MAPPING SENSORY-MOTOR BOUNDARIES IN AUGMENTED REALITY: IMPLICATIONS FOR VESTIBULAR REHABILITATION

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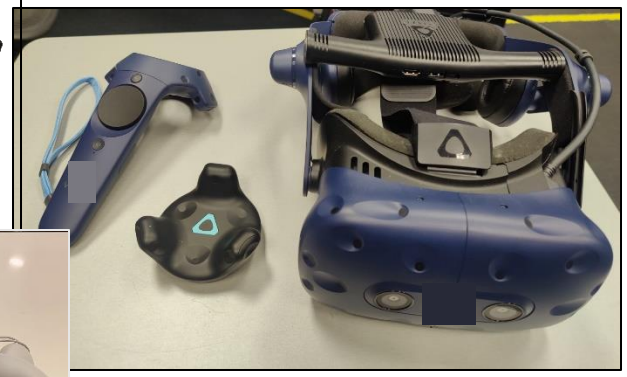
AR/VR REHAB TECHNOLOGY FOR TRAUMATIC BRAIN INJURY (TBI)

Use of augmented/virtual reality (AR/VR) technology today:

10 years of technology development →limited used in clinical settings, still a “promising” clinical tool



Common themes from systematic reviews:

- Mixed results in examining superiority over standard care
- Need for informed design
- Need for determining patient eligibility
- Implementation in clinical settings

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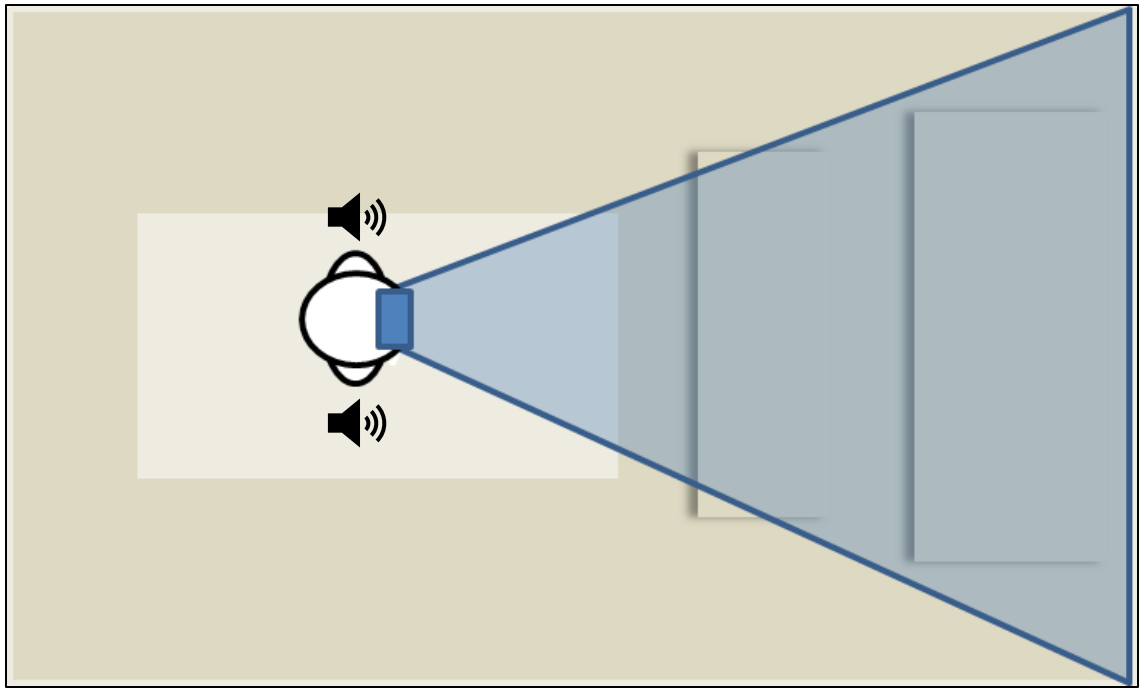
AR/VR REHAB TECHNOLOGY FOR TBI

Patient-specific considerations:

- Vestibular dysfunction
  - *Gaze stabilization*
  - *Balance and posture*
  - *Cervical mobility and control*
- Auditory dysfunction
  - *Hearing acuity*
  - *Sound localization*
  - *Acoustic startle reflex*
- Cognitive changes
  - *Memory and attention*
  - *Spatial navigation*
  - *Decision making*



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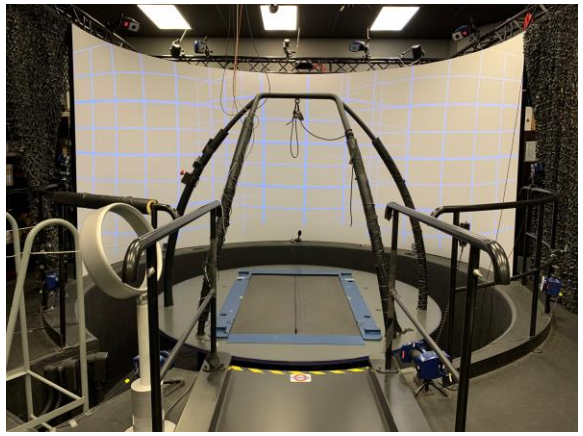
STUDY 1: MAPPING AUDIO AND VISUAL LIMITATIONS

Participants/Experiment

- 19 healthy (14 male) U.S. service members (SMs)
- Tasks completed: Standing and treadmill walking in both Environments
- Motion capture to capture head movement and gait parameters

Task Environments

- **C**omputer **A**ssisted **R**ehabilitation **EN**vironment (CAREN)
  - Mimics real-space performance
  - Physical audio (PA) setup (speakers) and virtual audio setup (headphones)
- AR headset – Magic Leap 1 with horizontal FoV, ±20 degrees; vertical FoV, ±15 degrees
  - Virtual audio using custom head-related transfer function (HRTF)



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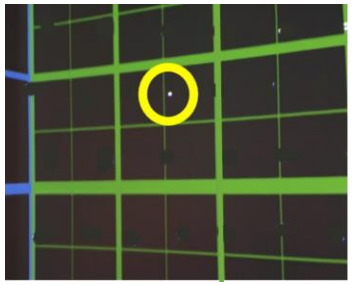
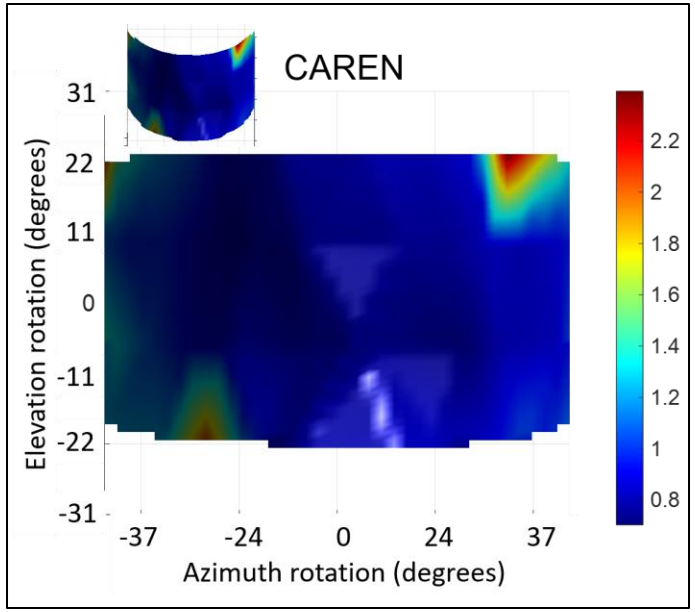
STUDY 1: VISUAL LOCALIZATION RESULTS

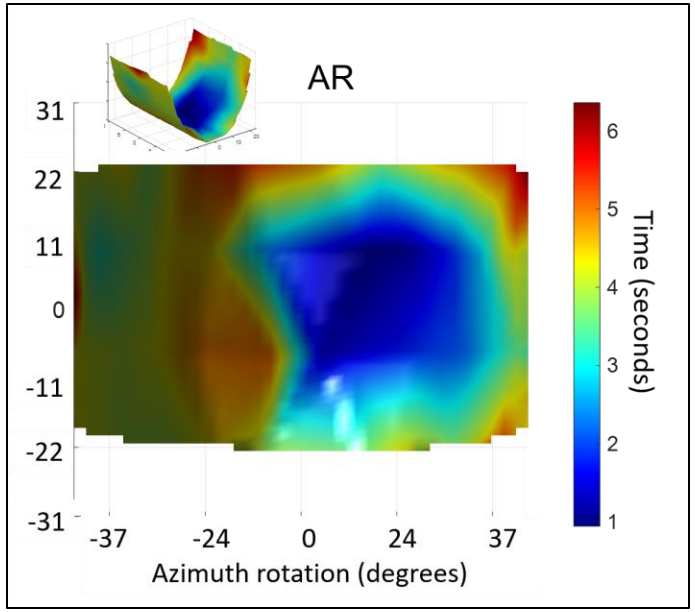
Task: Locate position of a visual stimulus within a 180° space



Results:

- Targets outside the +35 degrees, -8 degrees azimuth and -11 degrees elevation resulted in significantly longer completion times ($p<.001$) in AR versus CAREN.
- Biased performance towards right side in AR





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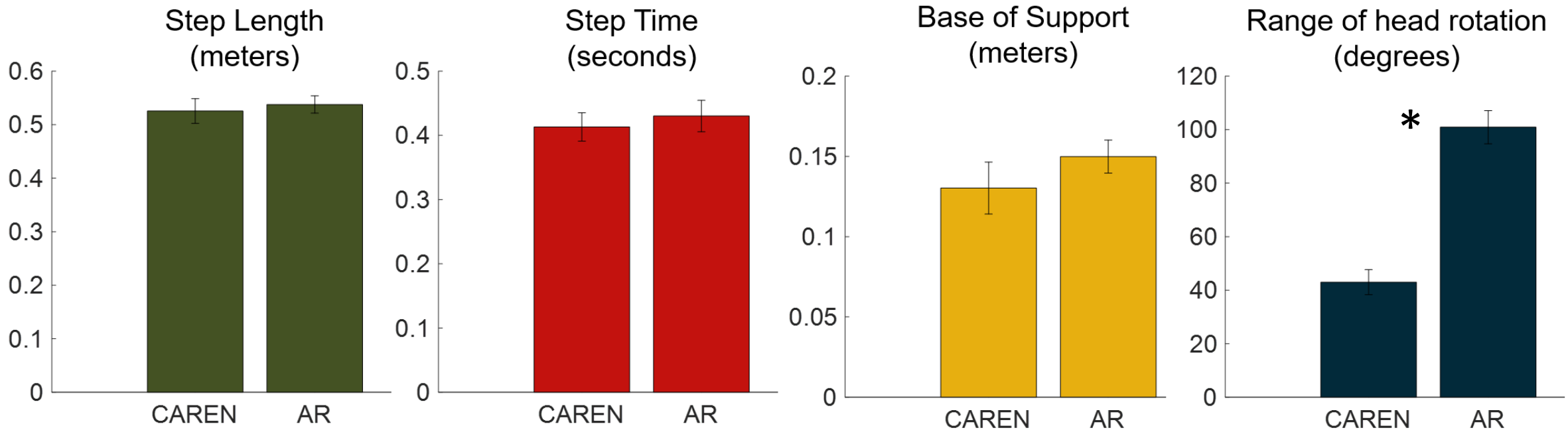
STUDY 1: VISUAL LOCALIZATION RESULTS

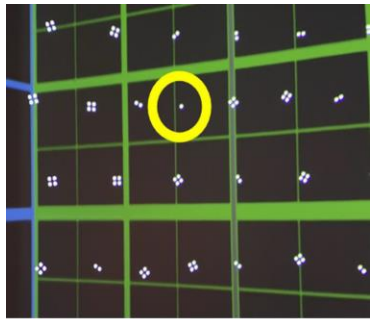
Gait and Head Rotation Biomechanics



Results:

- Head rotation was significantly greater in AR headset ($p<.001$)

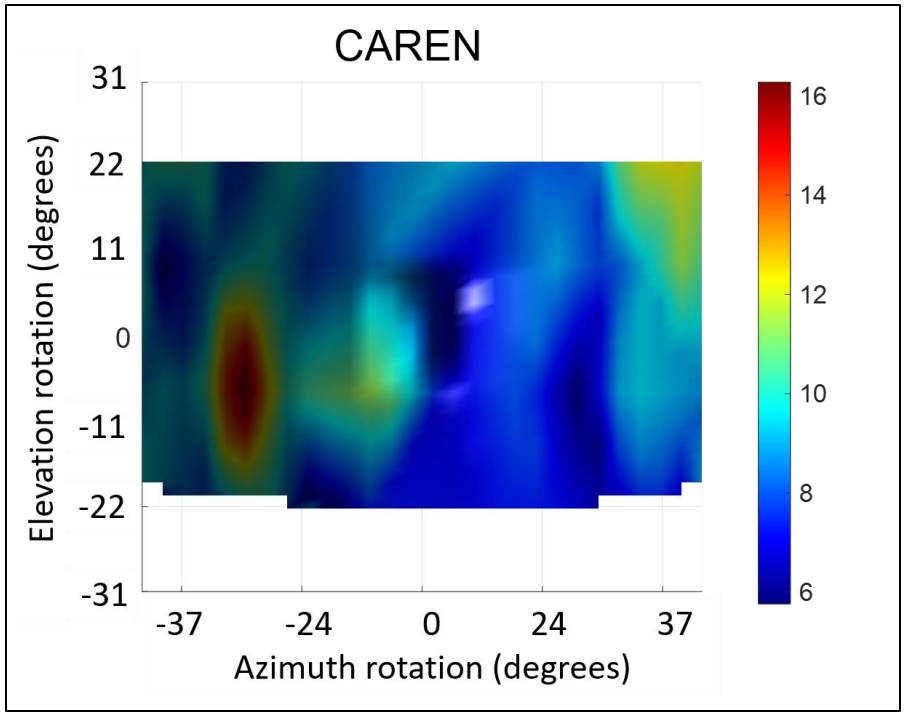
STUDY 1: AURALLY-AIDED VISUAL SEARCH (AAVS) RESULTS

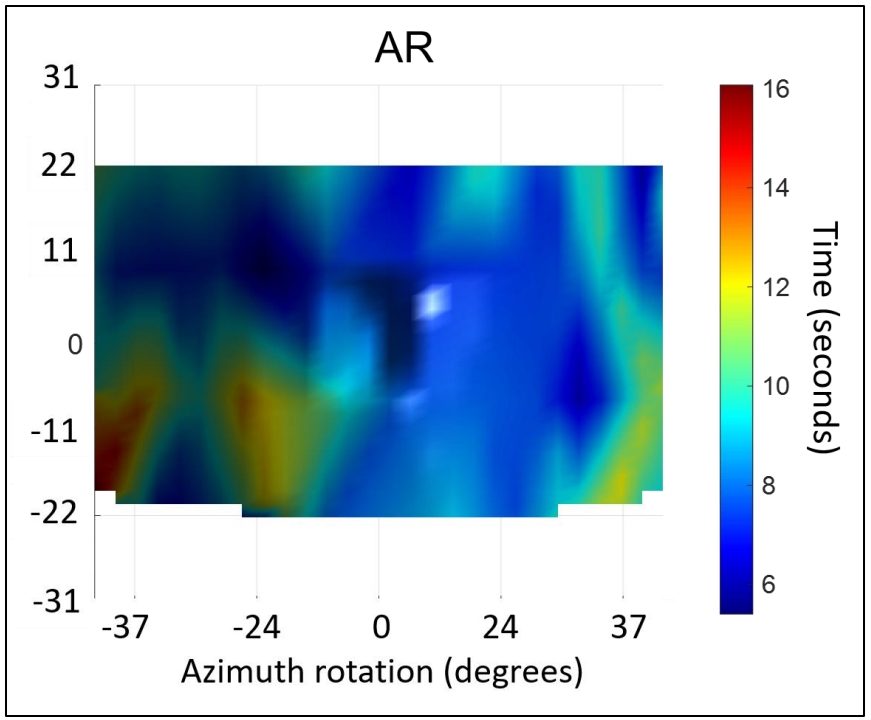


Task: Locate position of a visual stimulus target aided with auditory cue; visual distractors present

Results:

- Similar performance between both CAREN and AR





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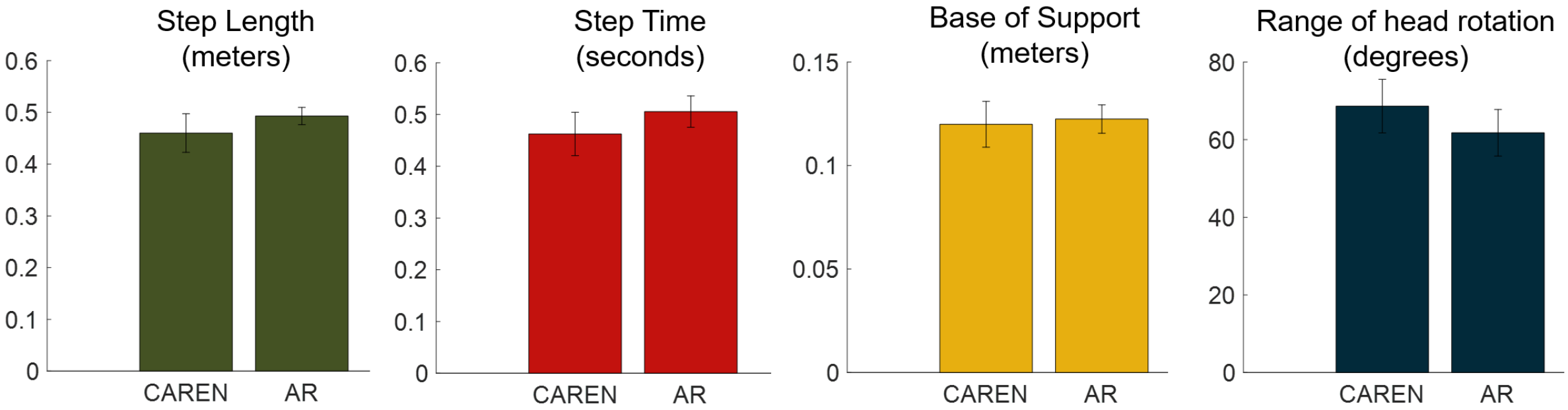
STUDY 1: AAVS RESULTS

Gait and Head Rotation Biomechanics



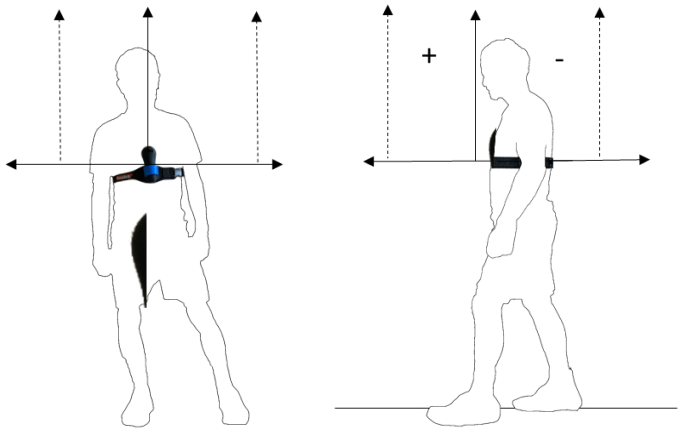
Results:

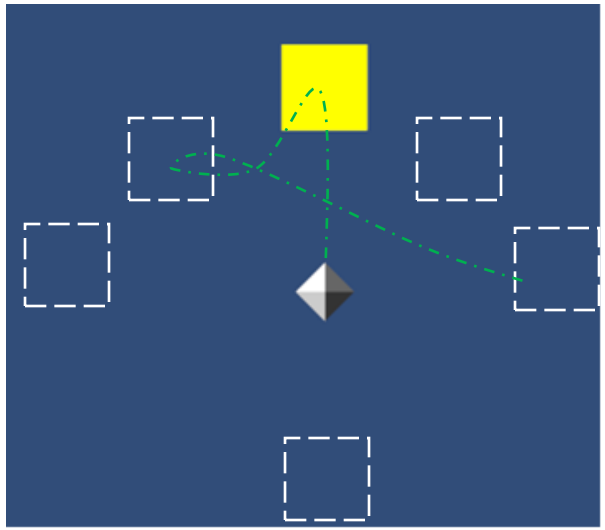
- All gait metrics and head rotation were similar within the CAREN and AR headset during AAVS (no significant differences)

STUDY 2: TESTING DEVICE IN A CLINICAL POPULATION

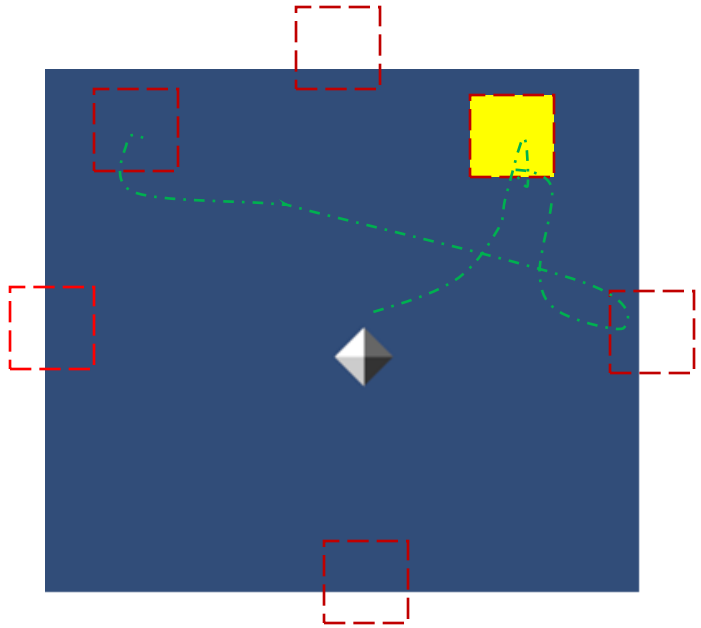
Participants/Experiment

- 33 (26 male) U.S. SMs or SM beneficiaries
  - 19 controls (no history of TBI)
  - 14 mTBI (history of at least 1 mTBI)
- Task: Balance Cubes; 30 targets





With-in field of view (in-FoV)



Slightly outside field of view (out-FoV)

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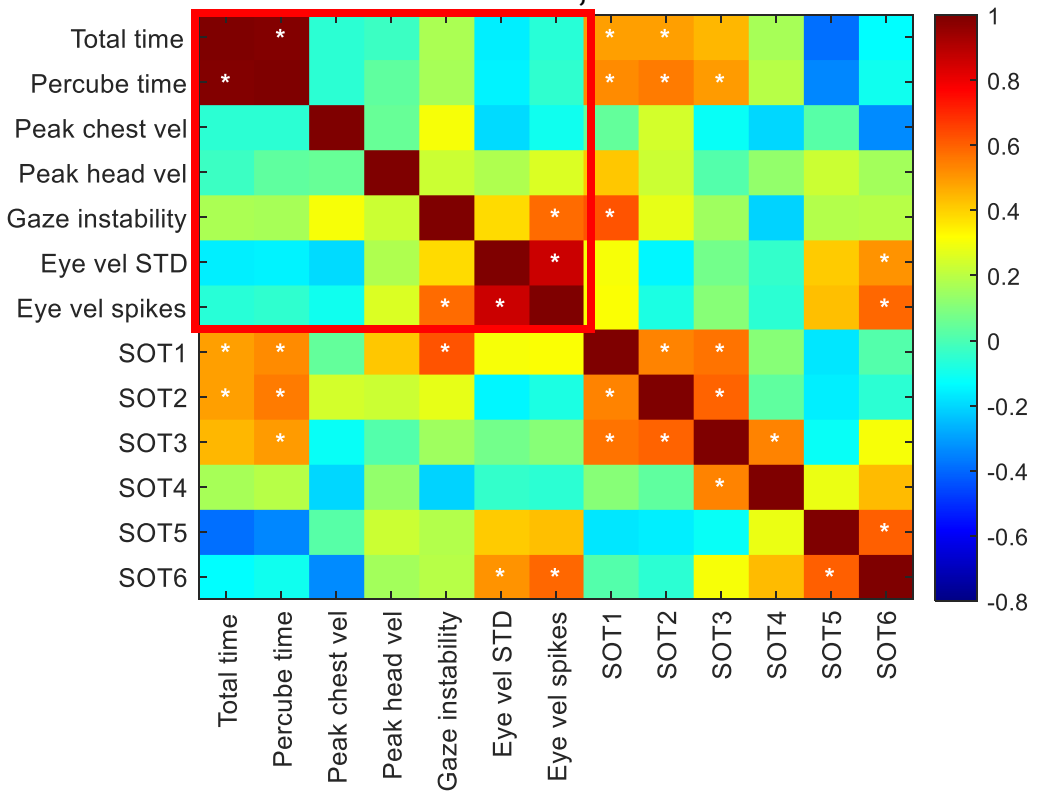
STUDY 2: BALANCE CUBES RESULTS

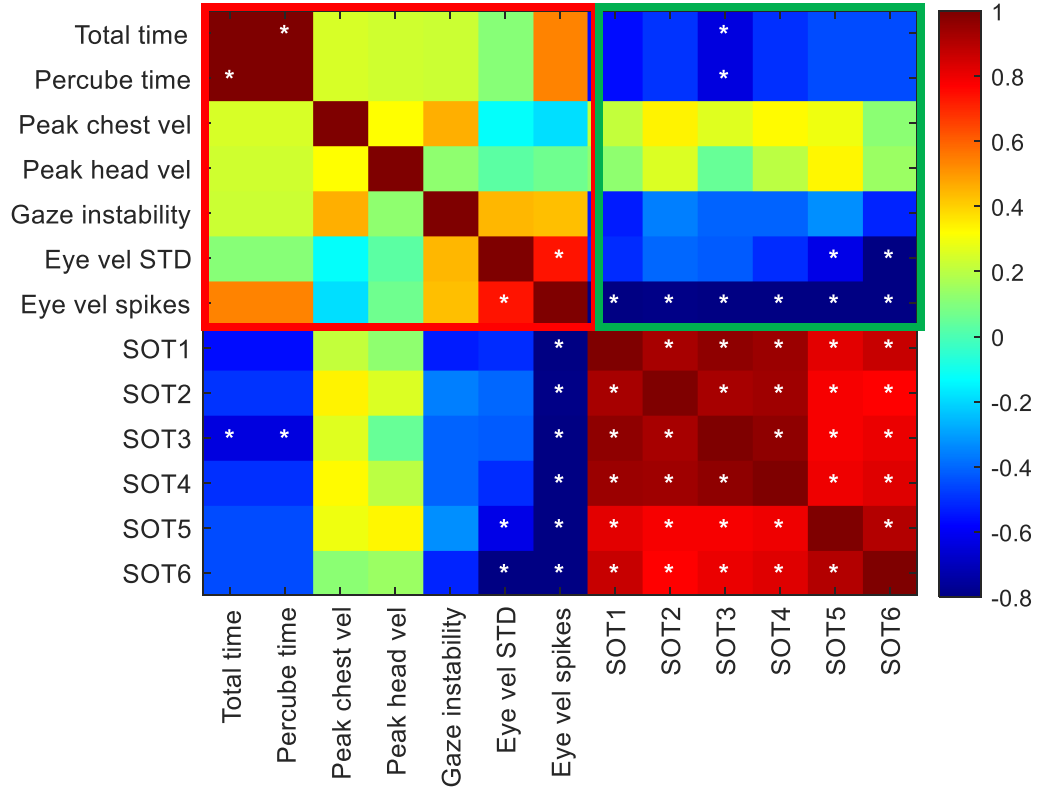
Results:

- Balance Cubes, in-Fov does not elicit enough movement across head, chest, and gaze to reveal significant relationships (red box)
- However, eye velocity spikes were significantly correlated with SOT scores (green box)

Controls, in-FoV



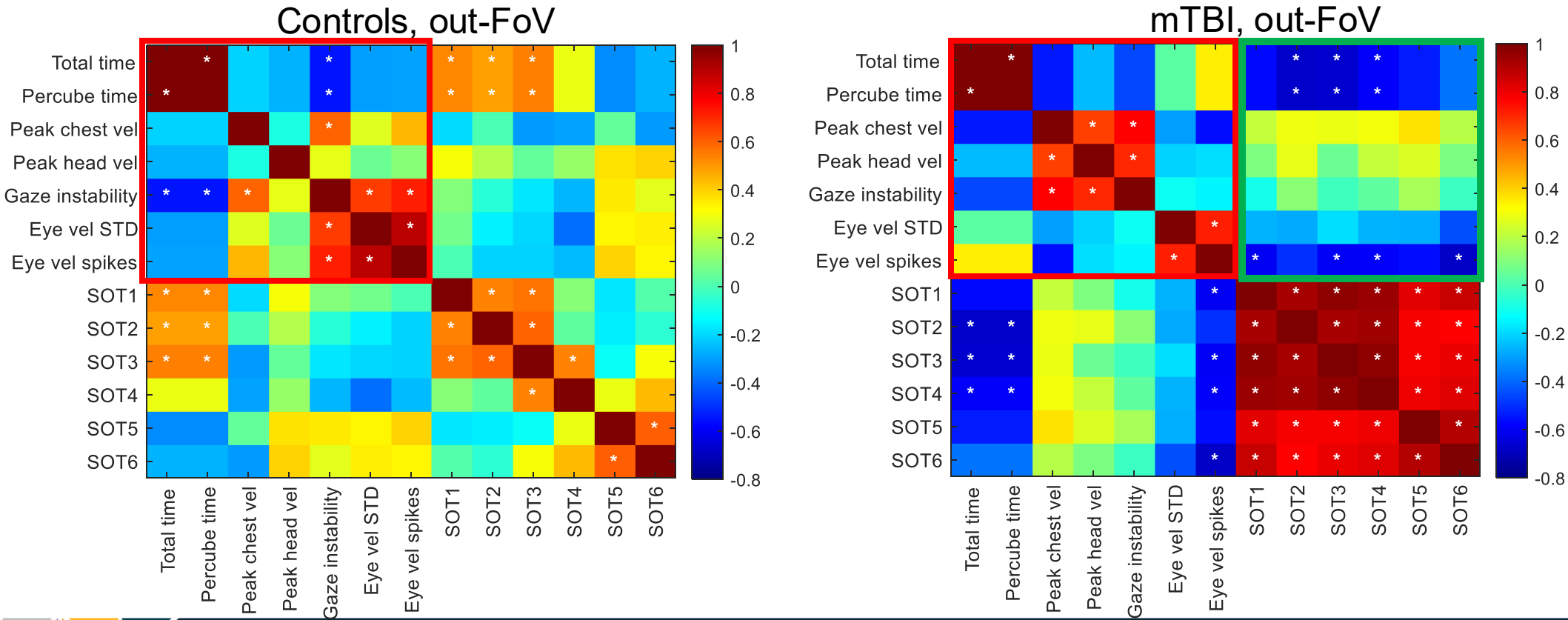
mTBI, In-FoV



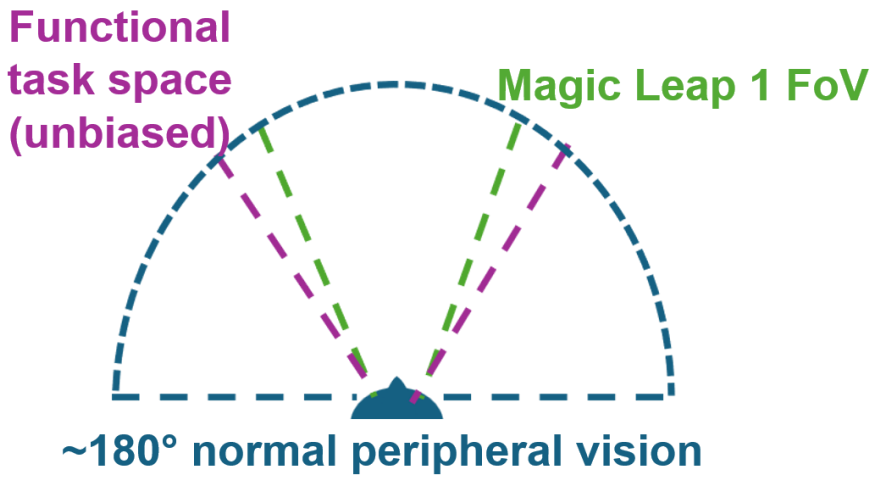
STUDY 2: BALANCE CUBES RESULTS

Results:

- Out-FoV starts to reveal relationships between performance, head, chest, and gaze movements. These patterns differ between Controls and mTBI group (red box).
- Individual SOT scores are correlated to performance metrics (green box)

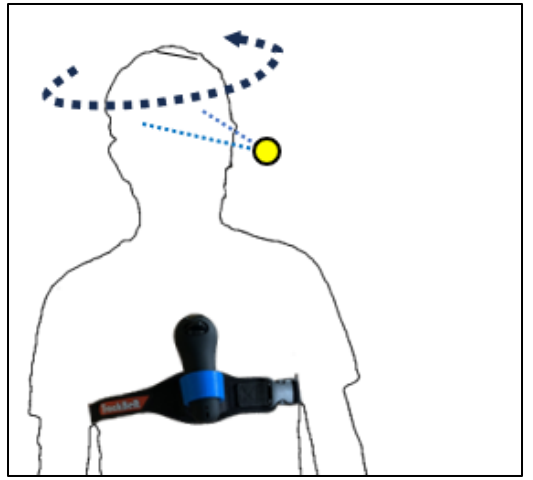


CONCLUSIONS



- *Task space can be kept within a set window or be leveraged as a* **programmable clinical parameter**.
- *Healthy adults show a* **bias** *towards the* **right hand side**.
- *Window found in this work can* **be scaled to FoVs in other headsets.**

In **healthy** *adults,* **gait is not affected** *by limited field of view, even when greater head rotations are required to overcome it.*



Head, body, and eyes *are all metrics that can be captured within headsets to measure and track clinical deficits*

Images courtesy of NHRC

THANK YOU

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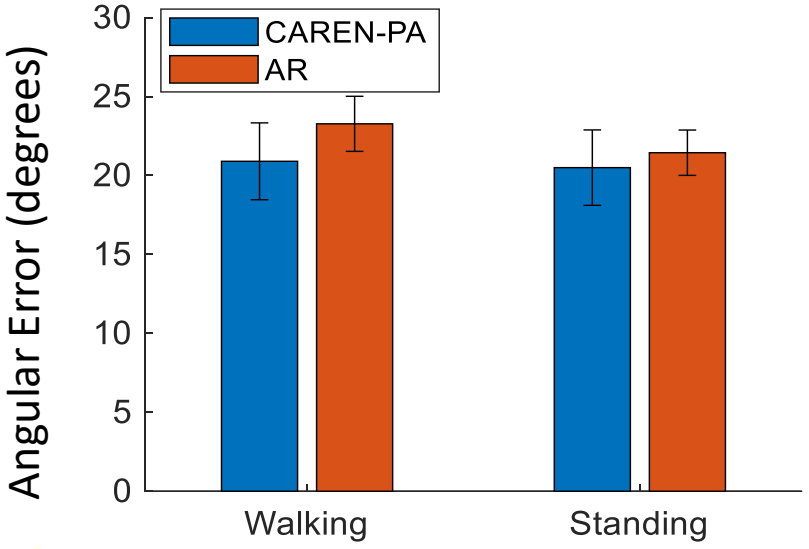
SUPPLEMENTARY SLIDES: AUDIO LOCALIZATION RESULTS

- Task: Audio Localization
  - *Locate position of a pulsed auditory stimulus in 180° space*
  - *CAREN system: physical speakers were used*
  - *AR headset: participants wore headphones capable of delivering spatialized audio*
    - *HRTF was custom designed*

- Results
  - *Average angular error was similar between the CAREN (using physical speakers) and within the headset (using virtual audio).*
  - *HRTF + spatialized audio setup was able to adequately imitate real sound in 180° space*



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