RESEARCH NEEDS FOR DEVELOPING QUALIFICATION STANDARDS FOR FLIGHT SIMULATION TRAINING DEVICES WITH HEAD MOUNTED DISPLAYS

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10/22/2024

Image: symetrie.fr and varjo.com

Outline

1. Introduction
   - Certification Standards
   - Research Gap
2. Vertical Motion Simulator
   - Visual System Upgrades
   - Platform for Setting Standards
3. Proposed research
   - Three examples

Image: nasa.gov

1. Introduction

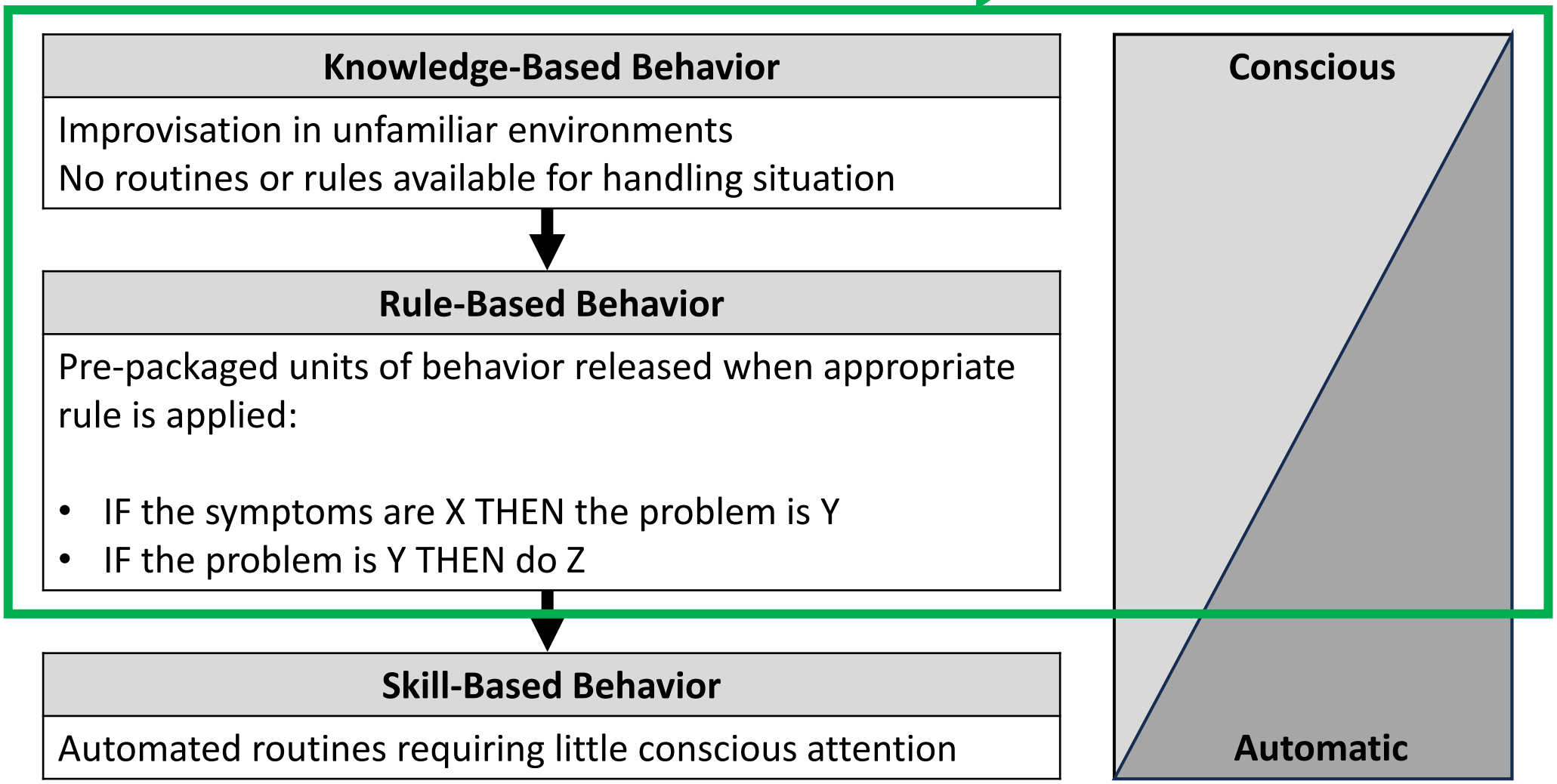
Current Certification Standards and Research Gap

Benefits of Extended Reality (XR) for Training

1. Reduced cost
2. More accessible training
3. Improved training and retention?

Current XR Use in Training

Benefits and implications of XR training best understood



Rasmussen's SRK Model

Certification of Simulators with Head Mounted Displays (HMDs)

- Certification Specifications for Flight Simulator Training Devices (FSTDs) do not contain adequate or appropriate standards and cannot serve as a qualification basis

- Special Conditions must be prescribed for qualification:
  - Training device manufacturers are heavily involved in development as they have the expertise
  - Special Conditions and tolerances do not apply to the same new hardware implemented by other training device manufacturers
  - Evaluation of positive transfer of training is subjective

Tolerances

- Current tolerances in Special Conditions are mostly based on:
  - Conventional visual systems
  - Limits of the state of the art
  - Subjective judgements

- There is a lack of understanding how skill-based behavior is influenced by HMDs vs. conventional visuals

- Tolerances should be based on research-based evidence

Research Focus

1. Skill-based behavior:
   - Synchronization with motion cues
   - Motion fidelity
   - Visual fidelity
   - Side effects
2. Comparison of XR with conventional simulator visuals
3. Virtual reality vs. mixed reality
4. Direct effects vs. training

Previous Fixed-Base Research

- Comparing Virtual Reality to Conventional Simulator Visuals: Effect of Peripheral Visual Cues in Roll-Axis Tracking Task
  - How does Virtual Reality (VR) compare to conventional simulator visuals?
  - How does the presence of peripheral visual cues affect human operator control behavior and performance in VR?
- Conclusions
  - Tracking performance in VR is comparable to conventional simulators
  - Peripheral visual cues had a stronger effect in VR
  - Simulator sickness was not significantly higher in VR

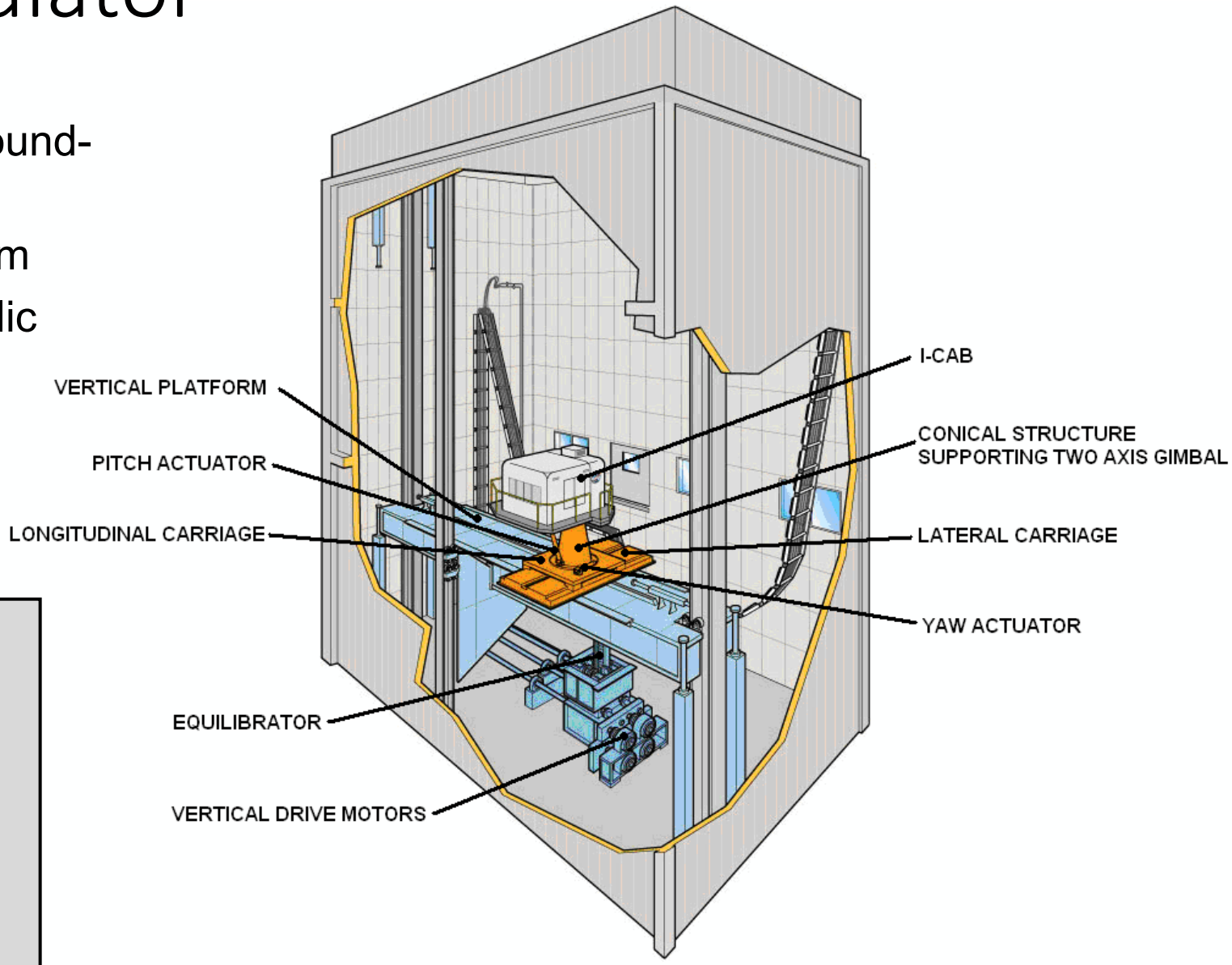
Terenzi and Zaal, “Comparing Virtual Reality to Conventional Simulator Visuals: Effect of Peripheral Visual Cues in Roll-Axis Tracking Task”, AIAA 2020-0170

2. Vertical Motion Simulator

Simulator Platform to set Simulation Standards

Vertical Motion Simulator

1. Largest motion envelope of any ground-based flight simulator
2. Six independent degrees-of-freedom
3. Combination of electric and hydraulic drives
4. Equilibrator balances out weight of 140,000 lbs.



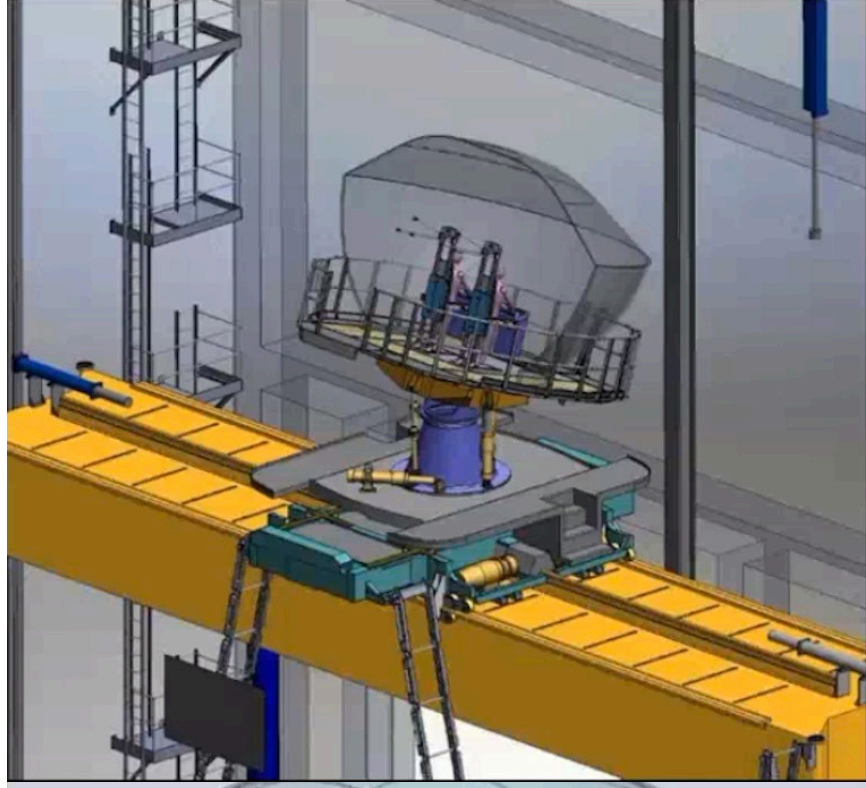
350+ simulation studies conducted, primarily for research in:

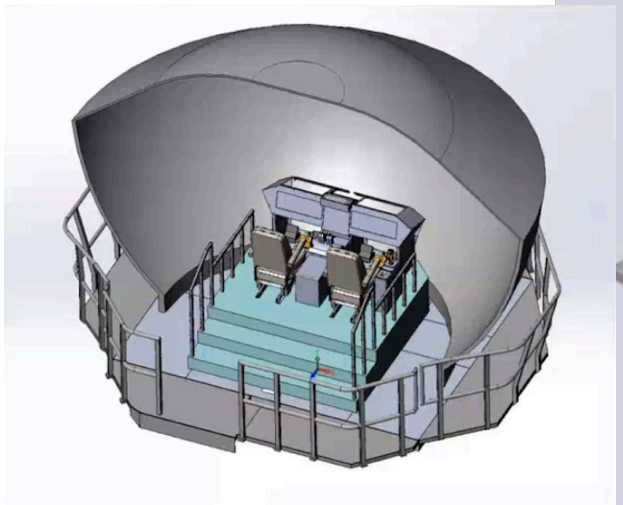
- Handling Qualities of Aircraft and Spacecraft
- Flight Controls and Displays
- Simulation Fidelity
- Ride Qualities

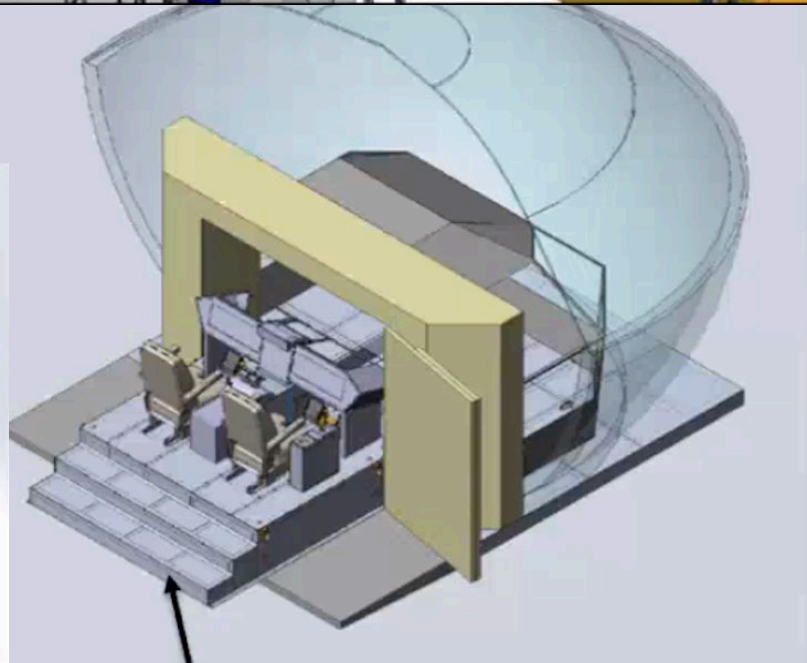
Out-the-Window Visual System Upgrade

Replacement of the existing Wide-Angle-Collimated (WAC) display systems with a wide projection display system:

- 10-foot spherical dome (200x50 deg)
- Large aperture glass collimating mirror
- Interchangeable flight decks
- Motion-base and fixed-base labs







Extended Reality Capability

1. Varjo XR-4 Focal Edition
   - 120°x105° field of view
   - 3840x3744 resolution
   - Eye tracking
   - Gaze-driven autofocus camera system
   - Inside-out tracking
2. ART SMARTTRACK3 Dual-Camera Tracking Solution
3. Quantum 3D image generator

Image: varjo.com

Setting Simulation Standards

The Vertical Motion Simulator has a rich history of informing simulation and certification guidelines and standards:

1. Requirements for flying and ground handling qualities of rotorcraft ADS-33
2. Helicopter Flight Simulation Motion Platform Requirements
3. Stall recovery training motion cueing
4. Objective Motion Cueing Test Criteria

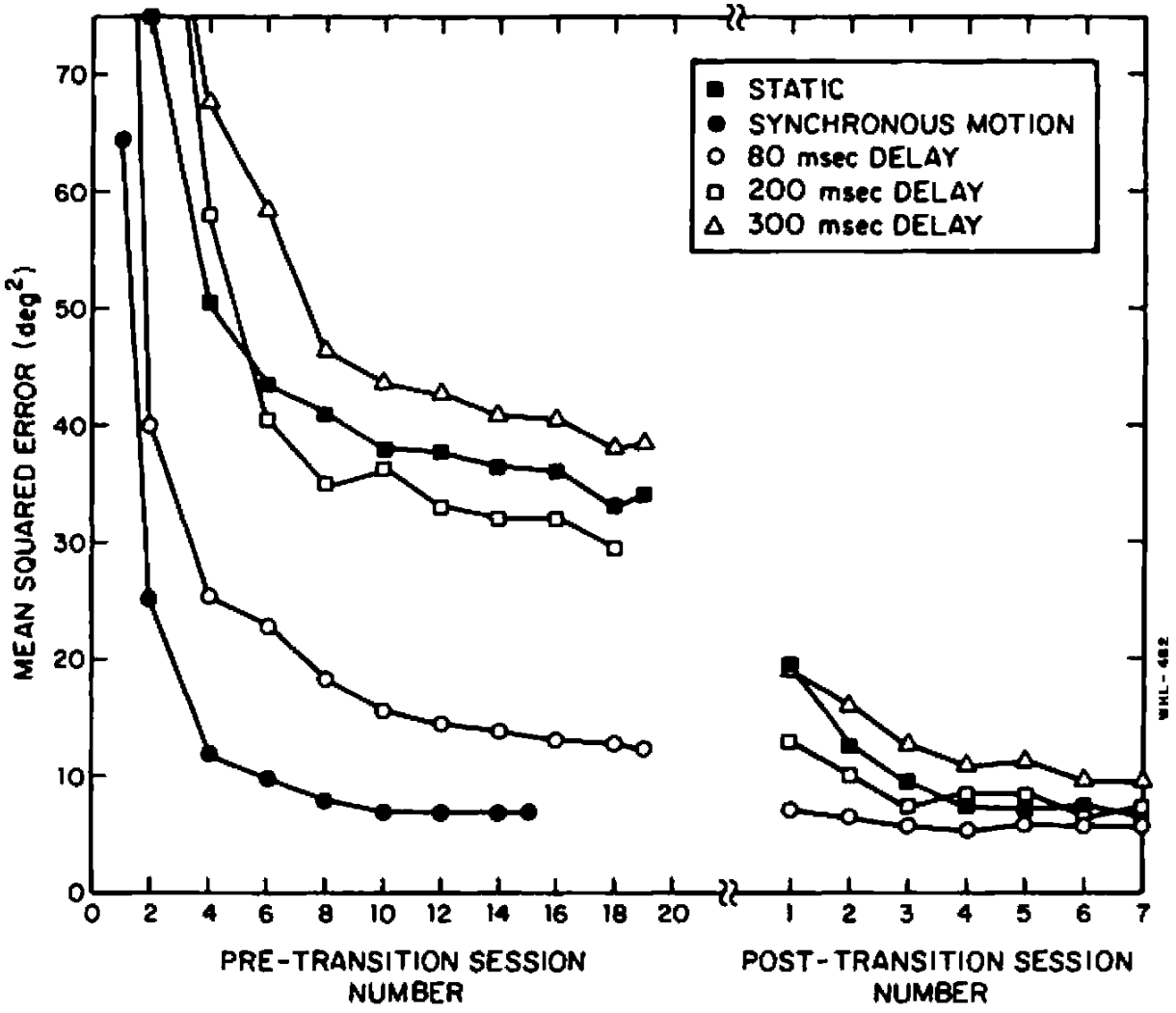
5. Criteria for XR with motion?

3. Proposed Research

Research Topic 1 – Synchronization of Visual and Motion Cues

Does increased visual immersion require tighter transport-delay and synchronization tolerances?

What is the interaction with head-tracking time delays?



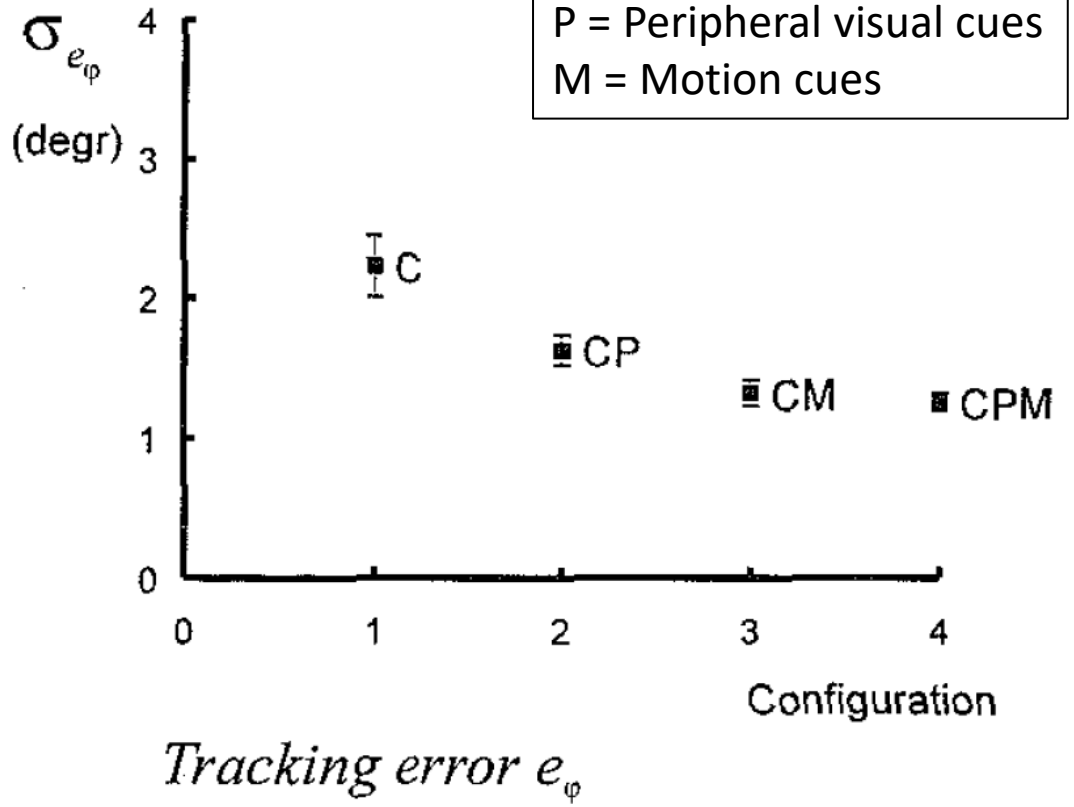
Levison et al., “Effects of Simulator Delays on Performance and Learning in a Roll-Axis Tracking Task”, 1979

Research Topic 2 – Motion Fidelity Requirements

Does increased visual immersion allow for reduced fidelity of physical motion cues?

Which tasks can be trained using HMDs with motion?

C = Central visual cues
P = Peripheral visual cues
M = Motion cues

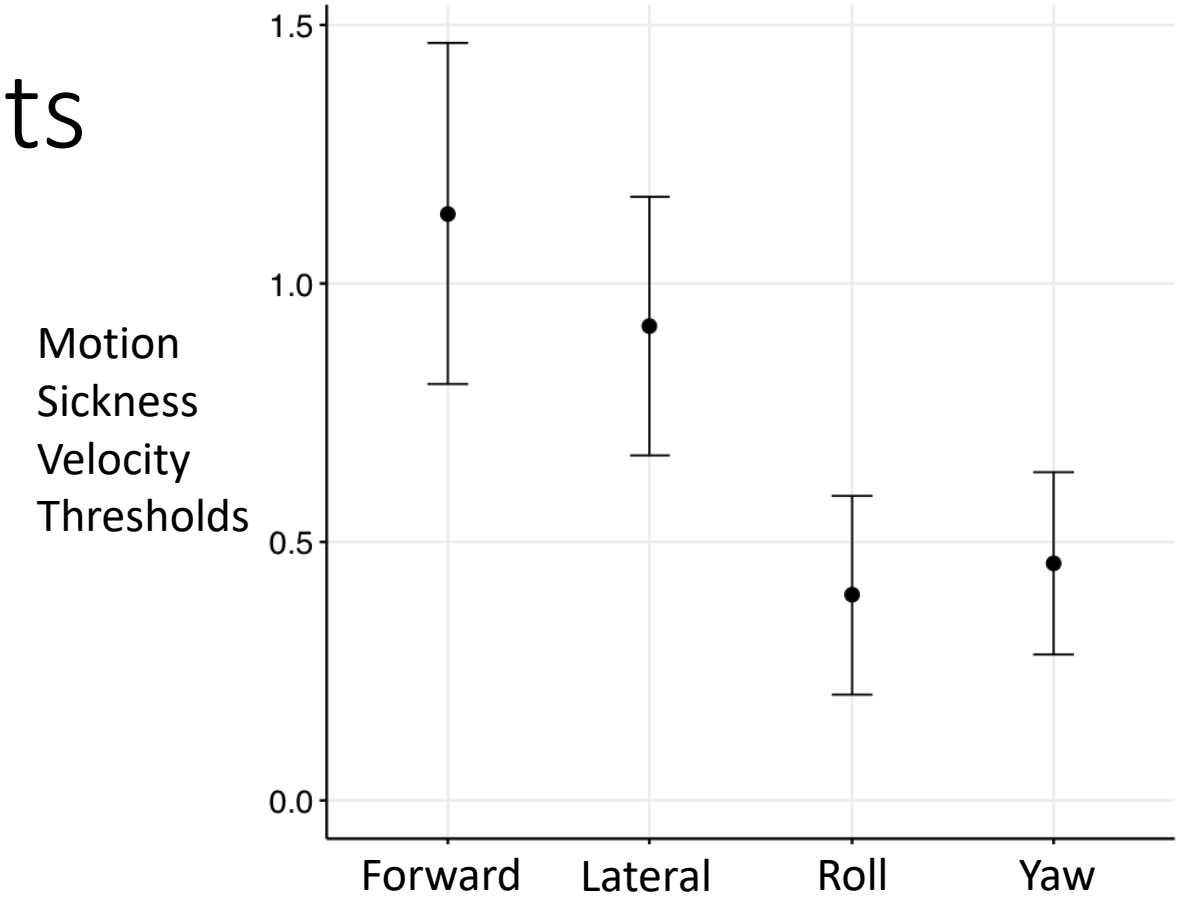


Hosman, “Pilot’s Perception and Control of Aircraft Motions”, 1996

Research Topic 3 – Motion Sickness Limits

What are the task limits for motion sickness with HMDs?

What are the HMD requirements for reducing motion sickness?



Terenzi and Zaal, “Rotational and Translational Velocity and Acceleration Thresholds for the Onset of Cybersickness in Virtual Reality”, 2020

Questions?

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