Adverse Health Effects

Mostly based on "The VR Book" Part III

Jason Jerald, ACM Press

VR course 2018

EPFL Immersive Interaction Group

Outline

- Introduction
- Motion Sickness
- Eye strain, seizure and aftereffects
- “motion to photon” Latency
- Sickness measurement
- Design guidelines

Introduction

- A key challenge hampering VR adoption
- A wide variety of causes
  - Aspects that are not specific to VR
    - Motion sickness is common (car, boat, …)
  - VR specific aspects
    - Accomodation-vergence conflict
    - “motion to photon” latency

- VR interactions leverage on motion-based skills
    - Bad skill exertion can produce accidents (next slide)

Application design and deployment must include user safety

Lack of haptic feedback or safety results in the user falling during a VR climbing experience

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Motion sickness (kinetosis/travel sickness)

Triggered by exposure to real/virtual motion

Main cause: perceptual conflict between the vestibular system (sensing linear and angular accelerations) and the visually perceived movement.

"I'm not moving" vs "I'm moving"

[ironshrink.com]

Symptoms: disequilibrium, fatigue, nausea, vertigo, …, vomiting

- If visually induced only, closing the eyes stops the problem
- If physically induced (by movement of the body) no easy solution

Cybersickness: motion sickness resulting from VR usage

Motion sickness (kinetosis/travel sickness)

Potential causes of the perception mismatch

- Scene motion:
  - Intentional : e.g. virtual navigation
  - Un-intentional: technology shortcomings = latency, poor calibration of viewing parameters, hw lense distorsion, sw perspective distorsion, etc…

- Vection = illusion of self-motion (*e.g. in a static train at the station*)
  - Constant relative linear velocity is not a problem as it is not sensed by the vestibular system
  - Linear velocity *variations* and any angular velocity lead to a conflict
  - Vertical (steps) or lateral oscillations are not recommended either

  - Missmatch with real-word movement (e.g. theme park rides, check feedback from http://techaeris.com/2016/08/28/six-flags-great-america-adds-vr-demon-improve-ride/)

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Motion sickness : the **rest frame** hypothesis

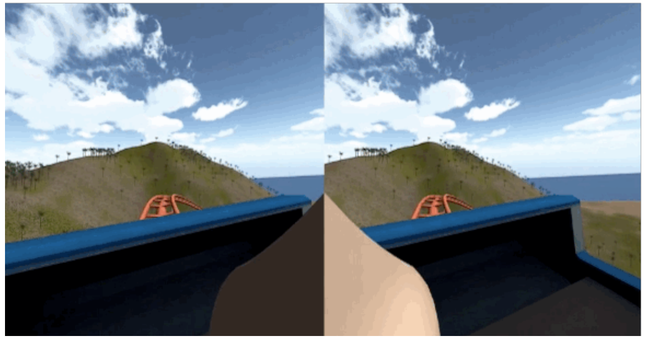
An alternate theory to the perception mismatch to explain sickness

- Hypothesis
  - The brain has an internal mental model of which objects are stationary and which are moving. The **rest frame** is the part of the scene the viewer considers stationary and judges other motion relative to.
  - Ex: a cockpit, the ground, a room etc..

[modern flight simulator with a tangible cockpit serving as a rest frame]

- If motion cues violate the current rest frame hypothesis, motion sickness results

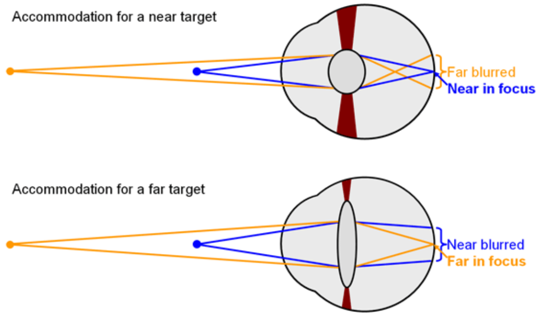
- The VR scene must provide a clear rest frame component that matches the user's physical inertial environment and vestibular cues (e.g. Head-Up Display HUD, virtual nose =>)

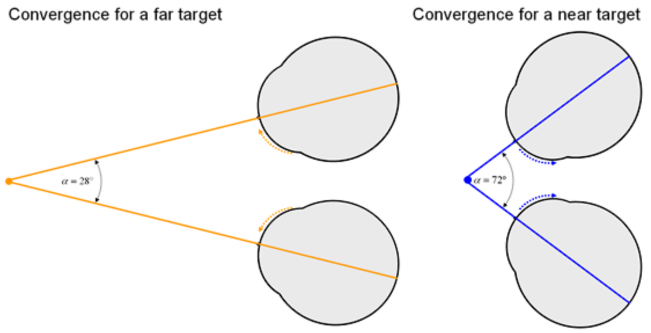


Note the virtual nose serving as a rest frame in a concept demo from Purdue University + [WWSOI18]

Eye strain & seizure

- Accomodation-Vergence conflict
  - Accomodation and convergence are thightly coupled to provide a clear view of the focused object.
  - In HMD, accommodation is constant (depends on HMD: often at infinity, or “distance of action” such as 1.2 m)
  - Results in eye fatigue and discomfort





- Binocular-occlusion conflict
  - 2D text in overlay is not well accepted in VR context
  - Text should be embedded as 3D object at a fixed depth and be subject to occlusion too.

- Flickering and flashing of light should be avoided
  - Anyone with a history of epilepsy should not use VR

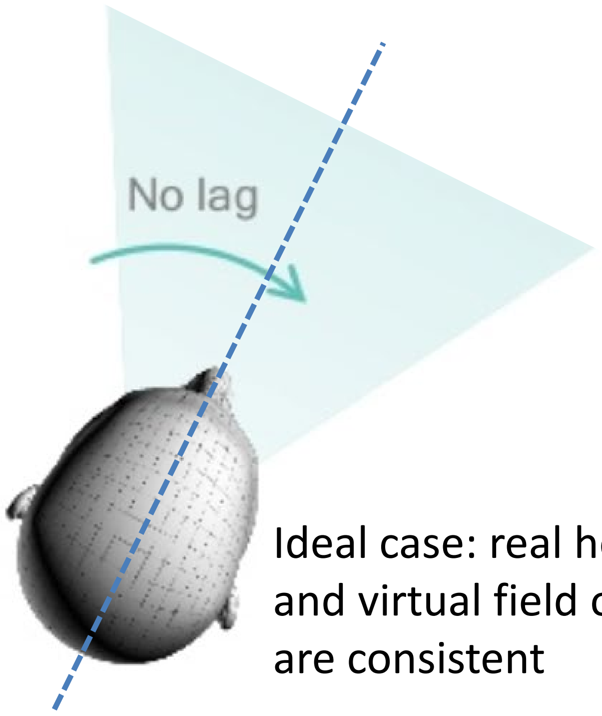
Eye Aftereffects

- May happen after VR experience
  - Perceptual instability of the world, disorientation, flashback
  - Up to 1 hour (driving forbidden 30-45 min after VR entertainment session)
  - Especially in case of sickness (around 10% of simulator users)

- Readaptation
  - The brain needed time to adapt to the VR context (&discrepancies)
  - Likewise the brain needs time to readapt to the normal world because the brain has put in place an inverse distorsion that makes the real-world looks incorrect for a while

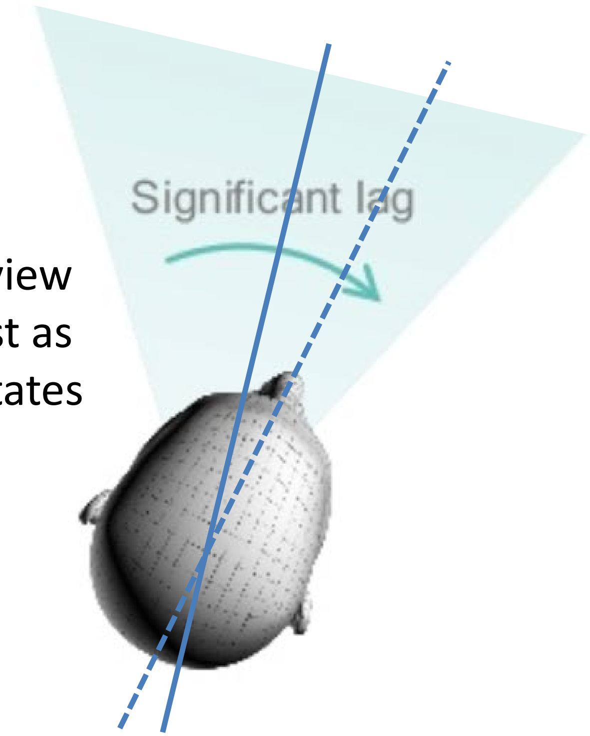
“motion to photon” Latency

- Latency is the time a system takes to respond to a user’s action
- Latency below 100ms is perceived indirectly : a static scene appears to be unstable when the user moves the head (swimming)
  - Visual cues lag behind other perceptual cues (vestibular & proprioceptive)
  - Frequent cause of motion sickness (high variability among users)



Ideal case: real head orientation and virtual field of view are consistent

The virtual field of view is not updated as fast as the head rotates



[based on Qualcomm Tech inc 2016]

Latency (2)

Negative effects

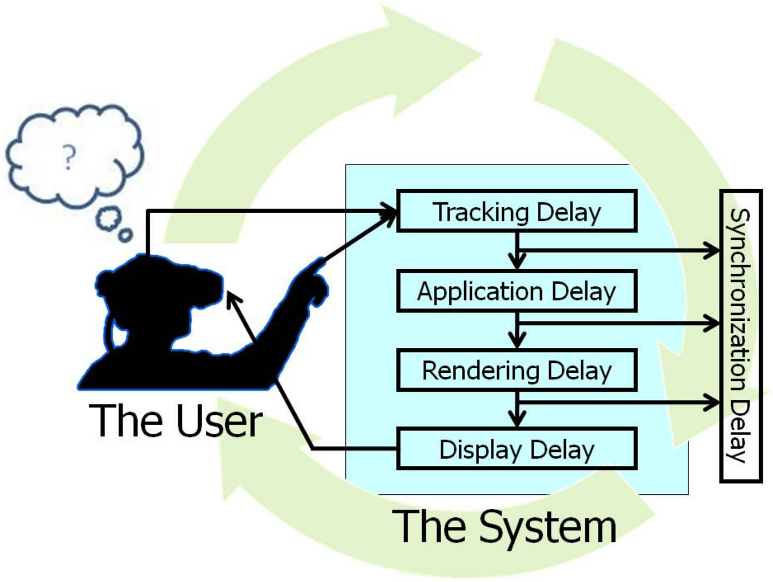
for vision, performances and training

“Break in Presence” [Meehan 2003]

Thresholds

Some sensitive users can discriminate down to 3.2 ms latency in VR

Sensitivity to latency increases with head motion (Jerald 2009)



[Jason Jerald PhD 2009]

System delay = tracking,(network),application, rendering, display.

- **Tracking** may include raw data low pass filtering to smooth jitter
- **Application**: update of the world model from tracked data
  - Must decouple a heavy simulation update from the rendering
- **Rendering** is currently well mastered with GPU
  - Inverse of the frame rate (or induce a rendering delay in non-pipelined systems)
- **Display**: 60Hz fps -> 16.7ms refresh time (+ vertical sync. of double buffer)

Measuring sickness

Objective measurement is difficult : high individual variability, adaptivity

⇒ Postural stability

⇒ Physiological measures

Subjective measurement through questionnaires

- Easy to administrate, widely used but ~weak
- Uneasy to fill because a posteriori, difficult to report

Kennedy Simulator Sickness (SSQ) questionnaire (1993)

1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. « Fullness of the Head »	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. *Vertigo	None	Slight	Moderate	Severe
15. **Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

* Vertigo is experienced as loss of orientation with respect to vertical upright.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Design guidelines (more in 3D interaction lectures)

Hardware:
- HMD : no flicker, light, balanced, fast response, low persistence
- Tracking: high update rate, no drift, *accurate* & *precise*
- Wireless system or hang wires from the ceiling

System Calibration
- To reduce unwanted scene motion.
- Match virtual and actual HMD field of views
- Measure interpupillary distance to calibrate stereo viewpoints

Latency
- Do not depend on filtering algorithm to smooth out noisy data
- Use prediction to compensate latencies only up to ~30ms
- *Post-rendering* technique (2D image warping) can correct for prediction error by selecting the correct image within a bigger rendered image than necessary for the final display

Design guidelines (2)

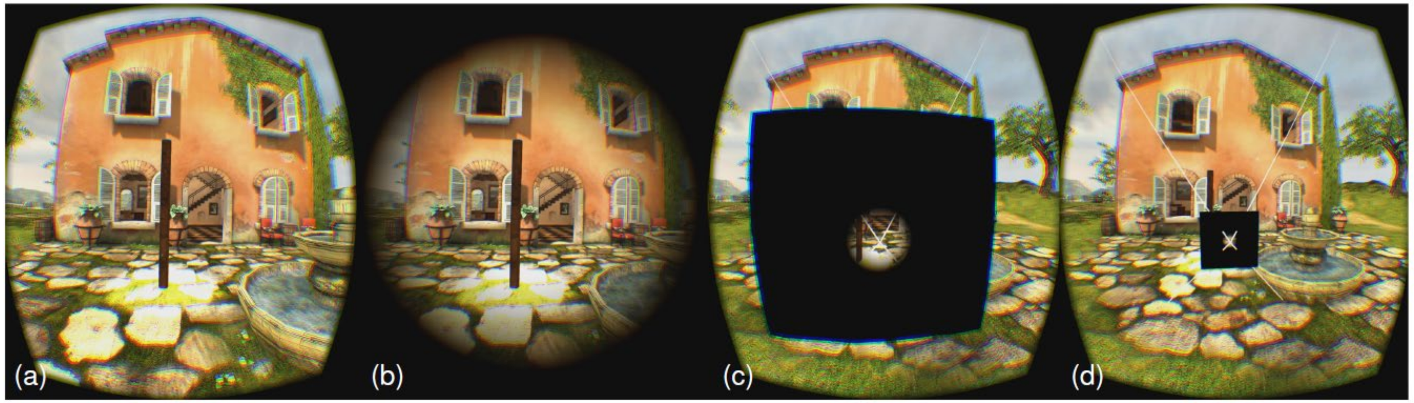
General Design:

- Minimize visual stimuli close to the eyes (vergence/accommodation)
- Position overlaid text in 3D at some distance
- flicker is less noticeable in dark scenes, no flashing light
- Provide protection against falling, or design seated experience
- Design for short experience

Motion design

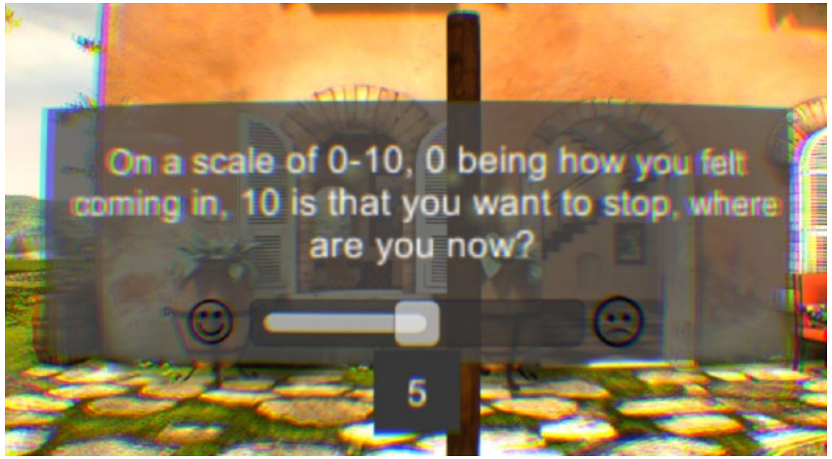
- If passive motion is required, minimize any motion other than linear velocity
- Use a stable cockpit for vehicle experience or world-stabilized rest-frame that matches vestibular cues
- Design for physical rotation instead of virtual rotation whenever possible
- Consider decreasing the field of view when moving [FF16]

Example [FF16]: FOV = f(movement)



General Concept (for HMD)**:**

- Dynamically adjust the FOV with soft-edge circular cutout (b)
- The FOV reduction down to 80° is driven only by the gamepad-selected travel speed, not by the user head movement speed.
- Evaluated through a navigation task with indoor/outdoor space
- Regular within-task feedback



Conclusion

Special care is necessary towards new users otherwise VR will miss one more great opportunity of adoption:

- Be conservative, prevent any risk of sickness
- Consider decreasing the field of view
- Encourage to minimize head rotation
- Start with modest sessions / Pause each 20-30min
- Do not force anybody to experience VR
- Pay attention to early warning signs of VR sickness (pallor or sweating)
- Plan some time for re-adaptation to real-world sensory input after a VR session (no driving for at least 30-45 min)

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