Adverse Health Effects

Mostly based on “The VR Book” Part III
Jason Jerald, ACM Press 2016

VR course 2017
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.

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”

**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 distortion, sw perspective distortion, 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/)
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..

• 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

[modern flight simulator with a tangible cockpit serving as a rest frame]
Eye strain & seizure

• Accomodation-Vergence conflict
  – Accomodation and convergence are tightly 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 distortion that makes the real-world looks incorrect for a while

• Flickering and flashing of light should be avoided
  – Anyone with a history of epilepsy should not use VR
“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.

[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)

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 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)

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

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

- Be conservative, present any risk of sickness
- Consider decreasing the field of view to start with
- Encourage to minimize head rotation
- Start with modest sessions
- 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)
References

Jason Jerald, PhD Thesis, UNC 2009,

