Feeding human senses through Immersion

1. How many human senses ?
2. Overview of key human senses
3. Sensory stimulation through Immersion
4. Conclusion

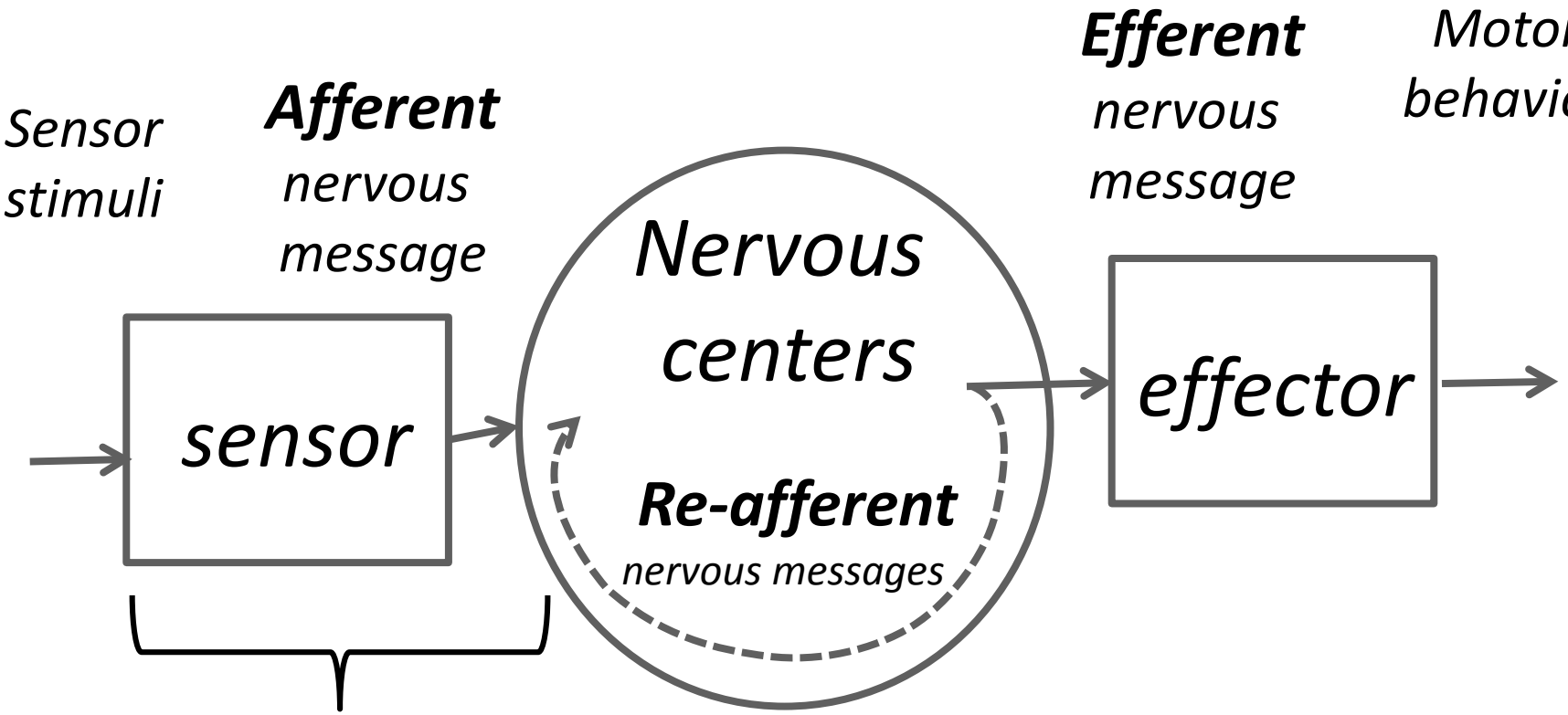
1. How many human senses ? [TRV 2006]

Example of a tennis player in interaction with his surrounding environment while playing. He is equipped with sensors allowing to perceive:

- Light within 380-750 nm: the ball is seen
- the ball hitting the racket produces mechanical phenomena, including:
  - vibration propagating in air 20Hz-20KHz
  - vibration of the ball hitting the racket induces vibrations propagating within the body and felt by skin and and deep bone sensors
- racket shape, weight, texture, temperature, humidity is felt through skin
- The player movements are sensed by the vestibular system and proprioceptive organs
- heat, humidity, wind speed, sweat are felt by the skin and internal thermic regulators
- sweat odor is smelt by the nose and tasted by the tongue

The tennis player example [Chap2 in TRV2006]

1.1 Terminology



Sensation: *low-level process*

Perception: *high-level process incuding interpretation and active behavior to filter and organize sensed information*

1.2 Sensor stimulation

All stimulated sensors above a minimum threshold lead to the formation of **action potentials** (amplitude of a few tens of mV and a duration of 1 to 2 ms) transmitted at a speed from 1 to 100 m/s through the nerves.

- it takes 10 ms to travel 1m at the max speed of 100 m/s
- strategic organs for survival have to be near the brain for fast closed loop control (e.g. eye movement)
- or there must be some intermediate autonomous control mechanism (e.g. low-level locomotion control at the spine level)

A stimulation must have a minimum duration to be sensed (~human sensitive system as a lowpass filter)

Conversely, if the stimulation is maintained the sensation disappears or is reduced (except for pain and some special case).

1.2 Sensor stimulation : Weber-Fechner law

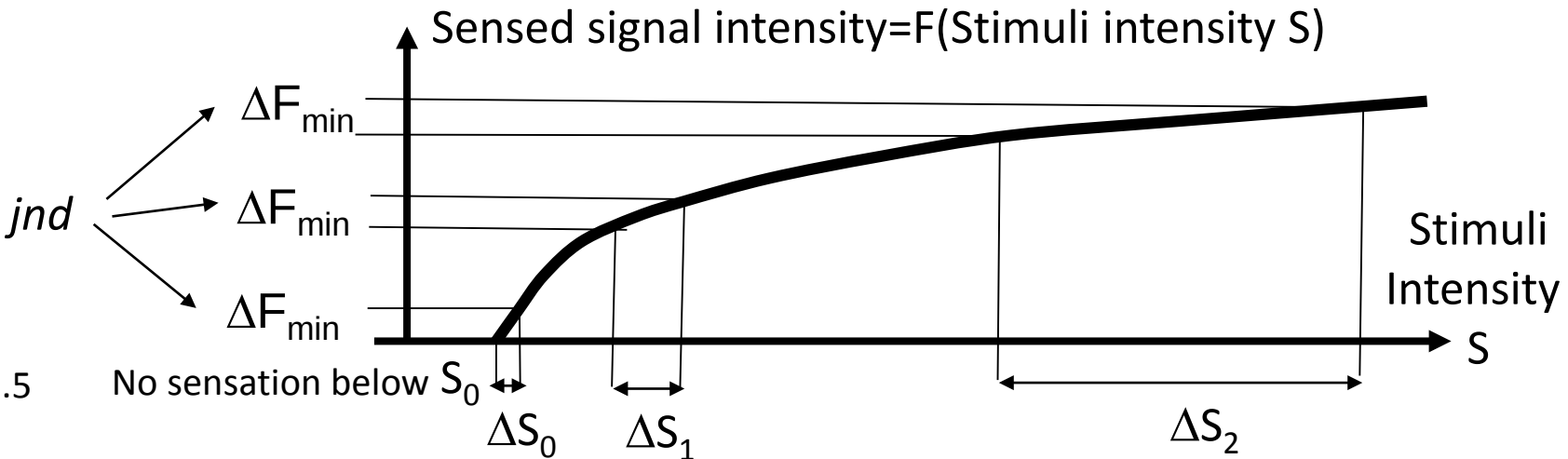
The *just noticeable difference*, noted *jnd*, is the smallest variation ΔF_{min} of the sensed signal F that the human sensory system can produce.

Given a physical stimuli intensity S, Weber & Fechner observed that the requested physical stimuli variation ΔS to produce a just noticeable difference ΔF_{min}, is *proportional* to the physical stimuli intensity S *:*

$$\Delta S = k.\Delta F_{min}.S \quad \text{so} \quad \Delta F/\Delta S = k'.1/S$$

(= sensitivity decreases as S increases)

The Weber-Fechner law is logarithmic : $F(S) = K.\ln(S) + Cte$



1.3 Sensor sensitivity

Absolute precision is low compared to the relative precision; human being has a great capacity of comparing two stimuli

Example:

- difficult to define an isolated color, easy to compare two nuances
- difficult to define absolute depth, easier to define the relative depth of two objects
- temperature, etc…

Sensors also have a maximum perceptible variation frequency (bandwitdh)

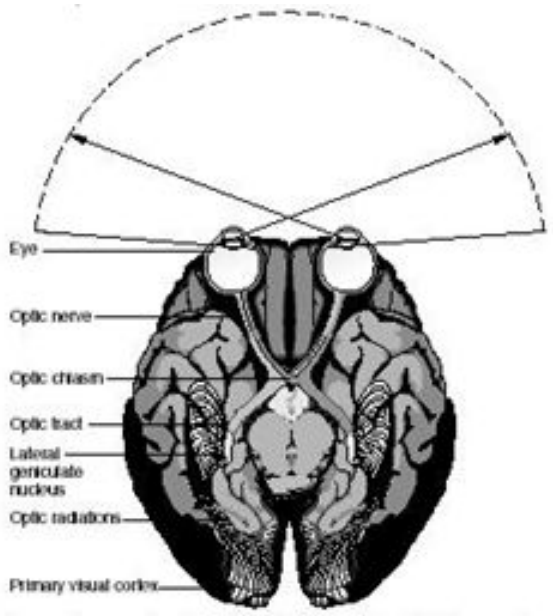
2. Overview of key human senses

- Vision
- Audition
- Skin and kinesthetic sensors
- Balance
- Taste & smell

Vision

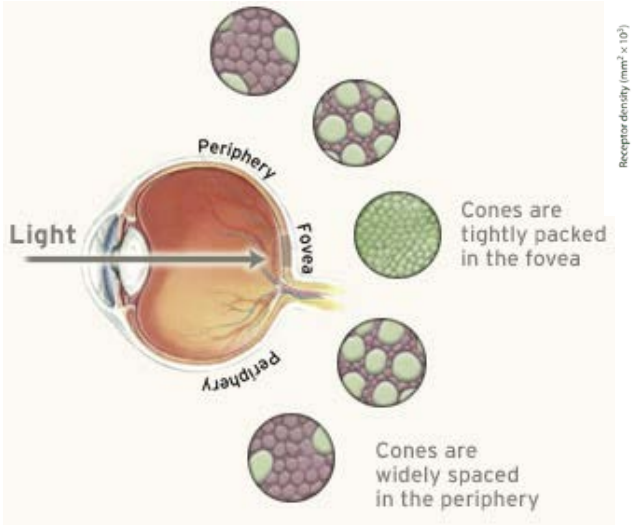
Field of view
Horizontally:
90-100° on head side, 50-60° on nose side

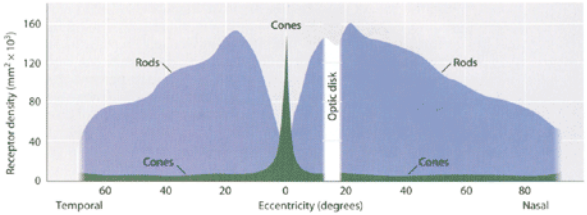
Vertically:
45-60° above, 70-75° below



Eye movement: ~+/- 45° Horiz. & Vert.
Eye coordination for depth perception [NW1]

The visual acuity is highly precise and
color sensitive (with cones) for the **fovea** region=1mm diameter





Fovea resolution:

1% of retina, 2-3° visual cone

drop of cone photoreceptors density from center:
center: ~160'000 photoreceptors / mm^2
0.5 mm: ~100'000 photoreceptors / mm^2
4 mm: < 10'000 photoreceptors / mm^2

~6 millions cone vs 125 millions rods (light & movement)

Visual saccades

Due to the small size of the high-resolution fovea region, the eyes keep making movements called saccades to explore the field of view:

- Around 3 saccades per second
- Max speed: 600-900°/s

- each saccade lasts 20 to 200 ms
- each fixation lasts 100 to 500 ms

- the brain filters out the signal (=we are blind) during the movement between two temporary static locations (fixations)

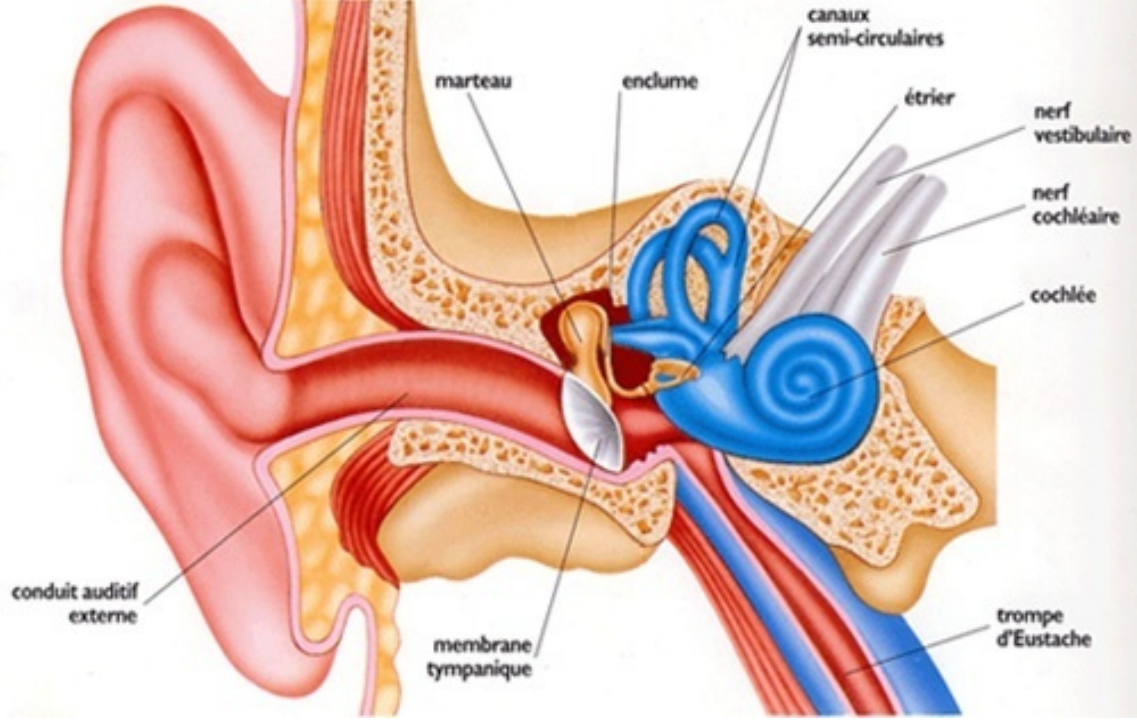
Saccades are unvoluntary movements, i.e. not under direct conscious motor control

Audition

20Hz-20 Khz

A minimum duration
is necessary

Masking effect of the first
arrived sound over a
different source.



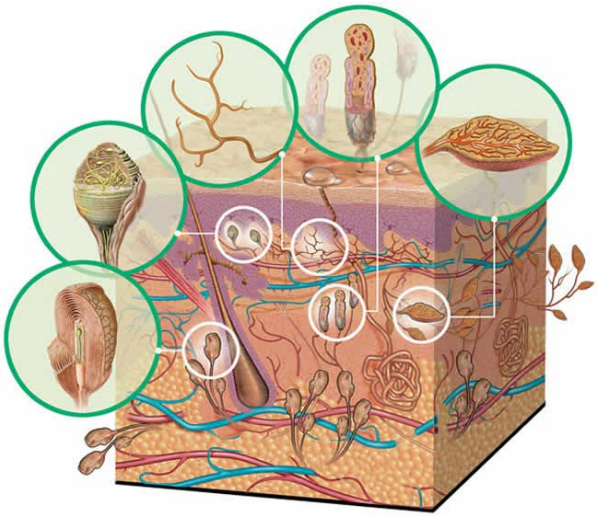
High sensitivity of spatial sound perception: 1° in front (15°laterally) but low accuracity of distance perception.

Sensitivity to reverberation improves in blind persons

Skin, Kinesthetic sensors, extero/interoception

Nociceptors: sense pain

Thermosensors: 2 types
-Sensation of cold
-Sensation of heat
Very specific distributions on the skin



Mechanical sensors
-High density on finger tips (2500/cm^2)

-**Proprioceptive** deep sensors: movements & muscle, tendons, joint tension (**kinesthetic sensors**)

Exteroceptive sensors: tactile with different time responses

Interoceptive sensors: stimuli from inside the body (pain, internal organs such as heart, lungs, digestion, etc..)

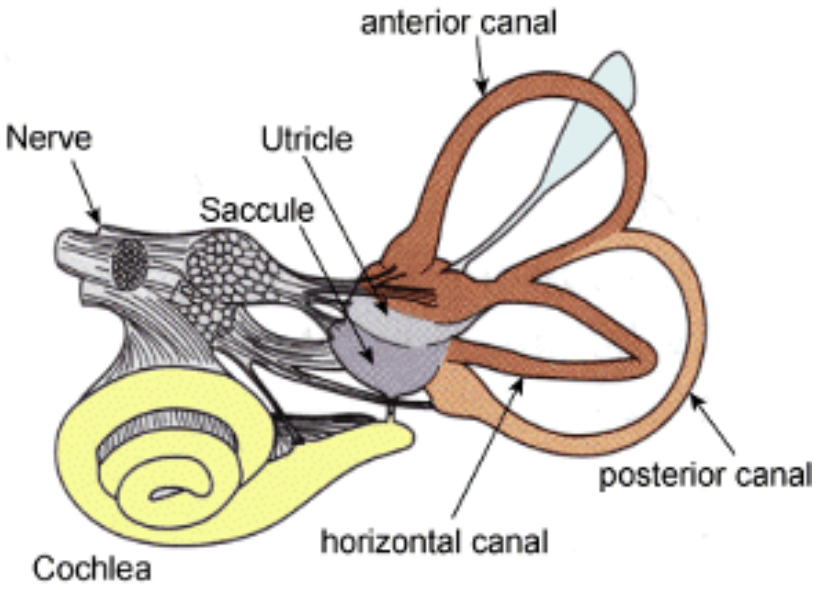
Vestibular system / the sense of balance

-**Three semicircular canal:** for sensing angular acceleration and angular velocity

- **two otholitic organs (utricule):** for sensing linear acceleration

-> Important to sense the vertical direction of gravity

-Note: the vestibular system is very difficult to trick, making the rendering of acceleration or lack of gravity nearly impossible.



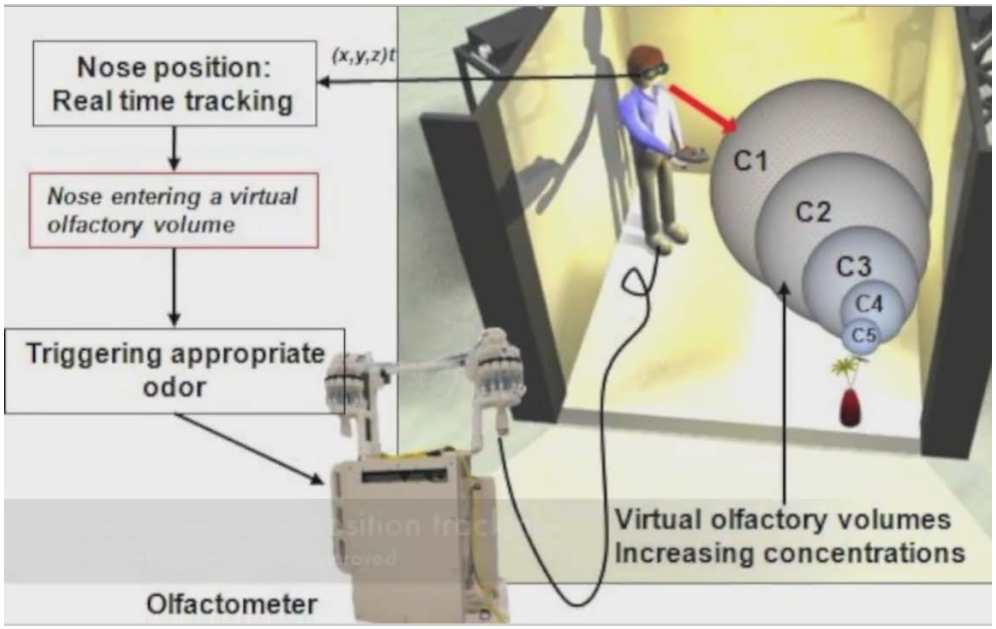
Other sensors : taste & smell

Specialized chemical sensors

Olfaction is often not exploited in daily activities

Odors & taste are associated with affective valence (good vs bad)

Seldom exploited in VR
exemple:
Olfaction in Geneva
(Swiss Center for Affective Sciences)



[virolfac system in Univ. Geneva center for affective sciences]

Up to 28 odorants

3. Sensory stimulation through Immersion

Immersion: is the **objective** level of fidelity of the sensory stimuli produced by a technological system [S2003].

• Measurable and controllable as it depends only on **technology**

• Different systems can be compared

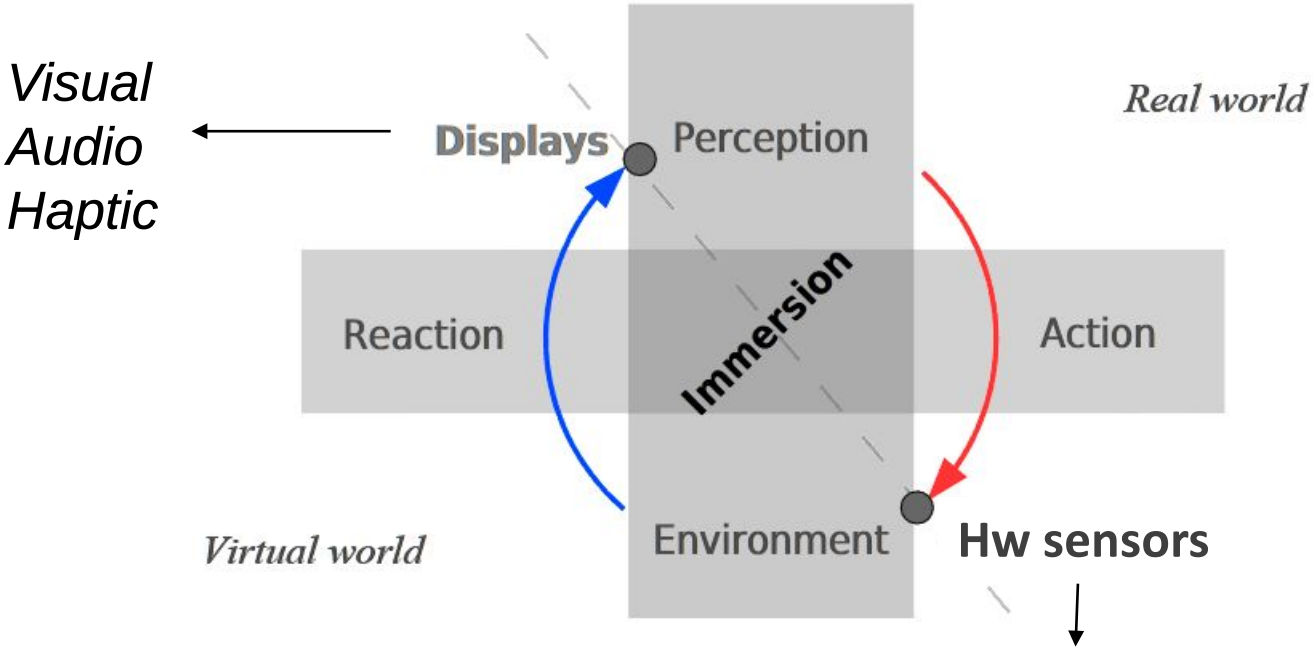
• in academic VR, the word «immersion» has nothing to do with involvement, enjoyment, etc… which are subjective feelings

[B2007] Bowman, D., McMahan, P.: Virtual Reality: How Much Immersion Is Enough? Computer, 40(7), 36--43 (2007), & Course notes from D. Bowman / Immersion & Presence

Immersion is achieved with technical systems

Mediation of feedback with devices

- The user acts according to perception (*and the prediction made through the internal models*).
- The system reacts accordingly

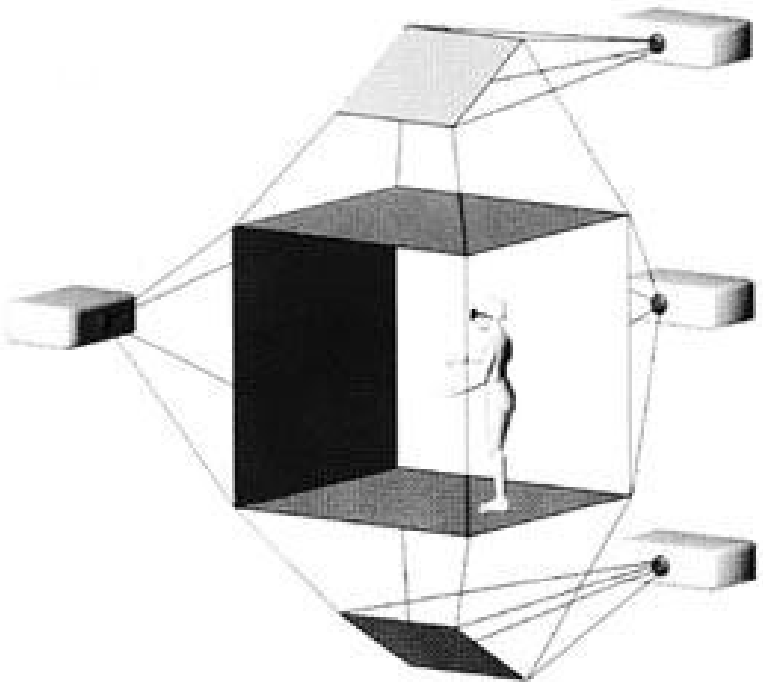


More on displays

- Surrounding the user senses
  – wearable or human scale

- Covering fully the senses
  – stereoscopy, spacial sound,..

- Covering every senses
  – vision
  – hearing
  – force feedback (robotic arm)
  – touch (vibrating devices, braille-like)
  - others



[CAVE]

5 Conclusion

The spectrum of human senses is large but vision is dominant over the other senses.

Immersion is the **objective** level of fidelity of the sensory stimuli produced by a technological system.

Most of the effort in immersion technology have focused on visual displays for which a broad range of technical means is available (complementary lectures follow).

Some classes of sensory stimuli are difficult to produce :

- critically useful for a wide range of applications:
    - Haptic (force) and vestibular (balance)
- Seldom exploited due to narrow class of applications: smell

[References]

[B2007] Bowman, D., McMahan, P.: Virtual Reality: How Much Immersion Is Enough? Computer, 40(7), 36--43 (2007), & Course notes from D. Bowman / Immersion & Presence

[TRV 2006] Traité de Réalité Virtuelle, Ed. P. Fuch, vol 1, chap2, Eds A. Berthoz & J.L. Vercher

[W2015] http://en.wikipedia.org/wiki/Weber-Fechner_law