Introduction to AR/VR

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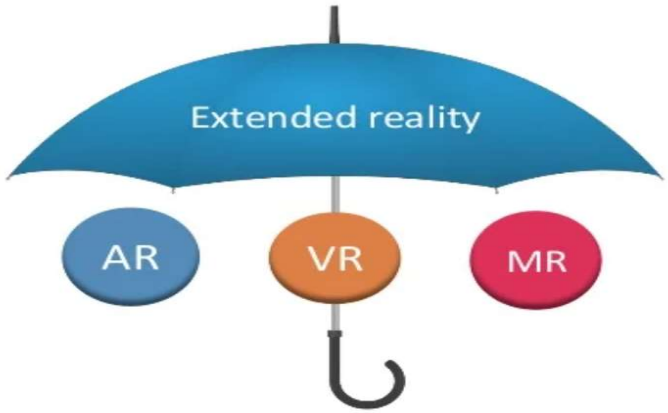
Extended Reality (XR)

- XR - umbrella term encapsulating all immersive technologies like AR,VR and MR
    - 'X' represents a variable for any current or future similar technologies



VR

An *artificial environment* which is experienced through sensory stimuli (as sights and sounds) *provided by a computer* and in which one's actions partially determine what happens in the environment

--- [Meriam Webster,2015]

AR

- *An interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated information, including visual, auditory, haptic, somatosensory and olfactory*

MR

- In MR, digital and real world objects co-exist and interact with one another in real time
- Also referred to as **hybrid reality** as includes both AR and VR together

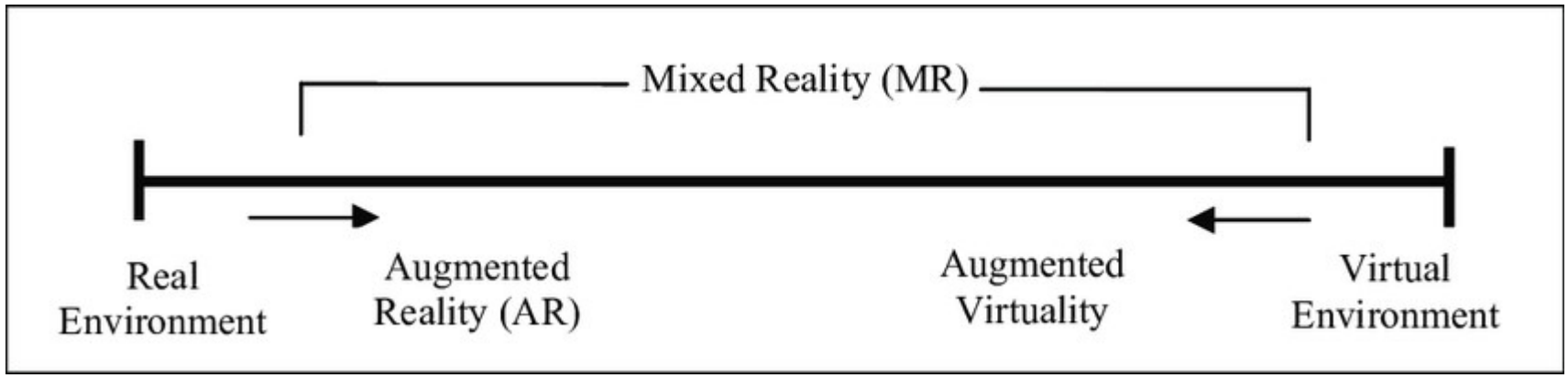
VR vs AR/MR ?

- AR/MR alters the ongoing perception of the real world
- VR completely replaces real-world environment

System characteristics

Forms of Reality

- Different forms of reality
- Reality-virtuality continuum



Aspects of XR

There are THREE aspects of XR systems (as per definition)

Aspects of XR

- Environment:
  - Artificial – VR
  - Real – AR
  - Real + artificial - MR
- Objects:
  - Real (with information augmentation) – AR
  - Artificial – VR
  - Real + artificial - MR
- Interaction

Experiencing XR

Experiencing VR

- Objective (by definition) – to “let user experience artificial environment through sensory stimuli provided by computer”

Experiencing VR

- Issues
  - Technological – generating suitable stimuli
  - Psychological – to “perceive” stimuli suitably (human factor)

Experiencing VR

- Brings us to TWO important concepts
  - Immersion
  - Presence

Immersion

"The objective degree to which a VR system and application projects stimuli onto the sensory receptors of users in a way that is extensive, matching, surrounding, vivid, interactive, and plot informing"

[Slater and Wilbur,1997]

Immersion

Essentially refers to technological support for VR experience

Presence

A *psychological state* in which even though part or all of an individual's current experience is generated by human-made technology, part or all of the individual's perception fails to acknowledge the role of the technology in the experience

-- International society on presence research

Presence

Essentially refers to a (psychological) state of mind (of user)

Immersion vs. Presence

Immersion *produces* a sensation of Presence

Goal of XR - to create high degree of presence.
i.e. make people believe they are really in extended reality environment

System types

Categorizing VR Experience

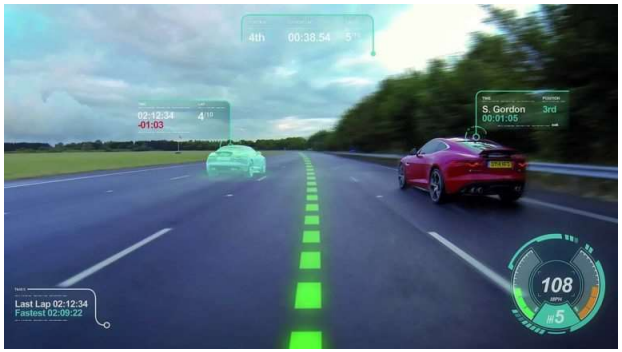
- **Non-immersive** – sensory organs “free” to sense real-world
- **Semi-immersive** – sensory organs “partially free” to sense real-world
- **Fully-immersive** – sensory organs “fully occupied” to sense virtual-world

Marker-based AR/MR

- Uses markers to trigger an augmented experience
  - Ex - pattern like QR Codes

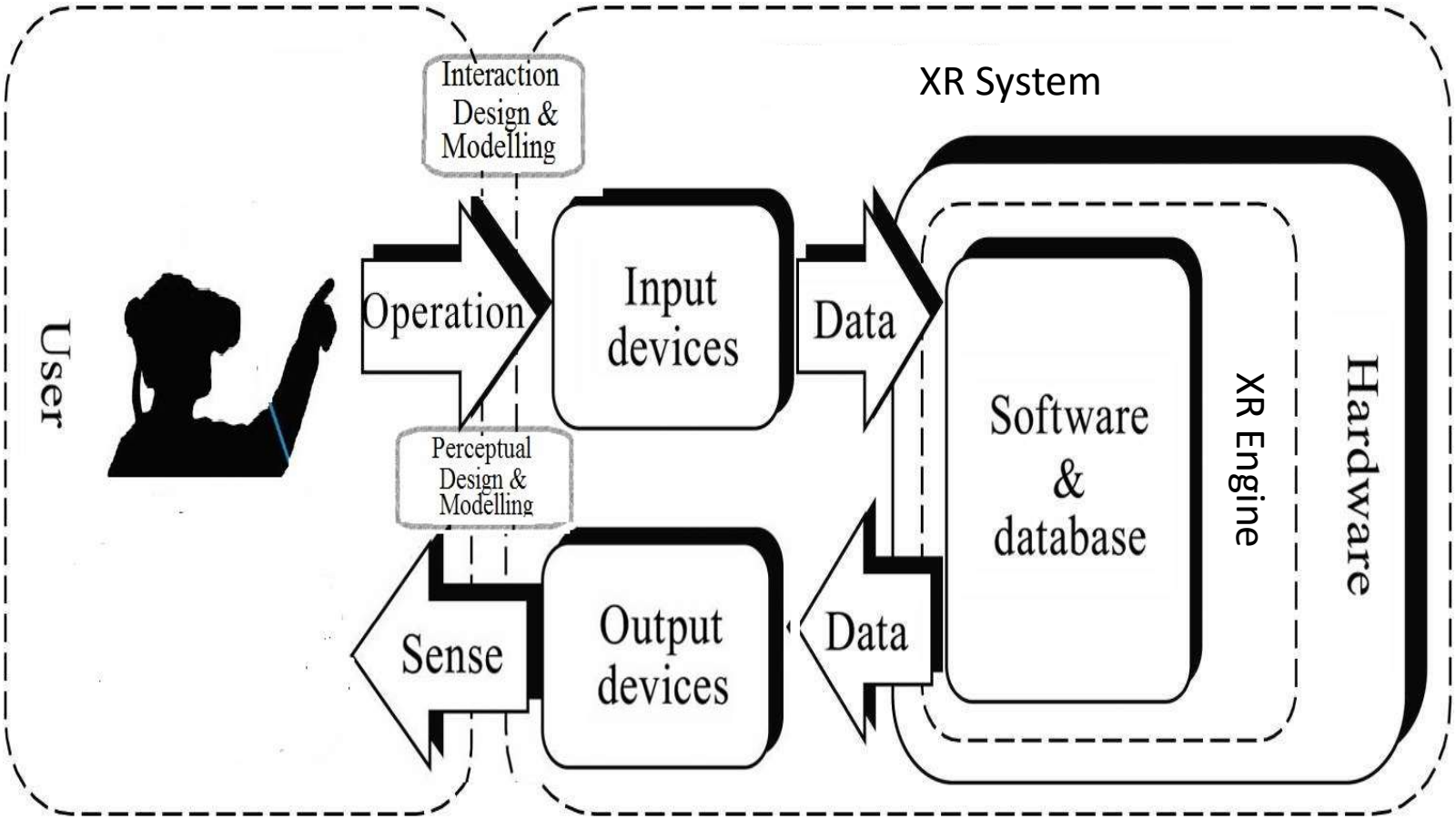
Marker-less AR/MR Types

- **Location Based:** ties digital content and experience to a specific place
- **Superimposition:** recognizes an object in physical world and enhances it in some way to provide an alternate view
- **Outlining:** uses object recognition to recreate user's immediate surroundings (e.g., driving in low light conditions)



Source: https://www.g2.com/articles/augmented-reality

XR System Workflow



Adapted from source: https://tinyurl.com/y2hmjl7w

XR: how it works

- Users' actions and position tracked and taken as **input**
- Input data processed and virtual environment **rendered** accordingly
- **XR engine** utilizes h/w resources to generate **output**
- Output excites users' stimuli using **o/p devices**

- Interaction and perception **designed** to create best possible **illusion of reality**

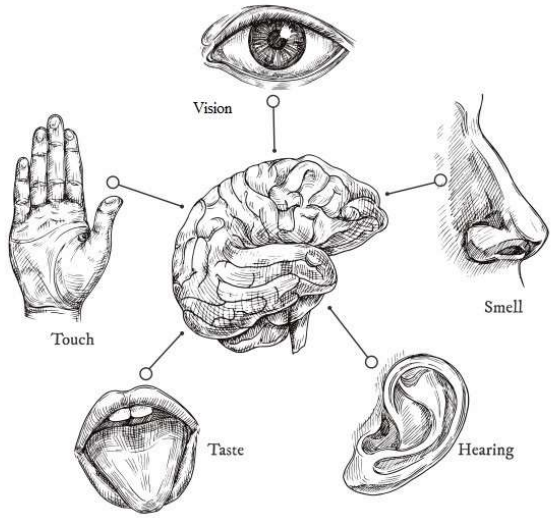
Human Senses & XR

Human senses

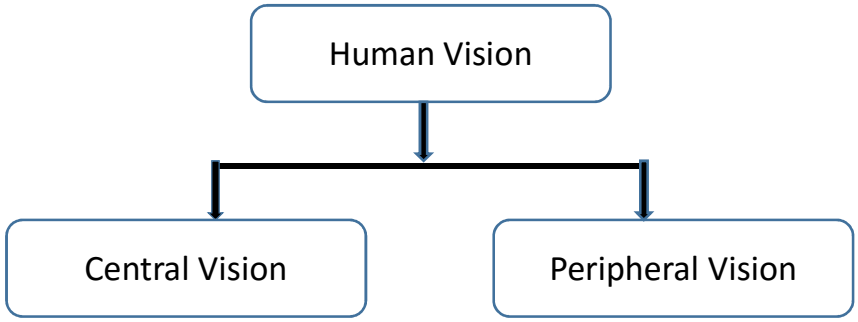
To “experience” XR (through the use of immersive technologies), we make use of our “senses”

Human senses

- We interact with virtual world using
  - Vision → display
  - Hearing → audio
  - Touch → haptics
  - Smell
  - Taste



Vision: Types



Vision: Types

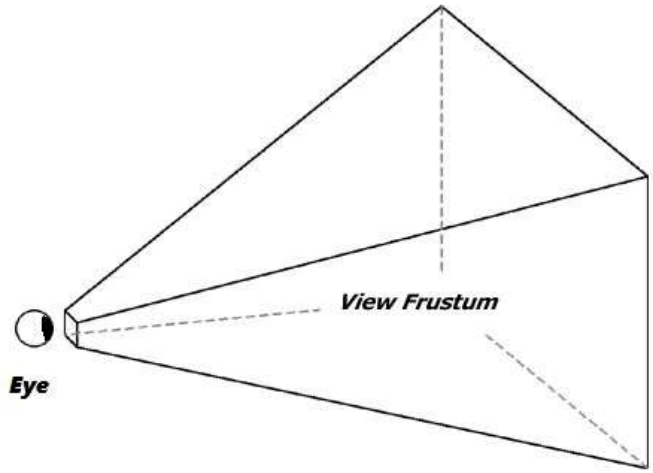
- Central Vision (Direct Vision) - Vision concentrated around fixated area
  - Has high clarity of vision
  - Is optimized for bright daytime conditions
  - Is color-sensitive

Vision: Types

- Peripheral Vision (Indirect Vision) - vision outside center of gaze
  - Color insensitive
  - More sensitive to light in dark conditions
  - Less sensitive to longer wavelengths (i.e., red)
  - Has fast response
  - More sensitive to fast motion and flicker and less sensitive to slow motions

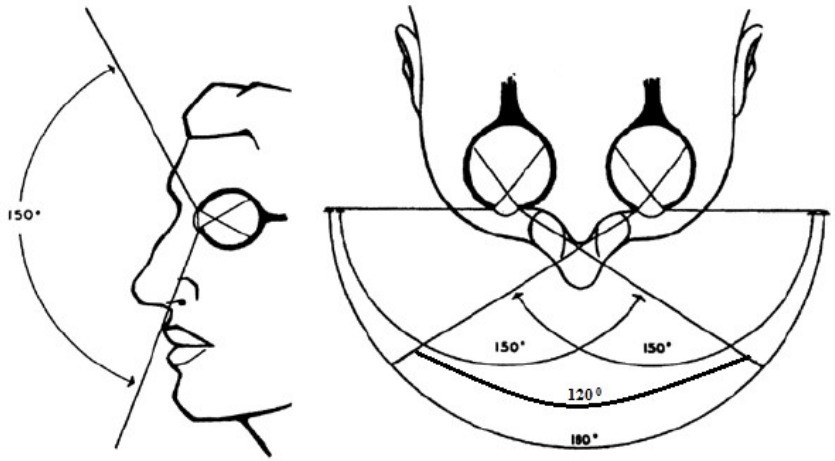
Field of view (FOV)

- Region visible to human eye
- Angular measure of what can be seen at a single point in time



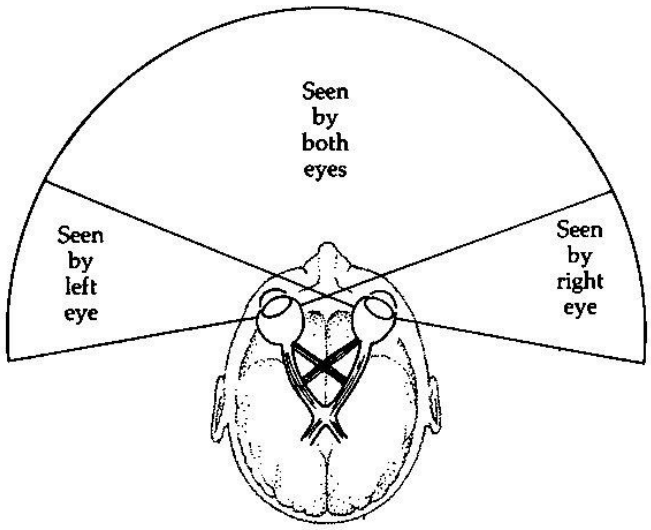
Field of view (FOV)

- Human eye has approximately
  - 180◦ horizontal FOV
  - 150◦ vertical FOV
- Both eyes can see same area over an angle of about 120◦ when focusing on infinity



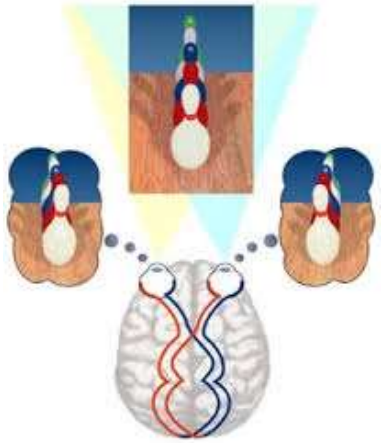
binocular Vision

- We have **binocular vision** – both eyes used to see same image
  - Enhances depth perception and relationship between objects in 3D space



stereoscopy

- We use two eyes to view two images simultaneously
  - Left eye process left image
  - Right eye process right image
- Two 2D images processed simultaneously to generate a 3D view of the object



stereoscope

- A device that facilitates the stereo viewing process

Stereoscope

- Uses stereopair images with slightly different spatial information

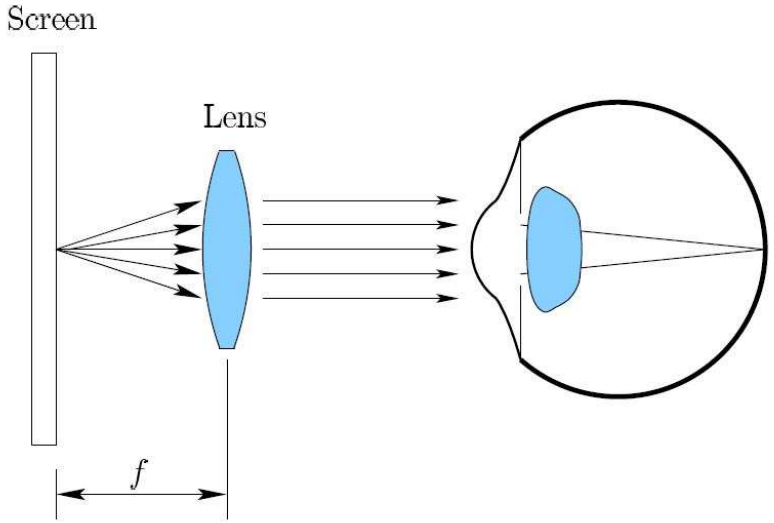
Light and optics

- Light emitted from display arrives on our retina in a way that reproduces how light arrives through normal vision in physical world

- In XR headsets, a system of both engineered and natural lenses (parts of our eyes) guide the light

Application of Lens in XR

- In XR headsets, lens is placed so that screen **appears** to be **infinitely far away**



Perception of Movement

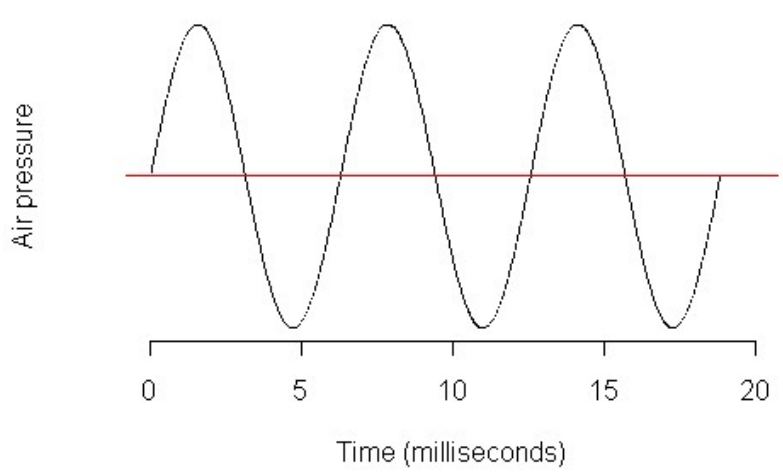
- A virtual world may allow up to two types of movements in 3D space
  - Translational - used for navigating in the 3D space
  - Rotational - used for moving at different angles along the translational axes

Degrees of freedom (Dof)

- Different ways an object can move in space
- Total 6 in 3-D space
  - Rotational – 3 DoF (yaw, roll, pitch)
  - Translational – 3 DoF (x, y, z)

WHAT IS SOUND?

- Pressure waves carried out in a medium (usually air)
- Produced by a vibrating surface
- Can plot displacement of air particles off the mean positions, and we get a sound wave



https://home.cc.umanitoba.ca/~krussll/phonetics/acoustic/img/sine1.png

PROPERTIES OF SOUND

Frequency

- No. of alterations (Max to Max) per second. Measured in Hz (Hertz)
- Humans can only hear a range of frequencies (20Hz to 20,000Hz)
- Children and animals are sensitive to a wider gamut

Amplitude

- Max. displacement from mean (rest position)
- Measured in dB, relative scale and logarithmic scale
- Measured relative to min sound detectable by humans at 1,000Hz (0.0002 dynes/cm2)

Phase

- Start position of a cycle, where it can begin at 0 to 360 degrees
- Measured in degree

HEARING: PROPERTIES

- Loudness
  - Attribute that corresponds closely to sound intensity
- Pitch
  - Perceived attribute that closely corresponds to sound frequency
  - For pure tones (sine waves), it's the frequency
  - For complex, it's related to the fundamental frequency

IMPORTANCE OF SOUND IN XR

- Sound combined with view affects our perception about (virtual) environment like size, volume, material, intensity, distance and so on
- Sound helps “reinforce” experience as “believable”
- Can help create emotional connect with the environment
- Overall, very important to maintain *presence*

Perception of sound

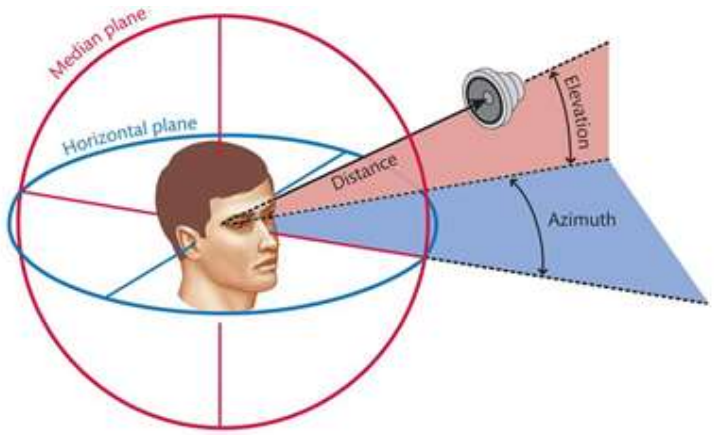
- We perceive sound at THREE levels
  - Social level: perception that helps social interactions of individual
  - Warning level: perception that provides alert or warning to individual
  - Primitive level: perception of naïve sounds like background noises, that we tend to ignore mostly

- Identification of suitable perception level can help VR developers help generate suitable auditory effect

Source: https://www.nap.edu/read/4761/chapter/7

LOCALIZATION

- Ability to judge direction and estimate distance of a sound source
- Auditory space - surrounds an observer and exists wherever there is a sound
- Observer can identify sound directly in front of them more accurately



Source: https://courses.washington.edu/psy333/lecture_pdfs/Week9_Day2.pdf
https://slideplayer.com/slide/10548861/36/images/9/Localizing+Sounds+Azimuth+Elevation+Distance+Side+to+side+dimension.jpg

LOCALIZATION

- Sound location calculated through three primary cues
  - Interaural time difference (ITD)
  - Interaural level difference (ILD)
  - Head-related transfer function (HRTF)

Source: https://courses.washington.edu/psy333/lecture_pdfs/Week9_Day2.pdf

Interaural time difference (ITD)

- Arrival time difference of sound reaching both the ears
- Happens because sound from source takes different path to ears

Source: https://courses.washington.edu/psy333/lecture_pdfs/Week9_Day2.pdf

Interaural level difference (ILD)

- It is the frequency and loudness difference
- Happens because loudness falls as a function of distance
- Depending on angle (of sound source) made with ear, frequency may also vary

Source: https://courses.washington.edu/psy333/lecture_pdfs/Week9_Day2.pdf

HEAD RELATED TRANSFER FUNCTION (HRTF)

- A response that characterizes how an ear receives sound from a location in space
- Size, shape of head, ears, ear canal and shape of nasal cavities all affect how sound is modified from a point in space
- Hence every person has a unique HRTF
- Pair of HRTF for both ears can be used to synthesize binaural sound

Source: https://en.wikipedia.org/wiki/Head-related_transfer_function#:~:text=A%20head%2Drelated%20transfer%20function,from%20a%20point%20in%20space.&text=This%20is%20possible%20because%20the,to%20make%20inferences%20about%20location.

auditory component in VR systems

- The auditory component in XR Systems should be (ideally)
  - Non-stationary (dynamic movements)
  - Interactive (dependent on listener's actions)

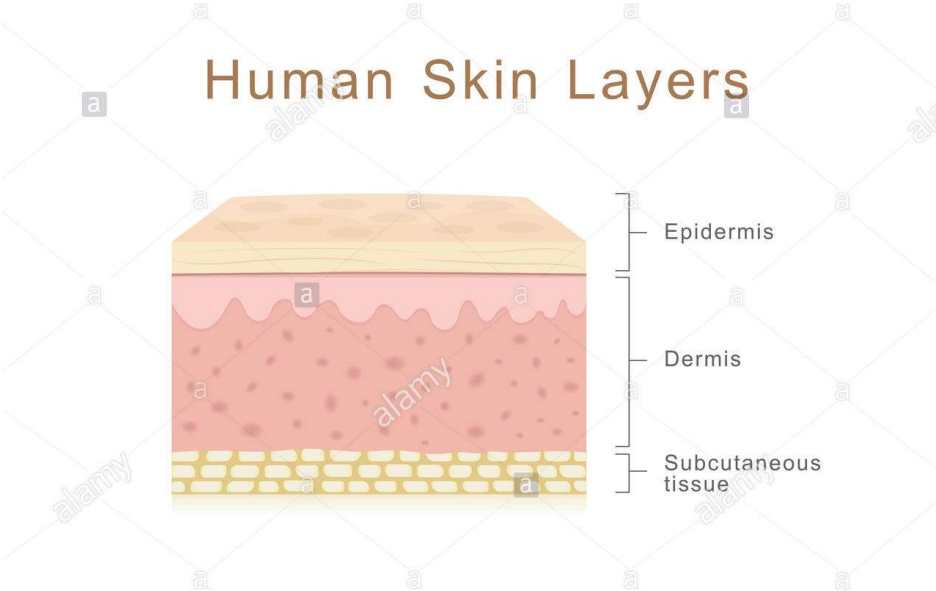
Haptics

- Term often used interchangeably with haptic technology (specific technologies that simulate tactile sensations) and haptic feedback (the way touch is used to communicate with users)

- Haptics - encompasses haptic technology, haptic feedback, along with physiology and neuroscience of touch

a little bit on touch

- Experienced through our skin
- 3 layers of skin
  - Epidermis
  - Dermis
  - Subcutaneous tissue
- Dermis has touch receptors that helps feeling touch



Source: https://learning-center.homesciencetools.com/article/skin-touch/

a little bit on touch

- 4 kinds of receptors
  - Mechanoreceptors
  - Thermoreceptors
  - Pain receptors
  - Proprioceptors

Source: https://learning-center.homesciencetools.com/article/skin-touch/

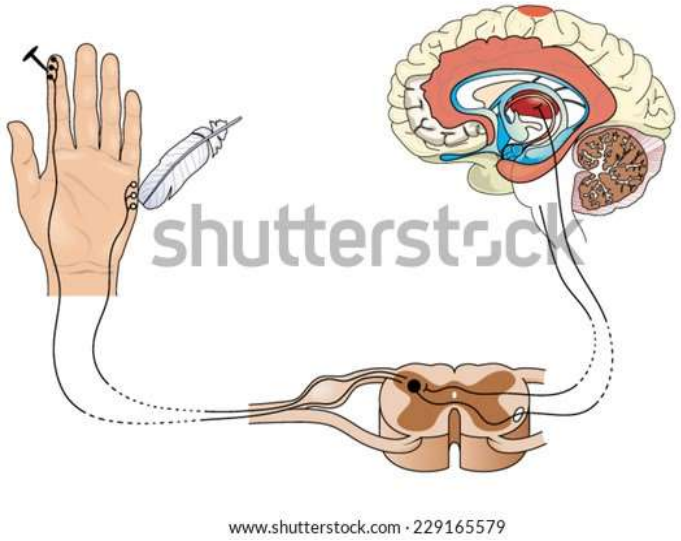
a little bit on touch

- Receptors connected to nerves – together called *somatosensory system*
  - Responsible for all touch sensations we feel – cold, hot, smooth, rough, pressure, tickle, itch, pain, vibrations, and more

Source: https://learning-center.homesciencetools.com/article/skin-touch/

a little bit on touch

- Ex - when hand touches object, mechanoreceptors are activated and start a chain of events by sending a signal to nearest neuron
- Neuron transmits message to next neuron and so on till it reaches brain.
- Brain processes message (giving us touch perception) and send messages back to your hand via this same pathway (to take corrective motor action if needed, e.g. remove hand from hot object)



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Haptics in XR

- VR Haptics technology offers an extra dimension to the VR world by letting users feel the virtual environment via the sense of touch
- In addition to visual and aural perception, It makes you feel truly immersive in the artificial world

- Ex - imagine yourself in a desert seeing the sand and feeling it glide under your feet as you walk

Enabling haptics in XR

- With help of devices, via which users receive feedback in the form of vibrations from XR applications

- Ex devices
  - Gloves
  - Body Suits

Haptic feedback generation techniques

- Vibration
- Force feedback
- Air vortex rings
- Ultrasound
- …