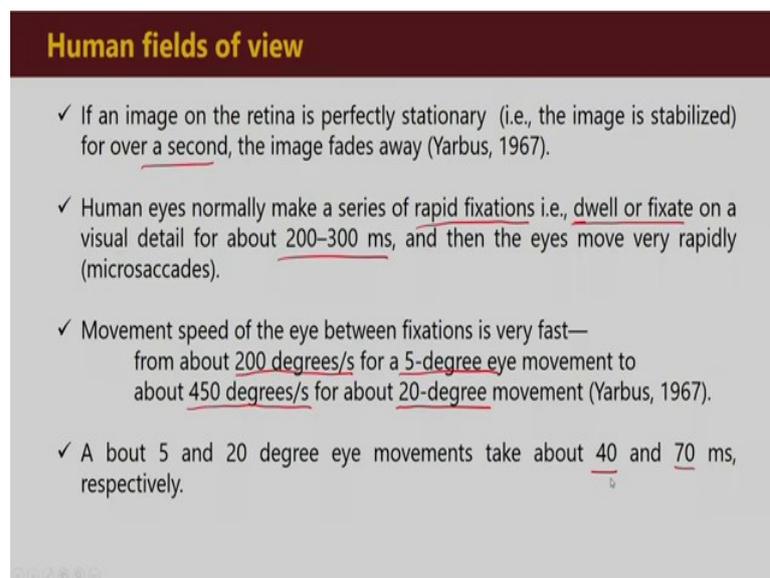
The density of the rod cells increases and as we mentioned, in the blind spot region, there are no rod cells or cone cells; after that, again the density increases, increasing and gradually it is reducing. So, the density of the cone cells is maximum at the 0 degree or 1 to 2 degree of the foveal area. So, at the fovea; 1 to 2 degree within this zone the concentration or density of the cone cell is maximum, and there are no rod cells.

Then, from that center point if we move towards the periphery; in both the direction, the density of the cone cells reduces but in case of rod cell; what is happening? The density is maximum within the area of 20 degrees, from the center point of fovea. So, both the sides; 20 to 30 degree; the density of the rod cell is maximum, then it gradually reduces. So, due to this type of distribution of rod and cone cells, visual acuity also differs. So, visual acuity is maximum within this zone; in this image, it is shown field of view

eccentricity from the fovea. So, if we consider, this is a foveal region; from the fovea if we go two-degree both sides; within this region, the visual acuity is the maximum. So, visual acuity within the 2-degree angle of fovea, it is maximum, that is 1.

Then, from 2 degrees to 20 degrees; within this zone, the visual acuity, where there the concentration of rod cells is increasing, and that is the maximum, within this zone, as we mentioned. So, that region, it has the visual acuity of 0.3. After that, from 25 to 45 or beyond that, it is drastically reducing, it is 0.1. So, maximum visual acuity is possible in the center point of the fovea, and gradually, it is reducing towards the periphery. So, visual acuity is maximum at the fovea centralis, and then is reducing gradually, as I mentioned. So, 0.3 from 2 to 20-degree angle and after that, it is only 0.1.

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Human fields of view

- ✓ If an image on the retina is perfectly stationary (i.e., the image is stabilized) for over a second, the image fades away (Yarbus, 1967).
- ✓ Human eyes normally make a series of rapid fixations i.e., dwell or fixate on a visual detail for about 200–300 ms, and then the eyes move very rapidly (microsaccades).
- ✓ Movement speed of the eye between fixations is very fast— from about 200 degrees/s for a 5-degree eye movement to about 450 degrees/s for about 20-degree movement (Yarbus, 1967).
- ✓ A bout 5 and 20 degree eye movements take about 40 and 70 ms, respectively.

Now, if an image on the retina is perfectly stationary, means, if the eye is not moving for over a second, then what happens? The image gradually fades away, as mentioned by Yarbus (1967). So, for that purpose, human eyes always move little bit, and rapid fixation happens. This small size rapid fixation is actually; we call it dwell or fixate on a visual detail for about 200 to 300 milliseconds.

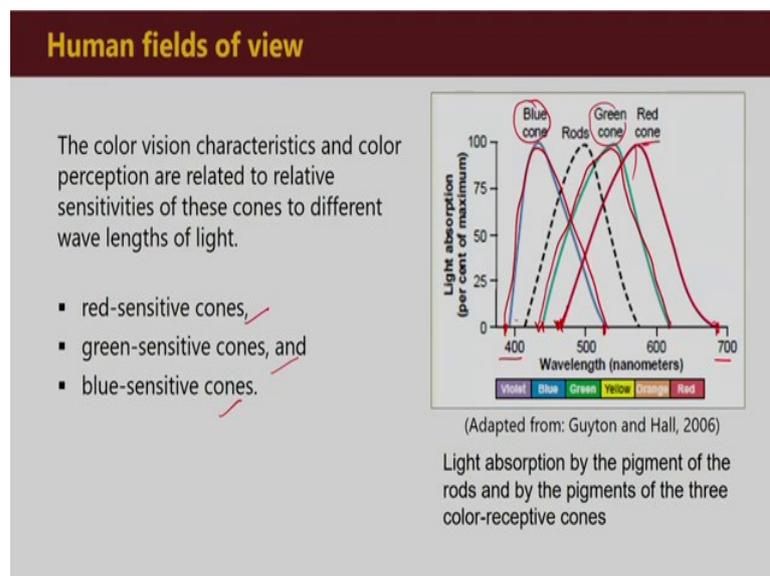
So, always, while we are fixing at a particular point, our eyes gradually move, and makes very small fixations, which is known as dwells for the duration of 200 to 300 millisecond and then eyes move very rapidly; microsaccades happens. So, this type of dwell

movement for the duration of 200 to 300 millisecond actually helps in refreshing the visual image; otherwise that image will be faded away.

Movement speed of the eye between fixations is very fast. So, from one point to another point, when eye fixation is happening, then eye movement happens at a very fast speed. So, from about 200 degrees per second for 5-degree eye movement. When there is a requirement of 5-degree eye movement, then, eye movement speed is 200 degree per second.

On the other hand, when there is movement of 20-degree eye movement, then eye movement speed is 450 degree per second. About 5 to 20-degree eye movement takes place within the time frame of 20 to 70 millisecond. So, for 5-degree eye movement, it takes time of 40 milliseconds; on the other hand, 20-degree eye movement takes the time 70 milliseconds.

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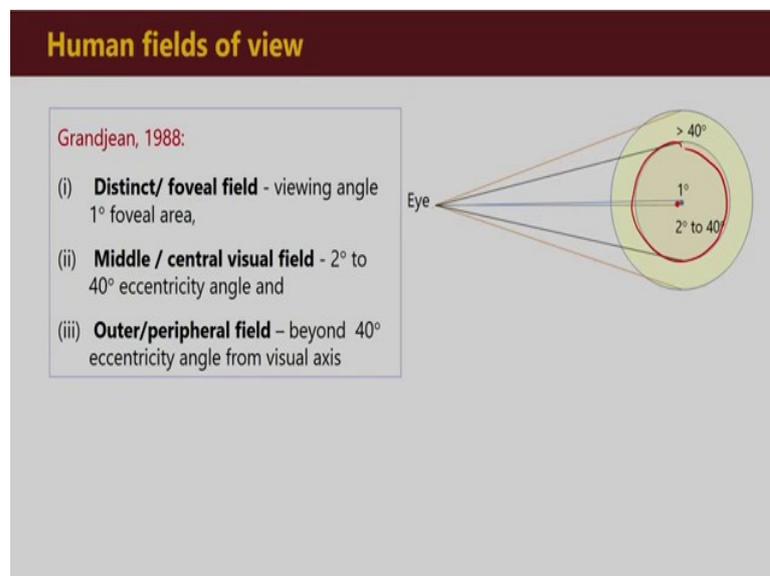


Now, on the retina, as we mentioned, in the foveal area, there is the maximum density of cone cells, there are different types of cone cells, that cone cells helps in color vision, and the sensitivity of the cone cells for different wavelengths of lights are also different. So, there are mainly three types of cone cells. So, one is; red-sensitive cone cells, another is green-sensitive cone cells, another is blue-sensitive cone cells.

So, color vision characteristics and color perceptions are related to relative sensitivities of these cones of different wavelengths of light. If we look at this image. So, from starting from 400 nanometers to 700 nanometers, within these wavelengths, there are different areas, where blue cones get activated; similarly, this is for green cones, and similarly, for, this is for red cones.

So, there, this is the sensitive zone for the blue cone; similarly, for green cones the wavelengths is also different; it is sensitive within this zone, from this point to this point, and for red cones, the wavelengths vary from this point to this point, and peak sensitivity is at this points, and this dotted line is showing the wavelength sensitivity for rod cells.

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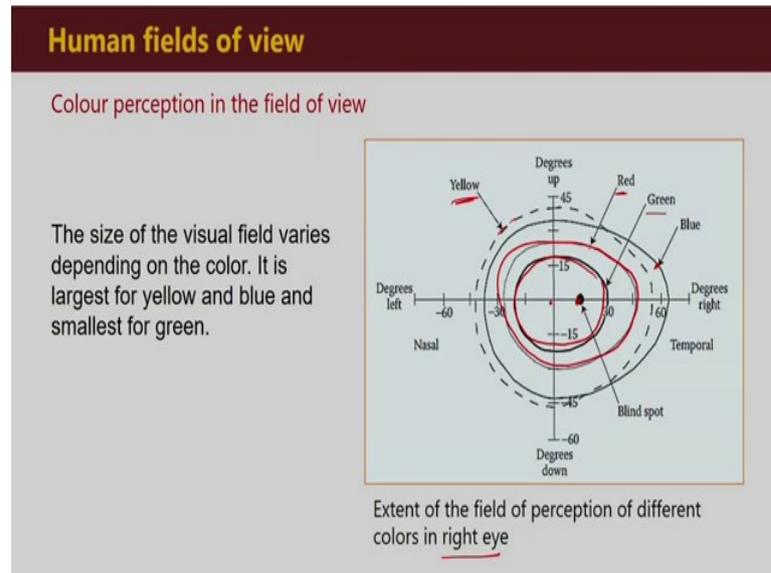


Now, Grandjean (1988) mentioned three types of human field of view; one is distinct or foveal field. This foveal field is the viewing angle of the 1-degree foveal area, while the human being is fixing their eyes at a particular point. So, that line connecting from the eye to that particular point, that is the line of sight or line of gaze, around that 1-degree foveal area is actually very good for visibility, and where very distinct vision is possible, that is called distinct or foveal field.

So, here it is shown, say if this is the eye. So, this 1-degree angle is actually very sensitive for the vision. So, that area is called distinct or foveal field; then from 2 degrees to 40 degrees, within this view cone, this is called middle or central field of view.

So, there is, that is also good for visibility but not as good as distinct or foveal field. After that, if it is beyond 40 degrees, that is called outer or peripheral field. So, beyond 40-degree eccentricity angle from the visual axis, this zone is called outer or peripheral field, where visibility or visual acuity is relatively less, only the objects which have some movement is perceived by eye.

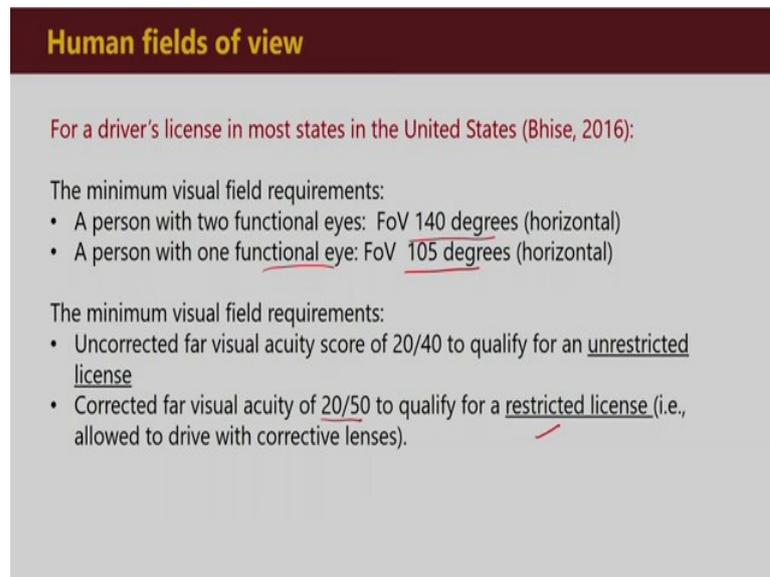
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Now, color perception in the field of view. In our field of view, the whole field of view is not equally sensitive for all the colors. The size of the visual field varies on the color; it is largest for yellow and blue and smallest for the green. So, if this is the center point, means, this is the fovea; if we move; left-right or up and down, then with the changes in degree color sensitivity differs.

So, within the view field, the viewing zone for different colors or sensitivity to different colors within our view field is different. So, these are different areas as it is shown. So, this area is actually sensitive for red color, then this one is for green, it is almost 15-degree up-down, and so, this is actually shown for the right eye; in case of right eye, this is the green sensitivity zone for view field. Similarly, this is for red; similarly, this is for blue, and these dotted lines showing the yellow sensitive zone. So, within the view field, all the points or all the areas are not equally sensitive for different types of color.

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Human fields of view

For a driver's license in most states in the United States (Bhise, 2016):

The minimum visual field requirements:

- A person with two functional eyes: FoV 140 degrees (horizontal)
- A person with one functional eye: FoV 105 degrees (horizontal)

The minimum visual field requirements:

- Uncorrected far visual acuity score of 20/40 to qualify for an unrestricted license
- Corrected far visual acuity of 20/50 to qualify for a restricted license (i.e., allowed to drive with corrective lenses).

Now, for a driver's license, in most of the states in the United States, what are the criteria, we are discussing. The minimum visual field requirements; a person with two functional eyes; the field of view - 140-degree horizontal angle should be there for getting the license. A person with one functional eye; field a view – horizontal angle should be 105 degrees. The minimum visual field requirement - uncorrected far visual acuity score of 20 by 40 to qualify for an unrestricted license.

On the other hand, for the restricted license - corrected far visual acuity, if the corrected far visual acuity is 20 by 50, then that person can qualify for restricted license. So, based on the field of view and visual acuity license are actually issued in United States.

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Driver's fields of view (inside vehicle and outside vehicle)

Target of the automobile designers is to provide 360 degree field of view to the driver seated on driving seat, means of both direct and indirect view.

Driver's direct field of view

- (a) Forward view (through the windshield),
- (b) Rearview (looking back through rear window), and
- (c) Side views (looking through the left and right side windows).

Driver's indirect field of view

- (a) Using inside mirror/ rear-view mirror,
- (b) Using outside mirrors (side-view mirror, and
- (c) Using display screens (camera view).

Now, after discussing various aspects of the human field of view or driver's field of view, we are moving to a field of view of the driver's; inside and outside of the vehicle. Target of the automobile designer is to provide a 360-degree field of view to the drivers seated on the driving seat, means, both direct and indirect view; it should be almost 360 degrees. So, the driver can see all around and can ride the car safely.

Driver's direct field of view and driver's indirect field of view; driver's direct field of view happens through forward-view, through the windshield. Then looking back, through rear-window; side views through the side-windows. So, by neck movement as well as eye movement, the driver can directly visualize the external world through the windshield side-view mirror, side windows, and back-side windows.

Apart from this direct view, there is also indirect views. So, for indirect views, the driver can use inside mirror or rear-view mirror, then outside mirror for side-view and using different types of the display screen, with the help of camera.

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Driver's fields of view (inside vehicle and outside vehicle)

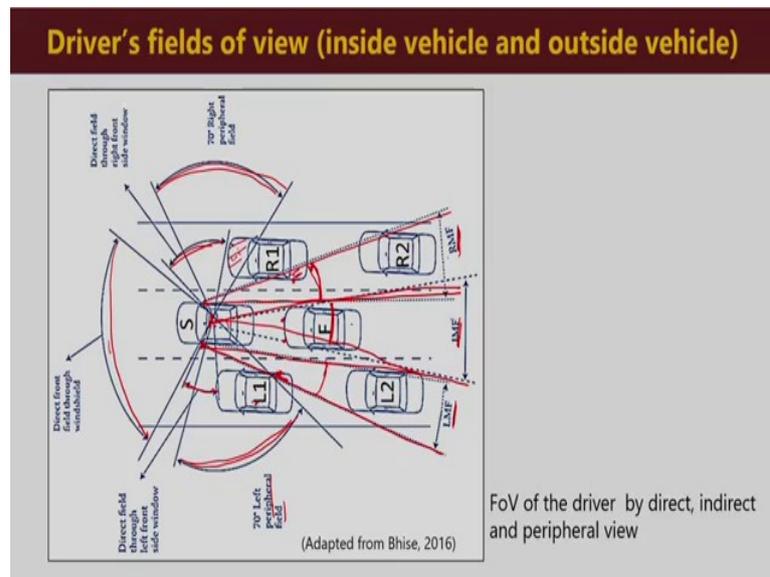
Visual obstruction or obscuration in the driver's FOV happens by vehicle structure and components such as

- pillars,
- mirrors,
- instrument panel,
- steering wheel,
- hood,
- lower edges of the window openings (belt line),
- Headrests etc.

So, both direct and indirect view field is possible. So, while we are discussing about the view field, then in that view field, there is also visual obstruction or obscuration due to the presence of different vehicle components or other objects. So, visual obstruction or obscuration in the driver's field of view happens by vehicle structure, and components such as A-pillar, B-pillar, C-pillar or different types of mirrors particularly inside rear-view mirror, side-view mirrors, then instrument panels may also create visual obscuration.

Steering wheel rim, the upper portion of the steering wheel rim, then hood, then lower edges of the window opening, the beltline, and headrest of the backseats. So, all these vehicle components may create obscuration in the view field.

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Now, if we look at this image, assume this is a vehicle under consideration, that is the subject vehicle, and this is the position of the driver, and around that vehicle, there are other vehicles in right-side and left-side lanes. So, this is the vehicle R1 and R2, on the right lane. Similarly, this is the L1 and L2, another two vehicles on the left lane, and this is a vehicle which is following the 'S' vehicle or subject vehicle. So, this is located just behind the subject vehicle. Now, how is the visibility of the driver? So, driver at this driving seat, he or she can see direct field through the windshield. So, this is the direct field of view through the windshield; forward view.

Similarly, this is the area, direct field of view through the right-side window; right-side front window. Similarly, this is the zone for the direct view through left-side window. Now, this portion, while the driver is looking at the side mirror, then he or she can also see directly 70 degrees right peripheral field. So, during looking at the side-view mirror, then there is also direct visibility of the outside, through the windows, that is actually mentioned as 70-degree peripheral field. So, this peripheral field, it is also present on the left side.

So, while the driver is looking at the left-side side-view mirror, then directly, he can see this area, through the side-view mirror. So, this is mentioned as the peripheral field. So, it is also 70 degree. So, direct forward-view, this is direct side-view; at the same time, this is direct peripheral view. Apart from this using different types of mirrors; side-view

mirror and rear-view mirror. So, using this right-side side-view mirror, drivers can see this area. By the help of right-side mirror, he can see, this zone. Using the rear-view mirror, inside rear-view mirror, this zone is visible to the driver.

So, inside the mirror field; this is the left mirror field, and this is the right mirror field. So, if we see, so, ultimately almost 360-degree area is visible for the driver. Only some portion is obscured (Refer Time: 41:51) by A-pillar, B-pillar or C-pillar. So, in this way, by direct visibility or indirect visibility, through different types of mirrors, it actually helps the driver to visualize almost 360 degrees around that driver during driving. So, due to this type of visibility, here you can see, either at least some part of the vehicle is visible to the driver, suppose R1, this much, this part is visible to the driver.

Similarly, for L1, this part is visible; the whole portion is actually visible through the peripheral field of view. So, using peripheral field of view, driver can see L1, similarly, using the peripheral field of view as well as the side-view mirror, he can see, these two portion of the R1, R2; it is visible through a rear mirror view field, this vehicle is visible using this inside mirror field and vehicle L2, it is actually visible through the left mirror field.

So, this is during day condition but in the night condition also; either the headlamp of the following vehicle or the vehicles on the side lanes are visible, otherwise at least the side indicator lamp, the indicator lamp on this side, it is also visible. So, due to this type of mirror arrangement; in the day daytime as well as in the night time, at least some part of the vehicle or the vehicle light are visible to the driver, and accordingly he can navigate his vehicle in relation to other vehicles.

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Driver's fields of view (inside vehicle and outside vehicle)

Driver's field of view is influenced by –

Characteristics of the driver:

- Eye locations in the vehicle (eye ellipse- SAE J941)
- Visual capabilities (visual acuity, accommodation, visual contrast threshold)
- Eye and neck movement
- Information-processing capabilities,
- Age of the driver

Characteristics of the vehicle:

- Window-opening dimensions ✓
- Obscuration by vehicle components (e.g. pillars, mirrors, sun-visors, hood etc.)
- Indirect vision devices (e.g., mirrors, sensors, cameras, and displays),
- Glare and/or reflections

Now, the driver's field of view is influenced by various factors; one factor is the characteristics of the driver. So, driver's eye location is very important; where driver's eye is positioned? So, it is actually depending on the driver's anthropometry, then according to seat adjustment. So, driver's eye location has been defined by SAE J standard 941, by the eye ellipse. So, eye ellipse, we discussed in our earlier modules, what is eye ellipse. So, from the eye ellipse, we can understand that how much will be the visibility for the driver. Then, visual capability of the driver; visual acuity, accommodation capability, visual contrast threshold.

So, these factors are also affecting the visibility or driver's field of view. So, visual acuity gradually reduces with age, for the older driver due to cataract and other problems there also loss of visual activity. On the other hand, with age, accommodation capability of the lens also reduces, then the eye and neck movement is also important for maintaining the field of view. Then information processing capabilities of the driver, that is also affecting, then, age of the driver; as we mentioned; with the age visual capability of the driver changes and accordingly it affects the driver's field of view.

Apart from the driver's characteristics, the characteristics of the vehicles is also influencing the field of vision and field of view. So, various aspects of the vehicle design, that is the window-opening dimension, obscuration by vehicle components, like A pillars, B pillars or C pillars, then mirrors, sun-visors, hood, all these components

actually creates visual obscuration, then indirect vision devices; mirror, sensors, cameras and displays; those actually also helps in increasing the driver's field of view.

Then, glares and reflections also affect the driver's field of view. If there is glare or glossy surface; from that, reflected lights are coming to the driver's eye, then there is the visibility problem.

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Driver's fields of view (inside vehicle and outside vehicle)

Targeted visual:

- Sizes,
- Locations, and
- Photometric characteristics of different targets (road signage, traffic signals pedestrians, vehicles etc.)

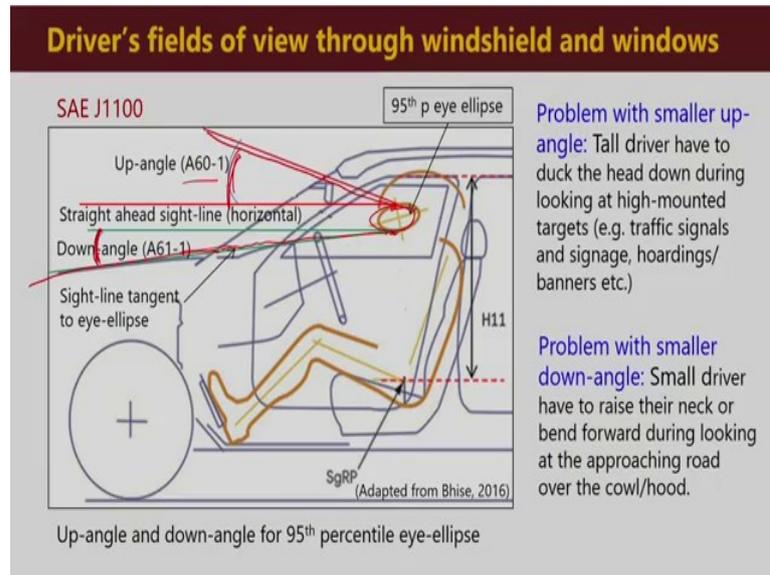
Environmental condition:

- Level of illumination
- Road condition
- Weather condition
- Reflections of interior and exterior sources

Then apart from this driver's characteristics as well as vehicles characteristics. So, the driver's field of view is also influenced by the targeted visuals, what is the size of the targeted visuals? Where it is located? Then photometric characteristics of different targets; for example, road signages, traffic signals, pedestrian, vehicles.

So, various photometric characteristics of these objects are also affecting the driver's field of view, then environmental condition; level of illumination, road condition, level of illumination; daylight, during night or it is during the early morning, so, illumination level is different. Similarly, road condition is also affecting it, whether that is crowded road or empty road, so, that is also affecting the driver's field of view. Then, weather condition, reflections of interior and exterior sources, that is also affecting driver's field of view.

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So, these are the various factors which influence the driver's field of view, within the vehicle as well as outside the vehicle. Now we are going to discuss about the up-angle and down-angle from the eye ellipse. In SAE J standard 1100; it is mentioned that; how we can define the up-angle, that is A60-1, and down-angle that is the A61-1. So, this is the eye ellipse for the drivers, 95th percentile eye ellipse.

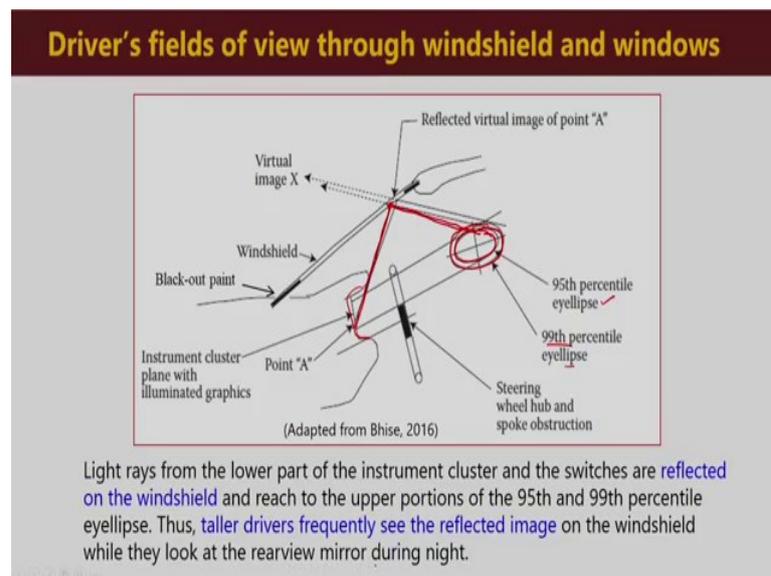
From that eye ellipse, if we draw horizontal lines and tangent line, from the 5th percentile eye location above the hood, that point is called above the hood or the lowermost point of the daylight opening, that angle is called down-angle. So, down-angle is, below the horizon, if we draw one tangent line from the 5th percentile eye location, in the 95th percentile eye ellipse; this tangent line is actually moving like this; above the hood or bonnet. This angle, below the horizontal level or below the straight-forward line, straight-ahead line that is called down-angle. The size of the down-angle actually defines; how much is the visibility of the drivers with lower body dimension, as I mentioned, 5th percentile eye location, that can be determined.

Similarly, driver with larger body dimension or taller driver, if their eye location, is at this point, that is the 95th percentile eye point. From the 95th percentile eye point, if we draw a tangent line in upward direction, below the lower edge of the daylight opening, down the roof, then this upward angle is called up-angle; this angle is also important for determining the visibility of the taller drivers in upward direction.

Now, the problem with the smaller up-angle; if this upper-angle is smaller, then, what happens? Then taller driver have to duck the head down, during looking at high mounted targets, like traffic-signals, signage, hoardings, banners. So, they have to bend forward, or they have to duck the neck down to see upward. On the other hand, if the size of this down-angle is less, then there is a problem with the drivers with smaller body dimension, means, 5th percentile or lower percentile eye location.

So, what type of problems they face? Smaller driver have to raise their neck or bend forward during looking at the approaching road over the cowl or hood. So, they have to bend forward, and they have to see the road. So, we can discuss this in later slides in details, that if this angle; down-angle is relatively less, then what is happening? Drivers with 5th percentile eye location, they have to move forward, or they have to bend forward to see the road over the hood or cowl.

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Now, rays from the lower part of the instrument cluster. So, if this is the instrument cluster. So, from the lower part of the instrument cluster and switches, lights are reflected on the windshield. On the dashboard different switches are there, illuminated displays are there, from those lights are reflected on the windshield, and then their images are projected on the windshield and then reflected to the eyes of the drivers.

So, this is the eye ellipse for the 95th percentile eyellipse and as well as the outer one is there. So, this is a 95th percentile eyellipse; inner one and outer one is the 99th percentile

eyellipse. In such situations, so, what happens? From these illuminated graphics or switches, the light from those objects fall on the windshield and is reflected to the eyes of the drivers with larger body dimension 95th percentile to 99th percentile.

So, that is why light rays from the lower part of the instrument cluster and the switches is reflected on the windshield and reach to the upper portion of the 95th and 99th percentile eyellipse thus the taller drivers see the reflected image on the windshield while they are looking at the rearview mirror during night time. So, this type of images on the windshield creates annoyance or disturbance for the drivers with relatively higher position of the eye in 95th or 99th percentile eye location.

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Driver's fields of view (inside vehicle and outside vehicle)



Forward view field and dead zone for shorter/ smaller driver

Visibility problems faced by smaller drivers (Bhise, 2016)

- ✓ The closest distance at which a driver can see the road (over the hood) is much longer for the short driver. In other word, **the dead zone in front of the car is more** for shorter driver.
- ✓ There is less or **no visibility of the front end and corners of the hood** in case of shorter driver. It creates problem for parking, maintaining lane and keeping safe distance from the objects located at the road ahead.

Now, we will discuss about the visibility problem faced by the smaller drivers. So, here, while a driver, assume this is a driver with smaller body dimension, means, 5th percentile or less than that, this type of driver with the shorter or smaller body dimension, they have to move their seat forward to reach the accelerator, brake, clutch as well as the steering wheel. So, while they are moving their seat forward, then what type of visibility issues happens?

The closest distance at which the driver can see the road, this point, the closest distance is much longer for the shorter driver. So, the closest or nearest distance which the driver can see, that point is actually far away from the vehicle, this space is actually known as dead space or blind zone. Within this zone, if some objects or say, some animals or kids

are there, so, it is almost impossible for the driver to see them. So, the distance or length of this zone is very large in case of smaller driver because their downward angle is less or down-angle is relatively less, and this line of sight is over the hood, touching the ground at a long distance. There is less or no visibility of the front end and the corners of the hood, in case of shorter driver.

It creates a problem; in case of parking, maintaining the lanes, keeping the safe distance from the objects located at the road ahead or the heading vehicle. So, they find difficulty, as they cannot see the front edge of the hood or the corners of the hood. Then, relatively smaller down-angle; due to the obstruction of forward-view by the top part of the steering wheel rim and instrument cluster.

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Driver's fields of view (inside vehicle and outside vehicle)

- ✓ Relatively smaller down angle due to obstruction of the forward direct view by the top part of the steering wheel rim and instrument cluster binnacle.
- ✓ The outside side-view mirrors may obscure the forward direct view.
- ✓ The shorter drivers requires more neck rotation for direct rear viewing through rear window and will experience reduced rear-visibility problems during reversing or backing up due to higher deck point and taller rear headrests.
- ✓ Driver's side A-pillar will create a larger obscuration in the forward field of view for smaller drivers as their seating position is relatively forward in comparison to larger driver.
- ✓ Short drivers require larger head-turn angles to view side-view mirrors due to their more forward sitting position as compared with the taller drivers.

So, they have the relatively smaller down-angle, and for that purpose, there is also obscuration problem due to the presence of steering wheel rim, instrument cluster binnacle. So, all this actually happens. The outside side-view mirrors may obscure the forward field of view. The shorter drivers require more neck rotation for direct rear-viewing through rear window and will experience reduced rear visibility problems during reversing or backing up due to higher deck point and taller rear headrests.

So, driver's with shorter body dimension or relatively low eye height, they find difficulties while reversing the vehicle due to the higher deck point and the taller headrest. Driver's side A-pillar will create a larger obstruction or obscuration in the

forward field of view for smaller drivers, as their sitting position is relatively forward, in comparison to the larger driver. Shorter drivers require larger head-turn to view side-view mirrors, due to their more forward sitting position, as compared to the taller drivers or larger drivers.

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Driver's fields of view (inside vehicle and outside vehicle)



Forward view field, up-angle and dead zone for taller/ larger driver

Visibility problems faced by larger drivers (Bhise, 2016)

- ✓ The closest distance at which a driver can see the road (over the hood) is much shorter for the taller driver. In other word, **the dead zone in front of the car is less** for them.
- ✓ As the larger drivers adjust their seat backward, the tall driver may have more side visibility problems due to (a) **more-forward B-pillar obscurations** in direct side viewing and (b) **more-forward peripheral awareness zones**.

Like shorter drivers; taller drivers also find problems in their view field. So, taller drivers adjust their seat backward, and their eye position is relatively up in the eyellipse. The closest distance at which the driver can see the road is much shorter for the taller driver. So, you can see, this blind zone distance is relatively short, in comparison to the shorter driver.

So, they can see the road very close, from the vehicle. As the larger driver adjust their seat backward, the tall driver or large driver may have more side visibility problems due to more-forward B pillar obstruction in direct side viewing, and more-forward peripheral awareness zones.

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Driver's fields of view (inside vehicle and outside vehicle)

- ✓ Relatively smaller up-angle in case of taller driver may create visibility problems for external objects placed at higher locations (traffic signals and signage, hoardings etc.)
- ✓ The inside rear-view mirrors may obscure the forward direct view.
- ✓ Due to a more rearward sitting position, larger/ taller drivers have lower indirect field of view through side/ rear view mirrors.

Then, relatively smaller up-angle in case of the taller driver may create visibility problems for external objects placed at higher location, like traffic-signals, signage, hoardings, etcetera. The inside rear-view mirrors may obscure the forward direct view. Due to more-rearward sitting position, larger or taller drivers have lower indirect field of view; through side or rear-view mirrors.

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Driver's fields of view (in side vehicle and outside vehicle)

Obstructions caused by A-pillars



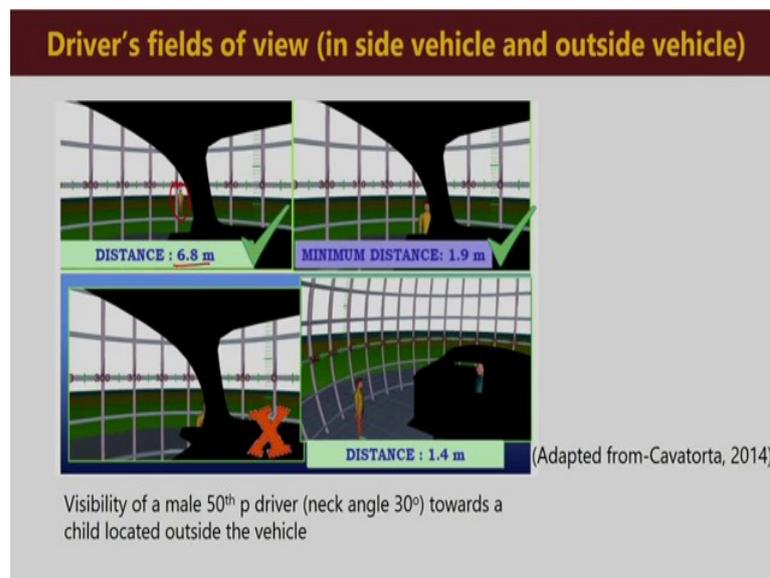
- Forward and side direct visibility of the driver is affected due to the obscuration by A-pillars (left and right).
- The area of binocular obscuration is dependent on the cross-sectional width of the A-pillar, thickness of the rubber seals used to secure the windshield, black-out paint applied to the glass to hide the joints

Location of A-pillar in a vehicle.

Now, obstruction caused by A-pillar. So, forward side direct visibility of the driver's; left-side or right-side is actually affected due to the obscuration or obstruction by the A-

pillars. The area of the binocular obstruction is dependent on the cross-sectional width of the A-pillar. So, how is the size of the A-pillar in different position? So, cross-section of the A-pillar, then thickness of the rubber sealing. So, how much is the rubber sealing thickness? This thickness of the rubber sealing, this black color rubber sealing thickness; this one and at the same time the blackout paint applied to the glass to hide the joints. So, all these factors actually create visual obscuration.

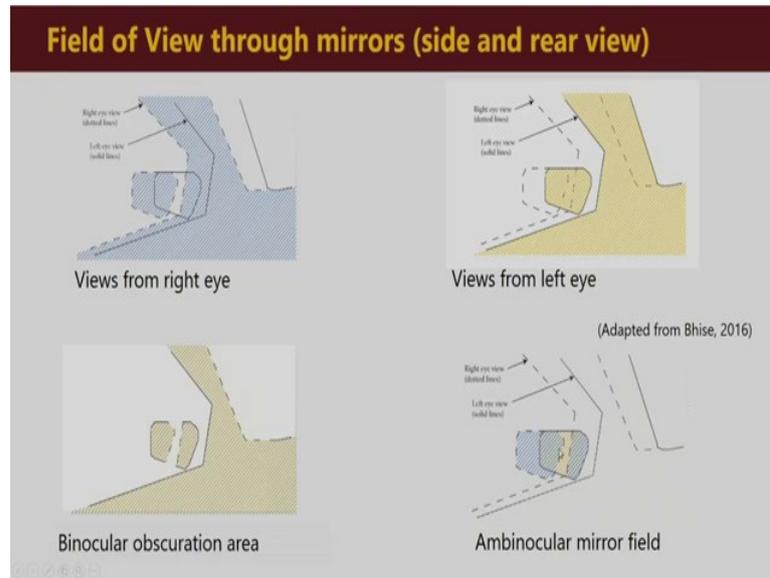
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Now, in their paper Cavatorta (2014), with digital human modeling simulation showed how this obscuration by the A-pillar happens and how it may lead to accident. So, when the distance is 6.8 meter, then the person, that, here it is shown with the 5th percentile driver, towards the child locator.

So, for the 5th percentile driver, with a neck angle of 30 degrees, the person can see the child beside the A-pillar. While the distance is 1.9 meter, still that child is visible. When the distance is 1.4 meter, then the child is not visible, the child is obscured by the position of the A-pillar. So, this is for the vehicle, and this is the location of the child. So, while they are nearby only 1.4-meter distance, then actually the location of the child is obscured by the A-pillar. So, size of the A-pillar and its design is very much important to avoid this type of visual obscuration.

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Now, regarding the field of view of the drivers, we are going to discuss about how monocular field of view and binocular field of view differs from each other and accordingly the field of view as well as the obscured zone or zone of obscuration is also different; due to monocular and binocular field of viewing. And if we take this case example, where this is the view field for the right eye, and this shaded blue zone, it is indicating the obscured area due to the A-pillar mirror and the structure of the vehicle.

Similarly, when the driver is looking using the left eye, then for the same A-pillar and mirror, the obscured zone will be little bit different, and its position is also different. So, in that view field, you can see, if we compare these two images, that view field for the right eye and a view field for the left eye is different and accordingly the obscured area for left eye, that is this yellow shaded one and for the right eye, this blue shaded one, these two are different.

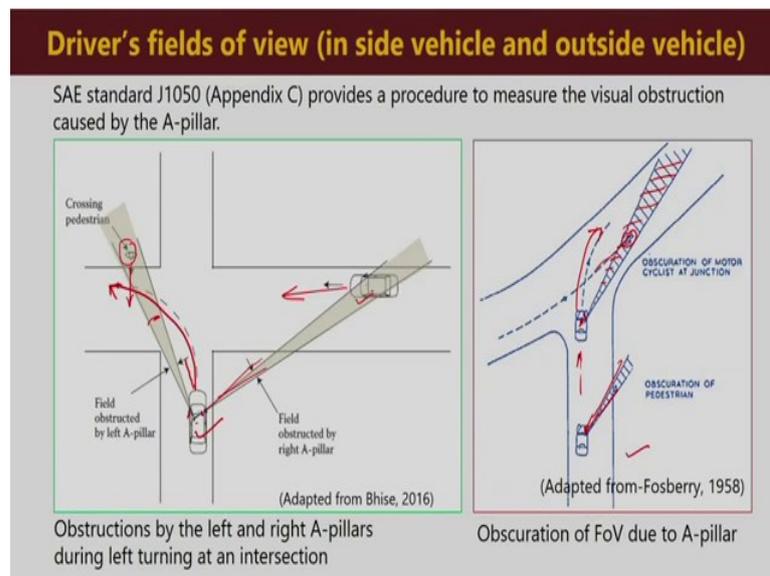
Now, if we superimpose the left eye view with the right eye view, then, how is the overlapping? Now, we can see, this is the view field for the right eye; now, this is the view field for left eye, and this is the middle portion, this is the overlapping zone, means, this is the obscured area, the blue shaded zone for the right eye and yellow shaded zone for the left eye and this is the middle portion and this portion of the mirror.

This is actually obscured, the backside of the area is visually obscured by the A-pillar and the mirror; and this is true for both eyes, means, this is a binocular field of

obscuration; obscuration zone. Although the monocular field of obscuration zone is relatively larger in size but while there is binocular field of view, means, we are looking through both eyes, then the obscured zone area reduces.

So, only this portion is obscured by the binocular zone. So, this portion will not be visible, backside of this area will be visually obscured. Similarly, the field of view through the mirror is also different for left eye and right eye. So, this yellow shaded area, this is for the left eye mirror-view and this blue shaded area this is the view field through right eye. But while we are using both the eyes, means, the combination of left eye and right eye, then the ambinocular field of view through the mirror is relatively larger, that is a combination of these two zones.

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Now, we are moving to the next slide, in this slide, we are going to discuss, how the visual obscuration by A-pillar; left side and right side is affecting the visibility of the driver and how that may lead to accident or near to accident.

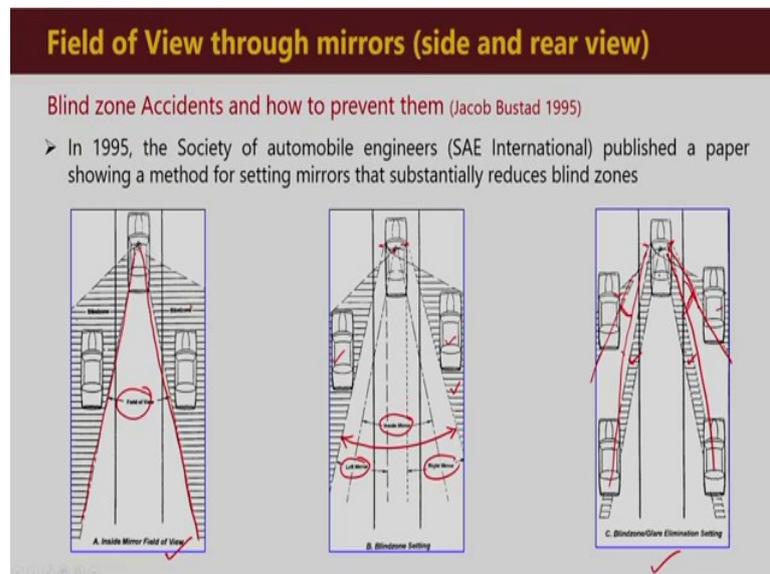
So, in this image, we are showing obstruction by the left and right A-pillars during left turning at an intersection and in this another image, we are showing, while the vehicle is taking the right turn, then due to visual obscuration by the A-pillar, how is the chance of accident? Now, if we look at this particular image, then you can see, while that vehicle is approaching forward and taking a left turn, then what is happening? Due to A-pillar, this

left-side A-pillar, this particular zone is actually not visible for the driver; similarly, for the right A-pillar, this zone will not be visible.

So, due to the presence of these; both A-pillar; left side and right side, these two areas are not visible to the driver, at this particular moment. Then, while the driver is proceeding forward, then, what will happen? And taking a left turn, then this vehicle, as this vehicle is not visible, and this vehicle is moving in this direction and another pedestrian, she is trying to cross the road, then there is chance of accident because at this particular moment, the driver inside this vehicle is unable to visualize this particular vehicle as well as the pedestrian.

Similarly, in the second image, while this vehicle is approaching forward, due to A-pillar, this zone is not visible to the driver, means, this is the obscured area. When that particular vehicle is moving forward and is taking a right turn, then what is happening? Due to the right-side A-pillar, this zone is actually obscured zone, visually obscured. Then, if any of the vehicle or any pedestrian comes from that side, then at that particular moment, the driver from the vehicle will not be able to visualize, and while that driver is navigating the vehicle and going to take a right turn, then there is chance of accident.

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Now, blind zone accidents and how to prevent this type of accident. So, for that purpose, there is a published paper by Jacob Bustad in 1995; he mentioned that how could a visually obscured zone can be reduced. So, for that purpose, we can use different types

of mirrors; inside rear-view mirror as well as side-view mirrors. So, in the first image A, it is showing the field of view for the rear-view mirror; inside rear-view mirror. So, this is the area where the driver can see this zone, using the rear-view mirror.

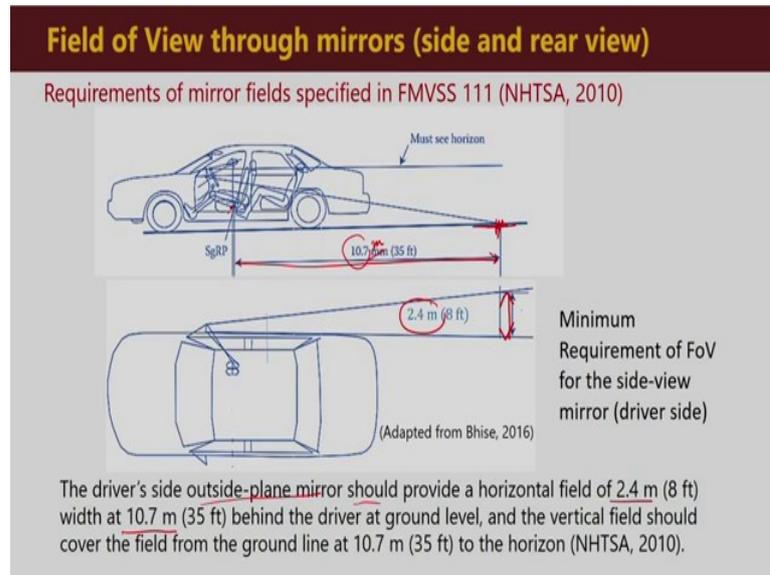
And if he or she is not using the side-view mirror, then these are the obscuration zone, and if any vehicle is present in this two side lanes, it will not be visible to the driver, means, the situation is that the driver is not using the side-view mirror. But while the driver is using both; rear-view mirror as well as the side-view mirror, then what is happening? This is the inside mirror-view, and this is the left mirror-view, and this is the right mirror-view.

So, this whole zone is right now visible for the driver, but these two vehicles, in the side lane is not visible to the driver because it is coming within the obscuration zone. Now, if we move to the third image; then, if the driver turns to the left-side and right-side side mirror is in such a way, towards the outside, then the field of view can be changed. And now, the mirror view; mirror field of view, is this one; for the right mirror and similarly for the left mirror; this is the view field; mirror-view field.

Then what is happening? Actually, now, the obscuration zone; the earlier obscuration zone is divided into smaller parts. So, the total obscuration zone has been fragmented in small-small zones; this is 1 zone, 2 zone. So, in that way, the obscuration zone is divided into smaller parts, and it is actually helping to visualize the drivers, visualize the other vehicles, which vehicles are following this particular vehicle by the side lanes.

So, in this way, by using the rear-view mirror as well as the side-view mirrors and their proper adjustment or their proper positioning, we can reduce the obscuration zone created by A-pillar, B-pillar and C-pillar.

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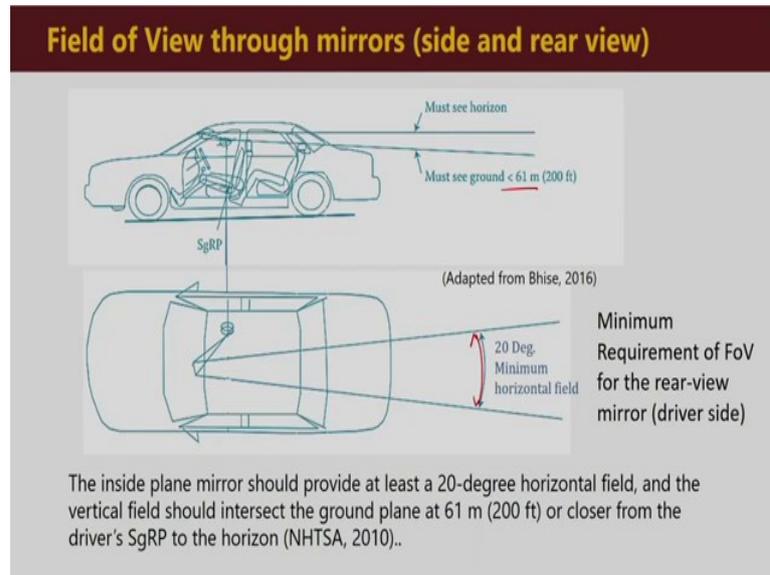


Now, the requirement of mirror fields specified by Federal Motor Vehicle Safety Standards. So, how much should be the field of view, for the mirror view? Now, while we are positioning the mirrors; designers or engineers positioning or designing the mirror, then they have to consider how much field of visibility should be there, for the particular mirror.

So, as per the guideline, the driver side; outside-plane mirror; if the driver is using the plane mirror, then outside a plane mirror should provide horizontal field of 2.4 meters. So, the horizontal field of view should be 2.4 meters, and it should cut the distance of 10.7 meters. So, from the driver's seating reference point, at a distance of 10.7-meter driver should be able to visualize the road level, this is the level of the road.

So, from the driver seating reference point, at a distance of 10.7 meters, the drivers will be able to see the ground or the road level. And at that juncture or at that point, the width of the field of view should be 2.4 meters. So, this is the minimum requirement for the mirror field.

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So, that was for the side-view mirror. Similarly, for the rear-view mirror, which is positioned inside the vehicle. So, for rear-view mirror; how much should be the field of view? So, minimum field of view should be at least 20-degree horizontal field of view for the rear-view mirror, and it should allow at the backside of the vehicle, the ground should be visible at a distance less than 61 meters.

So, in other words, we can say, the inside-plane mirror should provide at least a 20-degree horizontal field, and the vertical field should intersect the ground plane at 61 meters or closer, from the driver's seating reference point to the horizon.

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Field of View through mirrors (side and rear view)

Guidelines for inside rear-view mirror locations (Bhise, 2016)

- ✓ The mirror should be placed within the maximum (95th percentile) reach envelope with full hand grasp using SAE standard J287 procedure.
- ✓ The lower edge of the mirror should be located at least 20 mm above the 95th percentile driver's eye height.
- ✓ The mirror should be placed outside the head swing area (during frontal crash) of the driver and the front passenger

Now, the field of view through mirrors and for that purpose, there are different guidelines; that guidelines for inside rear-view mirror locations, how to position that mirror; inside mirror?

So, first; the mirror should be placed within the maximum, that is the 95th percentile reach envelope with full hand grasp, using Society of Automotive Engineers standard J287 procedure. The lower edge of the mirror should be located at least 20 millimeters above the 95th percentile driver's eyesight. So, the lower edge of the mirror should not come within the field of view of the driver; it should be at least 20 millimeters above the driver's eye level. Mirror should be placed outside the head-swing area to avoid the head crash against that mirror, during an accident.

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Field of View through mirrors (side and rear view)

Guidelines for side-view mirror locations (Bhise, 2016)

- ✓ A short driver seated at the forward most location on the seat track should not require a head-turn angle of more than 60 degrees from the forward line of sight.
- ✓ To avoid obscuration in the direct side view of at least 95% of the drivers, the upper edge of the mirror should be placed at least 20 mm below the fifth percentile driver's eye location.
- ✓ The mirror should allow short driver to see a part of his or her vehicle and a tall driver to aim outward to reduce the blind area in the adjacent lane

Now, guidelines for the side-view mirror and its position. So, the short driver seated at the front-most location on the seat track should not require head-turn angle more than 60 degrees, from the forward line of sight.

So, while a shorter driver is positioning his or her seat forward, at that point he or she should not require more than 60-degree head-turn to visualize the side-view mirror or to look at the side-view mirror. To avoid obscuration in the direct field of view at least 95 percent of the drivers, the upper edge of the mirror should be placed at least 20 millimeters below the 5th percentile driver's eye location.

So, the side-view mirror's top edge should be 20 millimeters below the eye level of the shorter driver. Mirror should allow shorter driver to see a part of his or her vehicle, and a tall driver to aim upward, to reduce the blind area in the adjacent lane.

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Key learning from Module 4

- ✓ Human Field of View (Monocular, Ambinocular and Binocular)
- ✓ Basic understanding on anatomy of eye and its functional aspects
- ✓ Eye movement and neck movement
- ✓ Visual acuity, visual accommodation, refractive power, blind spot,
- ✓ Driver's direct and indirect field of view
- ✓ Visual obstruction or obscuration in the driver's FOV
- ✓ Visibility problems faced by smaller/shorter drivers and larger/ taller driver
- ✓ Visual obscuration caused by A-pillars
- ✓ Requirements of mirror fields specified in FMVSS 111

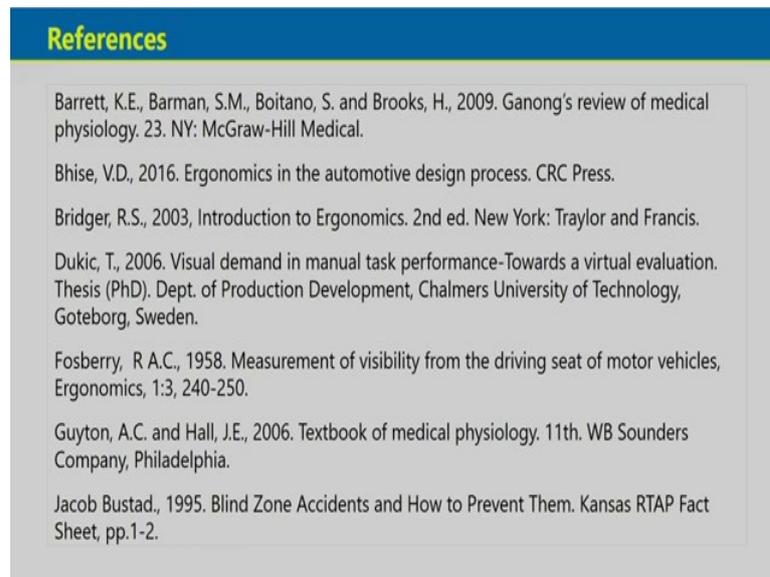
Now, from this particular module, what we learned? So, various topics; we covered in this module, related to the view field of the driver. So, first; we discussed about human field of view, under that, we mentioned about monocular field of view, ambinocular field of view and binocular field of view. Then, in this module, there was basic understanding of eye anatomy and functionality of its different components.

Then, eye movement and neck movement; what is the range of movement of the eye as well as for neck and how eye and neck move for visualizing any object? Then, we discussed about visual acuity, visual accommodation, refractive power, blind spot, etcetera. Driver's direct and indirect field of view, visual obstruction and obscuration zone in the driver's field of view has also been discussed, then we also discussed about visibility problems faced by the smaller driver as well as by the larger or taller driver.

While larger or taller driver or smaller driver is navigating the vehicle, how is the visibility related issues due to obscuration by various vehicle components as well as due to their sitting position; how much area is actually visible outside the vehicle. So, those aspects we discussed.

Then visual obscuration, particularly by A-pillar; we discussed in detail. Then, the requirement of mirror fields specified in Federal Motor vehicle safety standard. So, these are the various topics which we covered under module 4.

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References

Barrett, K.E., Barman, S.M., Boitano, S. and Brooks, H., 2009. Ganong's review of medical physiology. 23. NY: McGraw-Hill Medical.

Bhise, V.D., 2016. Ergonomics in the automotive design process. CRC Press.

Bridger, R.S., 2003, Introduction to Ergonomics. 2nd ed. New York: Traylor and Francis.

Dukic, T., 2006. Visual demand in manual task performance-Towards a virtual evaluation. Thesis (PhD). Dept. of Production Development, Chalmers University of Technology, Goteborg, Sweden.

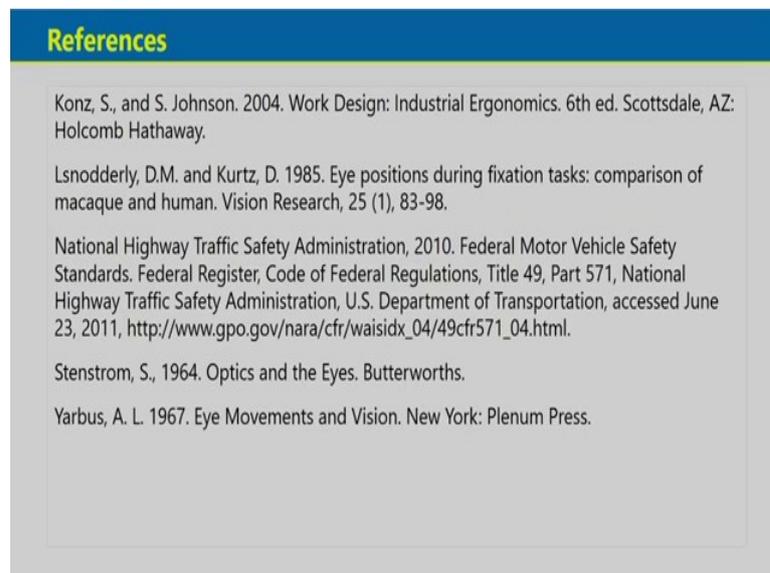
Fosberry, R.A.C., 1958. Measurement of visibility from the driving seat of motor vehicles, Ergonomics, 1:3, 240-250.

Guyton, A.C. and Hall, J.E., 2006. Textbook of medical physiology. 11th. WB Saunders Company, Philadelphia.

Jacob Bustad., 1995. Blind Zone Accidents and How to Prevent Them. Kansas RTAP Fact Sheet, pp.1-2.

Now, these are the references which have been used for this slide preparations. So, in different slides, all these references have been used. For a better understanding of this particular topic related to driver's field of view and obscuration zone, you can go through all these references; you can explore for your better learning.

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References

Konz, S., and S. Johnson. 2004. Work Design: Industrial Ergonomics. 6th ed. Scottsdale, AZ: Holcomb Hathaway.

Lsnodderly, D.M. and Kurtz, D. 1985. Eye positions during fixation tasks: comparison of macaque and human. Vision Research, 25 (1), 83-98.

National Highway Traffic Safety Administration, 2010. Federal Motor Vehicle Safety Standards. Federal Register, Code of Federal Regulations, Title 49, Part 571, National Highway Traffic Safety Administration, U.S. Department of Transportation, accessed June 23, 2011, http://www.gpo.gov/nara/cfr/waisidx_04/49cfr571_04.html.

Stenstrom, S., 1964. Optics and the Eyes. Butterworths.

Yarbus, A. L. 1967. Eye Movements and Vision. New York: Plenum Press.

Thank you.