Research Seminar: Cognitive Science

# Human factors of VR

25/Feb/2019

Tadamasa Sawada
School of Psychology

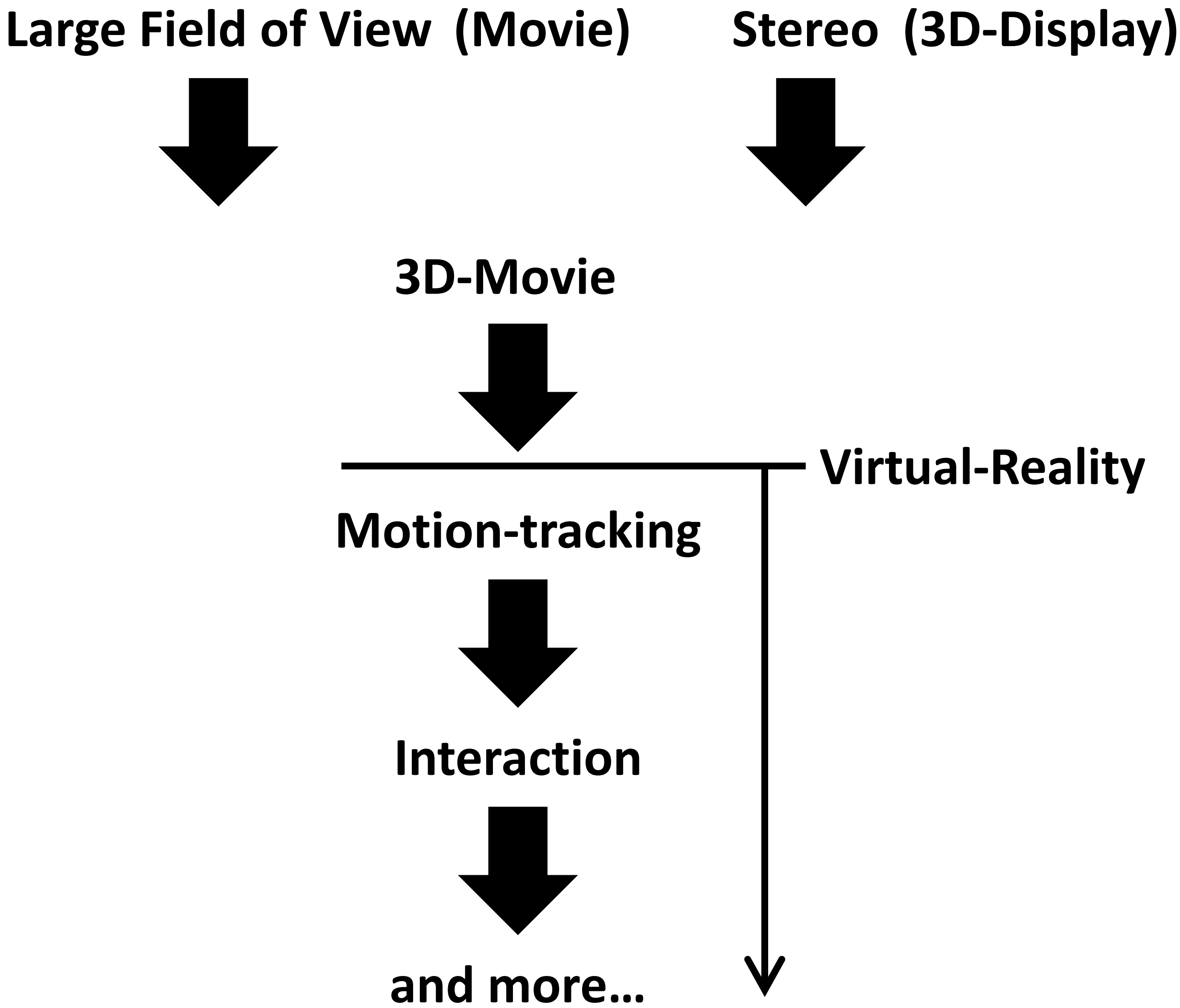
## What is definition of Virtual Reality (VR)

*Virtual reality or virtual realities (VR), also known as immersive multimedia or computer-simulated reality, is a computer technology that replicates an environment, real or imagined, and simulates a user's physical presence and environment to allow for user interaction. Virtual realities artificially create sensory experience, which can include sight, touch, hearing, and smell.* (from Wikipedia)

# Devices of Virtual-Reality (VR)

- **Head-mounted display**: a pair of small displays (one for each eye; e.g. Oculus-rift, HTC-Vive, Sony-PS-VR, Google Cardboard)
- **Large display** (or **displays**) with stereo-shutter/polarized glasses (e.g. CAVE)

# From a Display to a VR-device



# Large field of view

A large field of view is a critical factor for perceiving "***vection***" (visually-evoked-action) from a visual stimulus.

Väljamäe et al. (2008)

Palmisano et al. (2015)

## Stereo (binocular-disparity)

Humans can perceive depth from binocular-disparity, which is a small difference between a stereo pair of retinal images.

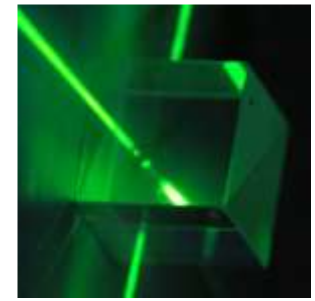
Note that it is the best studied depth cue of the human visual system (Howard & Rogers, 2012).

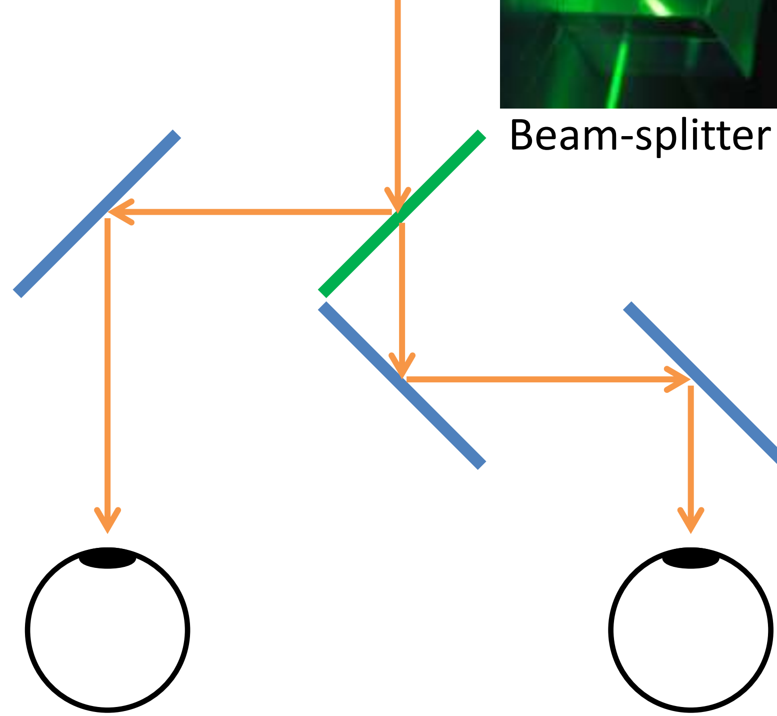
Afraz & Nakayama (2013)

# Stereo (binocular-disparity)

3~14% of people are stereo-blind/-deficient (Gaudia et al., 2014).

Humans can have stereo-like experience of a scene using a synopter (Wijntjes et al., 2016; Koenderink, van Doorn, & Kappers, 1994).

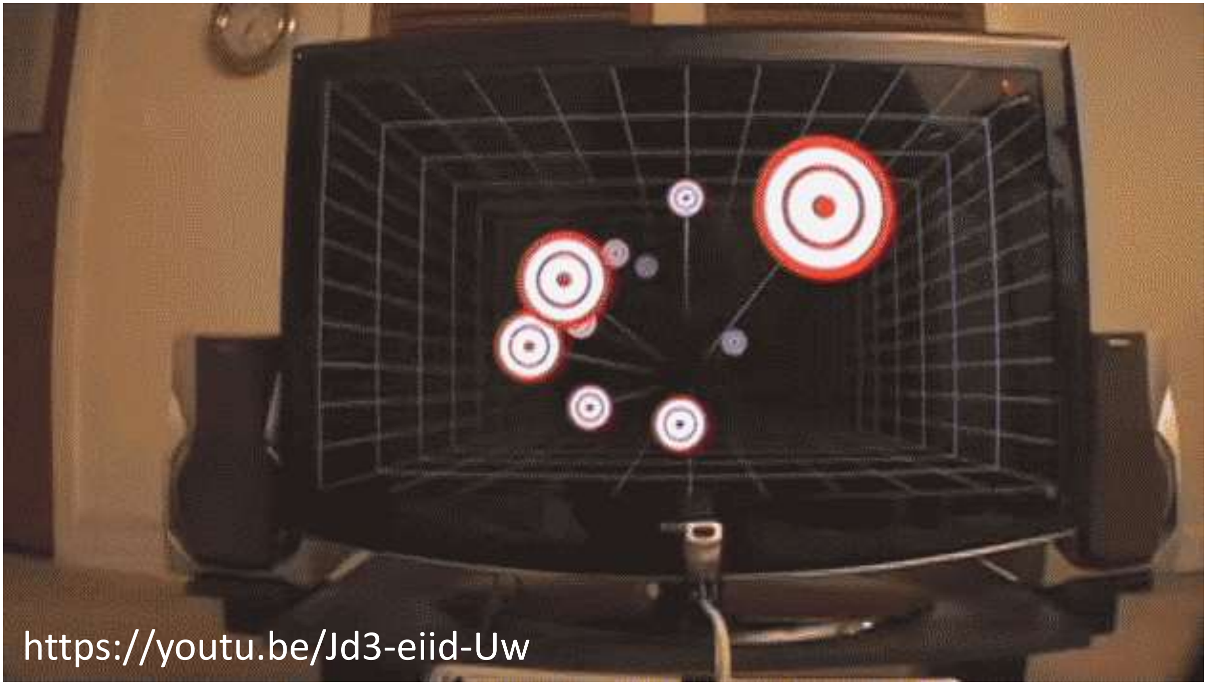





(Moritz von Rohr, patented by CarlZeiss, 1907)

http://binnenland.eenvandaag.nl/radio-items/60101/ik_neem_je_mee_synopter_in_het_rijksmuseum
https://physics.aps.org/story/v13/st21

# Motion-parallax and Head-tracking





We perceive 3D if an image on a display changes synchronously with our head motion. Therefore, VR should come with head-tracking:

(1) Rotation only (e.g. Google cardboard)
(2) Rotation + Translation (e.g. Oculus and Vive)

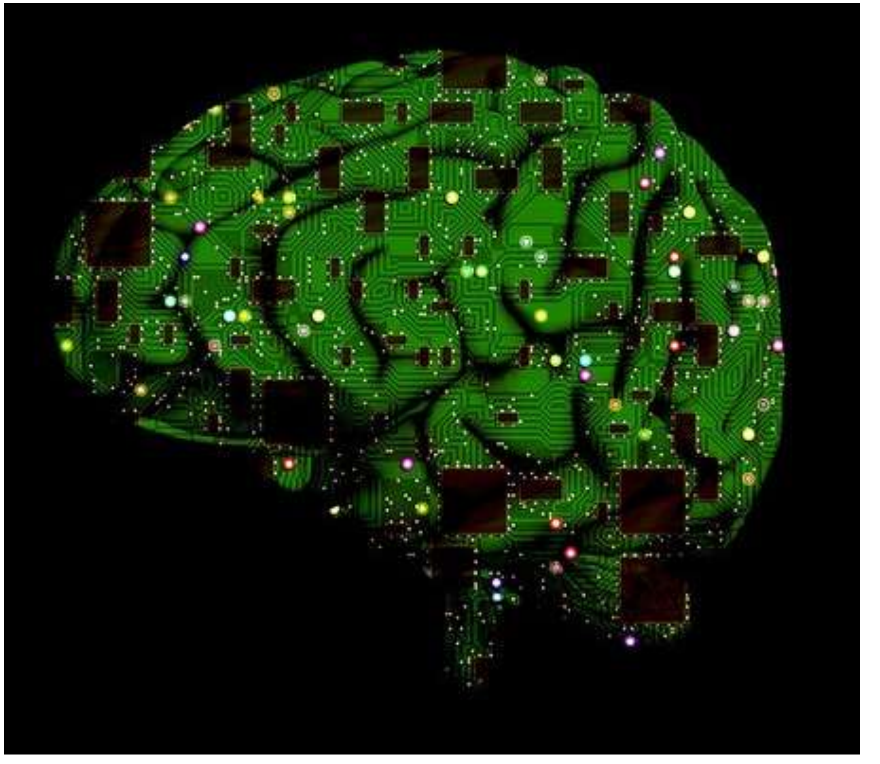
If the image does not change…

# Images viewed from correct/incorrect positions


We perceive a correct 3D scene only from a correct viewing position.
If we change a viewing position, an image on an display should synchronously change.

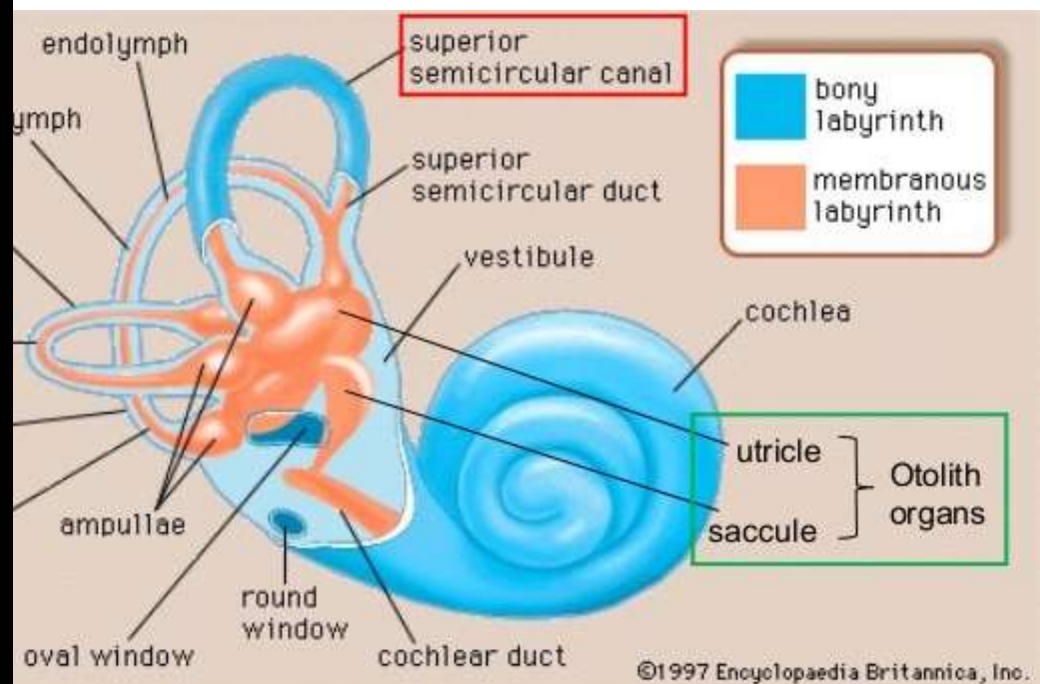
# Other types of sensory information for VR

- Vestibular information
- Somatosensory information (including tactile information)
- Auditory information
- Haptic information
- Olfactory information
- Gustatory information



# Vestibular information

The vestibular system (semicircular-canals, utricle, saccule) is for perception of body/head orientation and motion. In short, it is an accelerometer for rotational (3df) and linear (3df) motions. It cannot detect position or speed but acceleration.

# Vestibular information

The vestibular system is controlled in scientific experiments often by (1) using the gravity by changing a head/body orientation or (2) physically moving the body (e.g. a tumbling room in CVR at York Univ.).

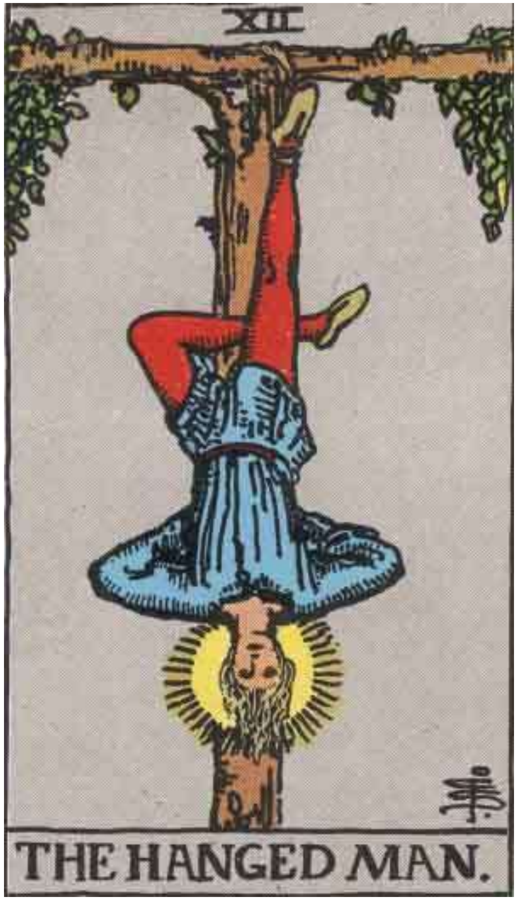
http://yfile-archive.news.yorku.ca/2004/04/29/bbc-arrives-at-york-to-highlight-vision-research/
https://jp.pinterest.com/pin/368028600784894849/

# Vestibular information

The vestibular system can be stimulated artificially using Galvanic-Vestibular-Stimulation and it causes reflexive actions of a body. However, mechanism of this phenomenon and a relation between the stimulation and the response of the system is still unclear (Fitzpatrick & Day, 2006).


# Somatosensory information

Somatosensory information is about changes of body parts (inside/outside). For VR, mechanical movements of a body and physical interaction of the body with a 3D scene (e.g. air pressure).




# Somatosensory information

Interface for the human somatosensory system.


http://www.techworld.com/picture-gallery/cloud/virtual-reality-gets-real-3400143/

https://www.xataka.com/galeria/birdly-vr/2/

# Visual, Vestibular, and Somatosensory information

Drop1: Vestibular = 0G, Somatosensory = motion↓ (wind)

Drop2: Vestibular = 1G↓, Somatosensory = motion↓

(Downward speed becomes constant because of air resistance)

Skydive Lillo Centro de Paracaidismo

# Visual, Vestibular, and Somatosensory information

Drop1: Vestibular = 0G, Somatosensory = motion↓ (wind)

Drop2: Vestibular = 1G↓, Somatosensory = motion↓

(Downward speed becomes constant because of air resistance)

Parachute1: Vestibular = $x$G↑, Somatosensory = motion↓ + hanged

Parachute2: Vestibular = 1G↓, Somatosensory = motion↓ + hanged

# Visual, Vestibular, and Somatosensory information

Drop1: Vestibular = 0G, Somatosensory = motion↓ (wind)

Drop2: Vestibular = 1G↓, Somatosensory = motion↓

(Downward speed becomes constant because of air resistance)

Parachute1: Vestibular = $x$G↑, Somatosensory = motion↓ + hanged

Parachute2: Vestibular = 1G↓, Somatosensory = motion↓ + hanged

http://www.ultravr.org/virtualreality/top-things-to-do-virtual-reality/

# Visual, Vestibular, and Somatosensory information

Space: Vestibular = 0G, Somatosensory = Neutral
(no pressure from any direction)

# Visual, Vestibular, and Somatosensory information

Space: Vestibular = 0G, Somatosensory = Neutral
(no pressure from any direction)

This situation can be roughly emulated in an airplane dropping down
(see https://youtu.be/LWGJA9i18Co).


http://www.faust-ag.jp/soul/adventure/soul142.php

# Visual, Vestibular, and Somatosensory information

Stimulating all the sensory systems properly in VR is still a difficult problem. Especially, a viewing position is forced to change quickly by some outside factor.

http://japanese.engadget.com/2016/04/12/vr-vr-zone-project-i-can/

## Visual, Vestibular, and Somatosensory information

Stimulating all the sensory systems properly in VR is still a difficult problem. Especially, a viewing position is forced to change quickly by some outside factor.

**Auditory information**

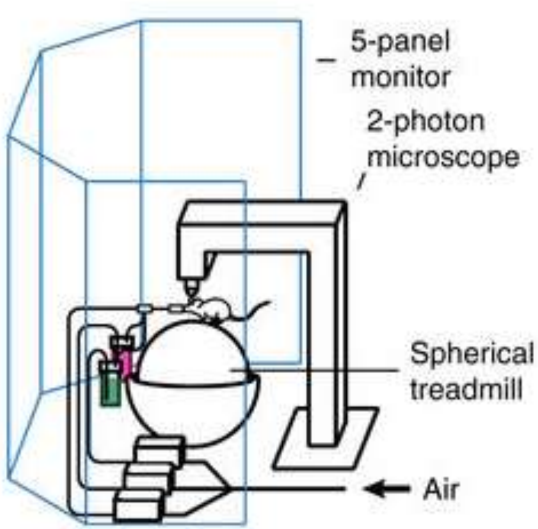
Binaural recording considers shapes of the human ears.

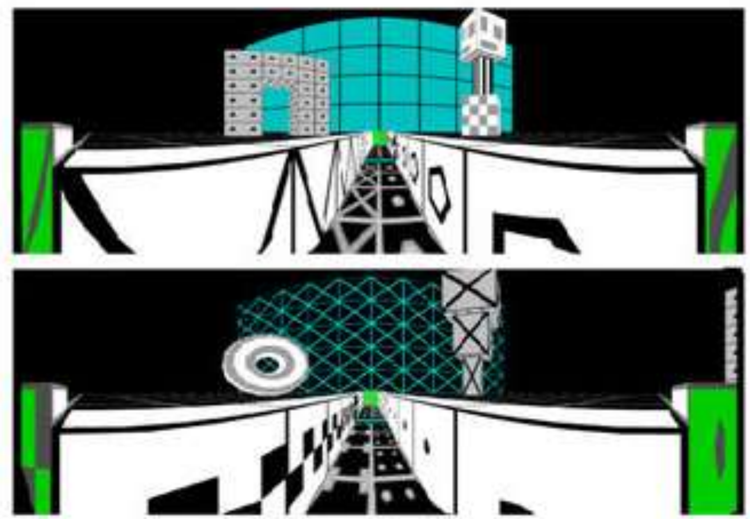
For example: https://youtu.be/IUDTlvagjJA

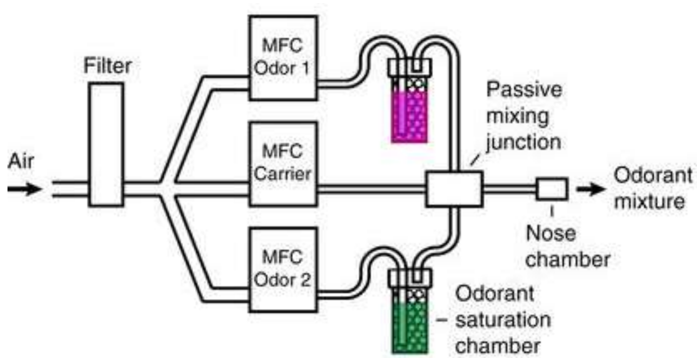
http://twogoodears.blogspot.ru/2016_03_01_archive.html

# Olfactory information

Radvansky & Dombeck (2018) developed a olfactory VR system for mice and they found that the mice can navigate in a scene based on olfactory information.



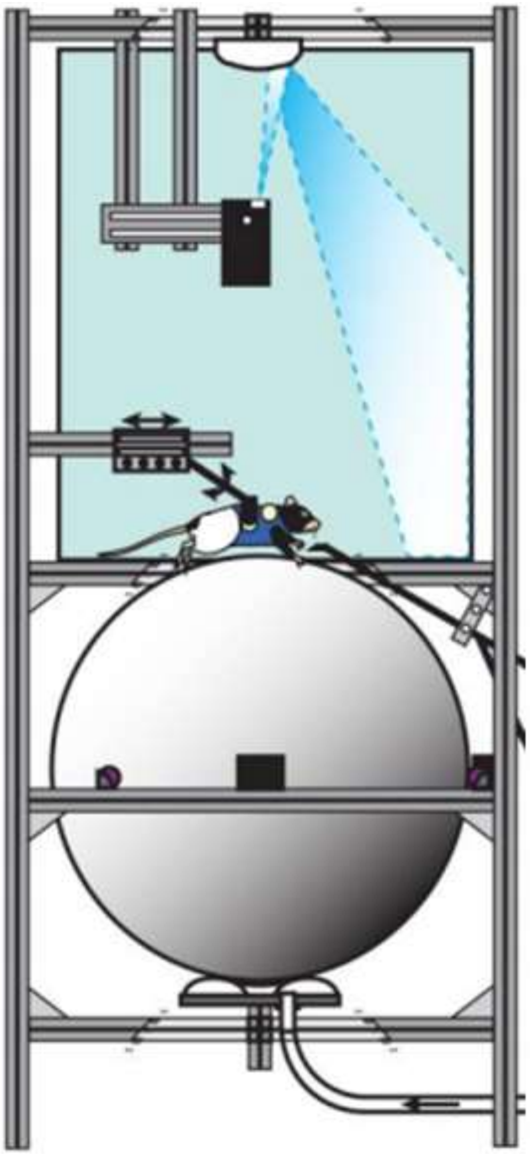



Radvansky & Dombeck (2018)

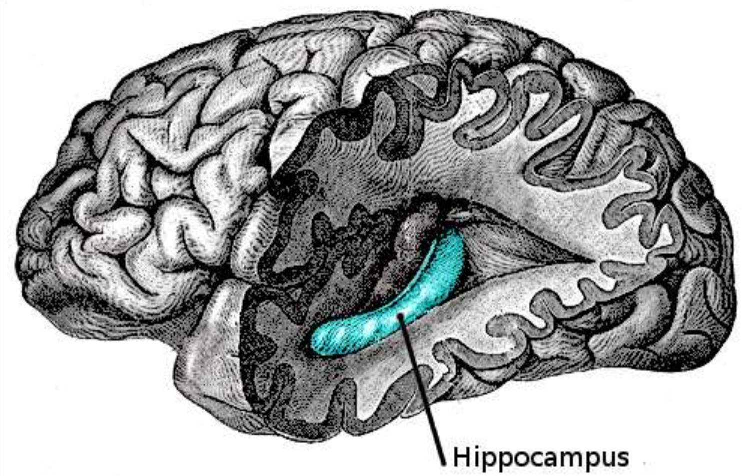
https://www.sciencedaily.com/releases/2018/02/180226152702.htm

# Visual, Vestibular, and Somatosensory information

All visual, vestibular, and somatosensory (action) information contributes to perception of a self-spatial position (Dorsal hippocampus).



C




Aghajan et al. (2015)
Ravassard et al. (2013)
Cushman et al. (2013)

See also Sato et al. (2017)
Lee & Mason (2017)

# Problems of VR

# VR-sickness (Cyber-sickness)

Its "reported symptoms include stomach awareness, burping, salivation, drowsiness, nausea and occasionally even vomiting, as well as disorientation, dizziness, headaches, difficulty focussing, blurred vision, and eyestrain" (Barrett, 2004, see also Read et al., 2015).

A user of a head-mounted display should take a rest without wearing the head-mounted display every 20 minutes (Kennedy et al., 2000) or whenever she/he experiences any nausea (Hu & Hui, 1997).


# VR-sickness (Cyber-sickness)

Sources and potential sources of VR-sickness

1) Conflict among Visual, Vestibular, and Somatosensory information
2) Temporal delay between head-motion and update of an image
3) Slow Screen refresh-rate
4) Low Screen resolution
5) Narrow Field of View

(3–5: Display)

6) Constant lens accommodation
7) Approximate model of the eye

(6–7: Eye-ball)

# VR-sickness (Cyber-sickness)

Sources and potential sources of VR-sickness

1) Conflict among Visual, Vestibular, and Somatosensory information
2) Temporal delay between head-motion and update of an image
3) Slow Screen refresh-rate
4) Low Screen resolution
5) Narrow Field of View

} Display

6) Constant lens accommodation
7) Approximate model of the eye

} Eye-ball

Problems 1) and 2) are especially critical for VR-sickness.

Problems 2), 3), 4), and 5) are very technical and are matter of time and money. These problems are getting resolved.

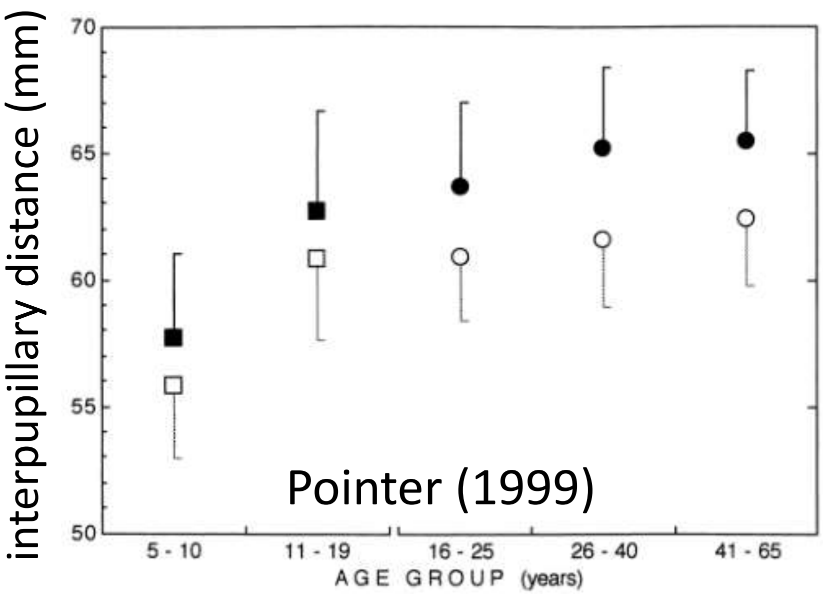
Problems 6) and 7) may be factors causing VR-sickness. But, they are theoretically difficult to be studied and to be resolved.

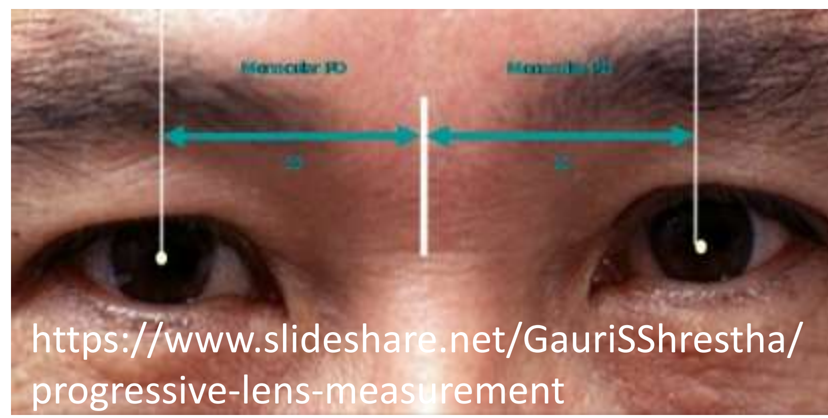
# Age limit for 3D contents?

e.g. Sony PSVR (12yo), Oculus-rift (13yo), Nintendo 3DS (6yo)



Inter-pupillary (inter-ocular) distance increases as a person gets older.




The visual system of children for stereo vision should be plastic in some aspect to accommodate with the growing inter-pupillary distance.

# Age limit for 3D contents?

Strabismus is developed before 6 years old of life (Hollwich, 1983/1986).
60% of cases before 2yo and the other 40% before 6yo.

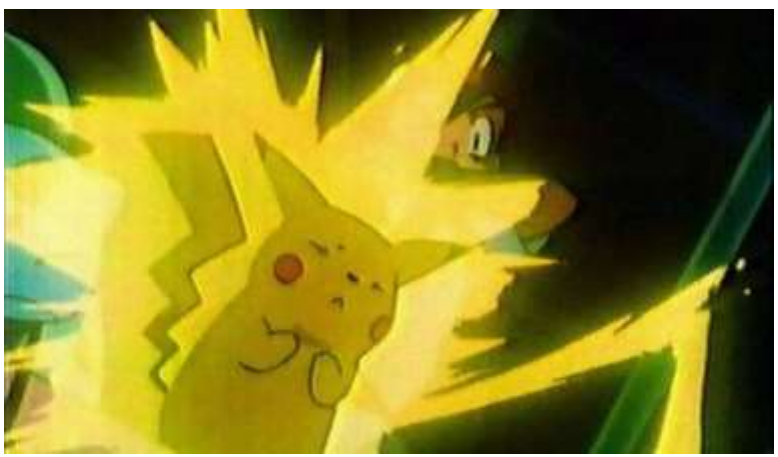
http://d.hatena.ne.jp/koikesan/20140910

At least, there is one case report (Tsukuda & Murai, 1988). A 4yo child developed strabismus (*acute onset esotropia*) after watching a 3D movie (probably, 15 min long cartoon animation using anaglyph).

**(On the other hand, this is just a case report.)**

# Photosensitive epilepsy

Visual information from VR devices occupies wide field of view. It means side effects of the visual information can be also bigger.
Epileptic seizures can be induced by image flickers. It is suggested to avoid an image flicker between 2 Hz and 55 Hz should for the seizures (in the section 508 of the Rehabilitation Act in the USA, https://www.section508.gov/content/quick-reference-guide, see also Walter, Dovey, & Shipton, 1946; Epilepsy action, 2010).




https://en.wikipedia.org/wiki/Denn%C5%8D_Senshi_Porygon
http://gizmodo.com/a-grand-jury-just-called-tweeting-an-animated-gif-assau-1793477149

## Interaction with a VR space

To interact with a VR space, your body posture information should be captured.

Maurizio Pesce (https://www.flickr.com/photos/pestoverde/16241057474/)

# Interaction with a VR space

There are devices for capturing hand postures, body postures, facial expressions, and eye-movements. Proper physical feedbacks to actions of a user should be considered.


https://www.leapmotion.com/


http://blog.ocad.ca/wordpress/digf6l01-fw201302-01/2013/10/project-2-facial-capture-system/?doing_wp_cron=1492420969.7187809944152832031250

https://www.xsens.com/


https://manus-vr.com/

## Interaction with a VR space

Another approach is a kind of video-game controllers. Instead of natural-realistic interaction, they can provide specifically-designed (and restricted) interfaces. It is not necessarily bad. For example, people can type letters nowadays faster than hand-writing.

VIVE


oculus

www.roadtovr.com/including-controllers-htc-vive-and-oculus-rift-could-be-evenly-matched-on-price-touch/

# Applications of VR/AR/MR

# Phantom-limb illusion

Phantom-limb illusion is a condition that you perceive some object as a part of your body. This illusion has a medical application for phantom-limb pain. Some patients who lost their body parts perceive some pain, itchiness, etc on the lost parts. The pain (or something) can be relieved if their phantom-limbs are "treated". A conventional method of this application is using a mirror. But this method is  limited to unilateral amputations (Kiabi et al., 2013). The VR/AR devices are not limited by these restrictions (Dunn, 2017).

http://www.dana.org/Briefing_Papers/Mirror_Therapy_for_Phantom_Limb_Pain/
http://arizonapain.com/pain-center/pain-conditions/phantom-limb-pain/

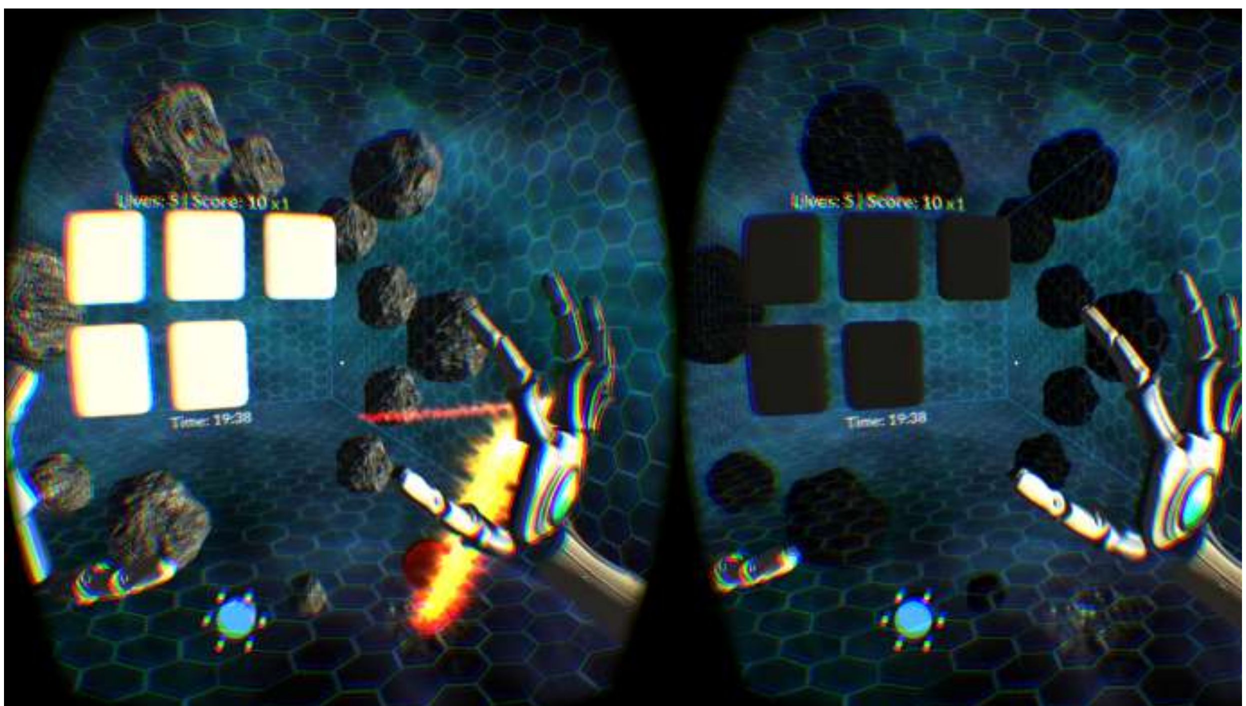
# VRET (Virtual Reality Exposure Therapy) for Panic disorder

Exposure therapy is an evidence based treatment approach for panic disorder (e.g. phobias and PTSD). A patient is exposed to his/her feared stimuli repeatedly for prolonged periods without any actual threat. The exposure is increased gradually during the therapy so that the patient can become gradually habituated and the phobia can be mitigated.
VR techniques have been used for exposure therapy.

www.sarajevotimes.com/young-bosnians-developed-software-overcoming-fear-phobias-help-virtual-reality/
https://thrive.uk.com/blog/2014/7/4/iraq-war-ptsd-and-virtual-reality-cocktail-mix

# Treatment of Amblyopia (and Strabismus)

Amblyopia is a condition that a pair of eyes have very different acuities from one another. A person with Amblyopia usually relies on only one eye and the other eye (lazy eye) is ignored. Once the lazy eye becomes ignored, this problem cannot be treated only by wearing a pair of glasses. Amblyopia can cause Strabismus. Its treatment using VR has been studied by multiple groups and companies (Vivid Vision; Foss, 2017; Gargantini et al., 2017).




https://www.linkedin.com/pulse/virtual-reality-game-could-cure-lazy-eye-aubrie-johnson

# Architecture

https://www.vertexvr.nl/bim-goes-virtual-next-level-architectural-visualization/