

Reach Performance using Touchscreens under G and vibration conditions

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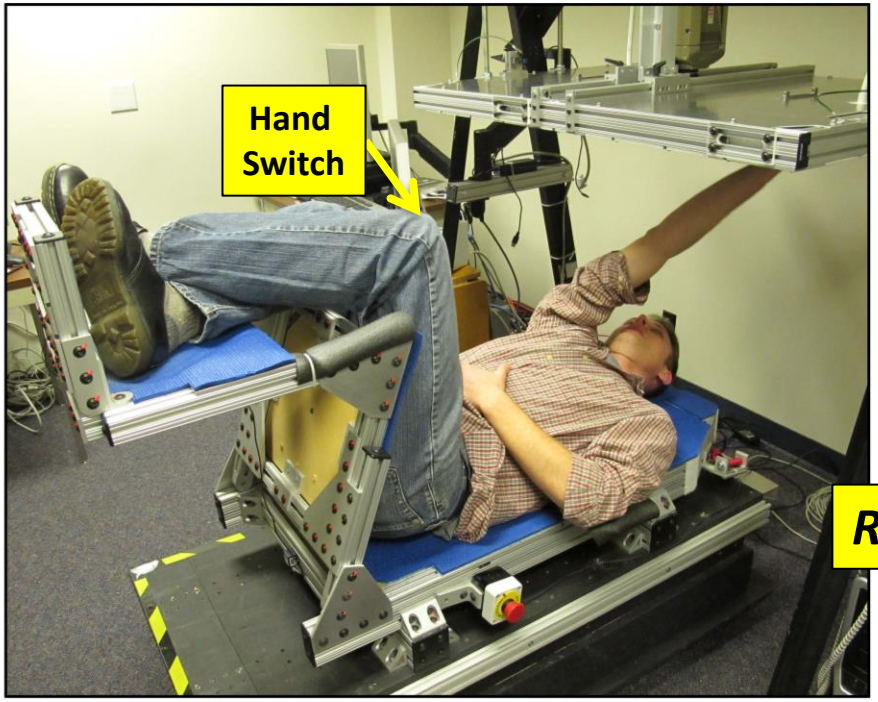
Data collected at NASA ARC under Project Title:
Robust Human-System Interface Design for
Spaceflight Induced Environments

NSBRI Project Number: SA02002 (L. Stone, PI)

UP-FRONT CAVEAT

- The reaching studies described here were performed to examine the induced environment created by an SL1 launch of Orion (~3.8 Gx + high vibration at ~12 Hz), and thus were NOT designed to examine the induced dynamics of a lunar landing (< ~1 Gz + lower vibration).
- Thus, the quantitative ballpark estimates herein must be interpreted with caution due to the fundamental difference between high Gx and low Gz exposure on human performance, as well as differences in the interface (seat/display) geometry of any proposed lunar vehicle.
- Nevertheless, in both scenarios, crew are adapted to a different baseline G levels (1 G or microgravity) and are suddenly exposed to an altered G bias plus vibration that will induce qualitatively similar errors. Furthermore, in all cases, performance is also limited by underlying biomechanical constraints that are captured in our data.

➔ Simulation on earth of lunar landing dynamics is very difficult (e.g., transient exposures to lunar G during parabolic flight or on the VMS)



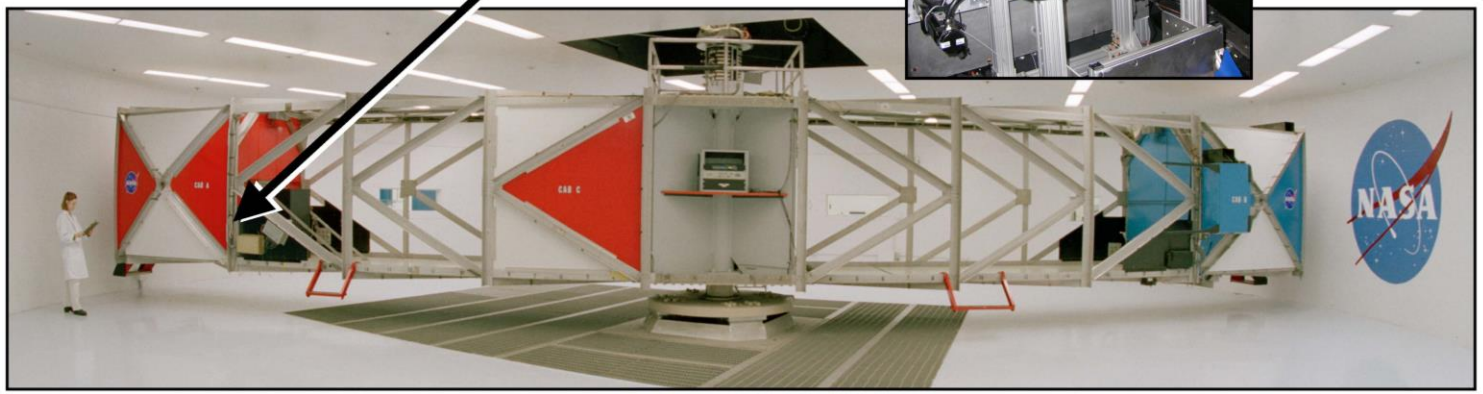
ARC Human Vibration Lab

1Gx testing (supine posture)

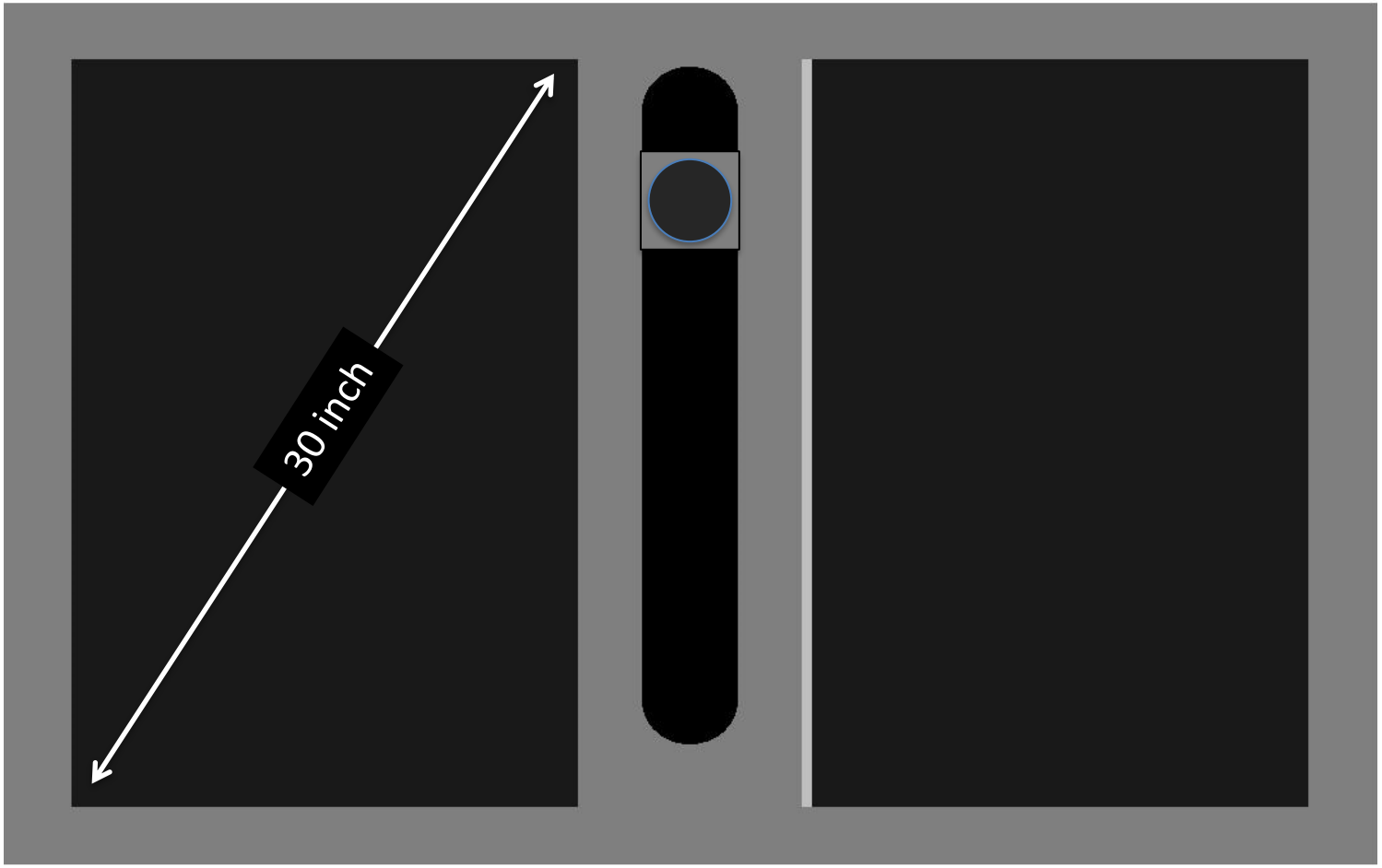
Room/cab are darkened during data runs

ARC 20-G Centrifuge

3.8 Gx testing

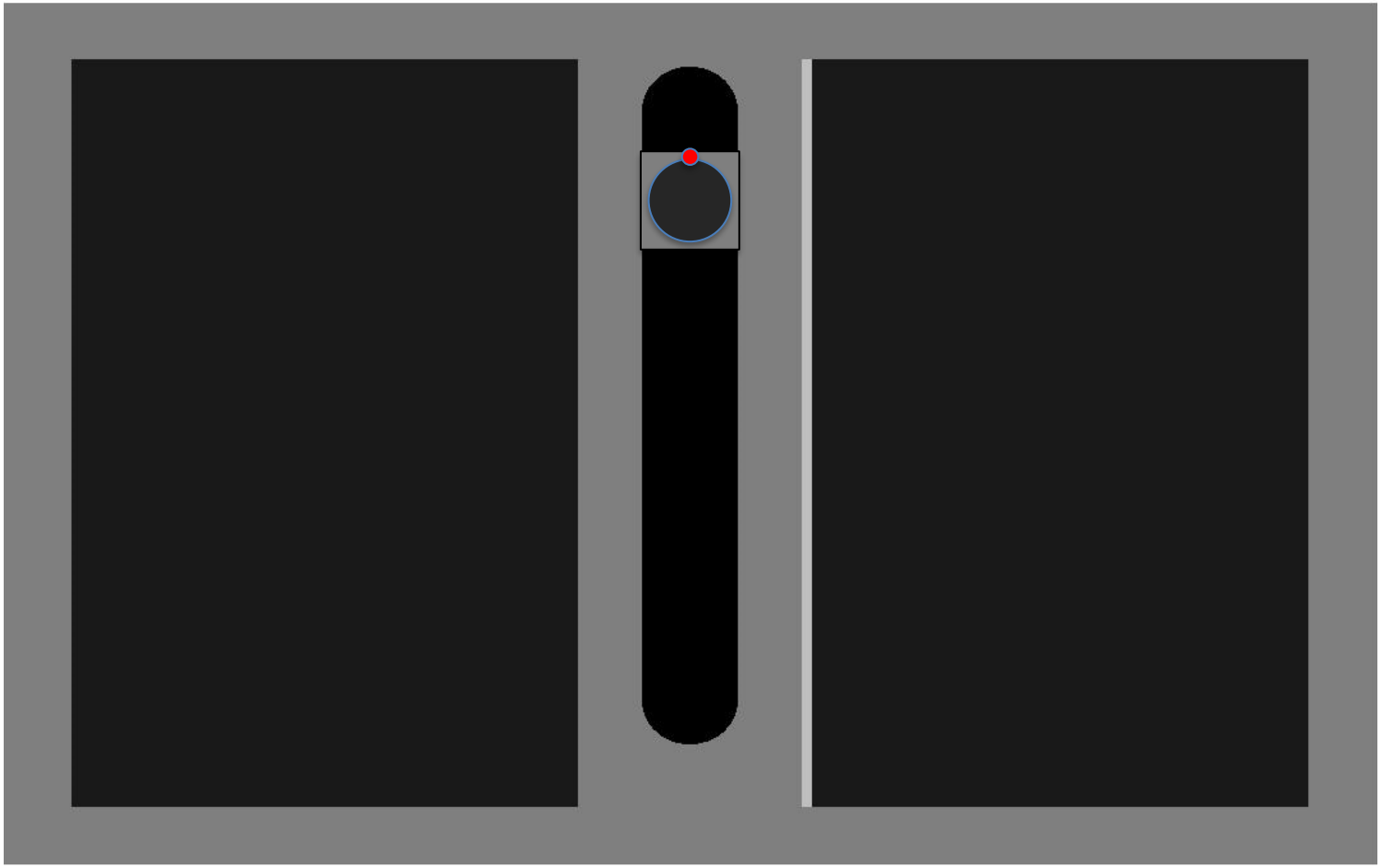


Dual Display Touchscreen Panel
With High-Resolution High-Frame-Rate Camera



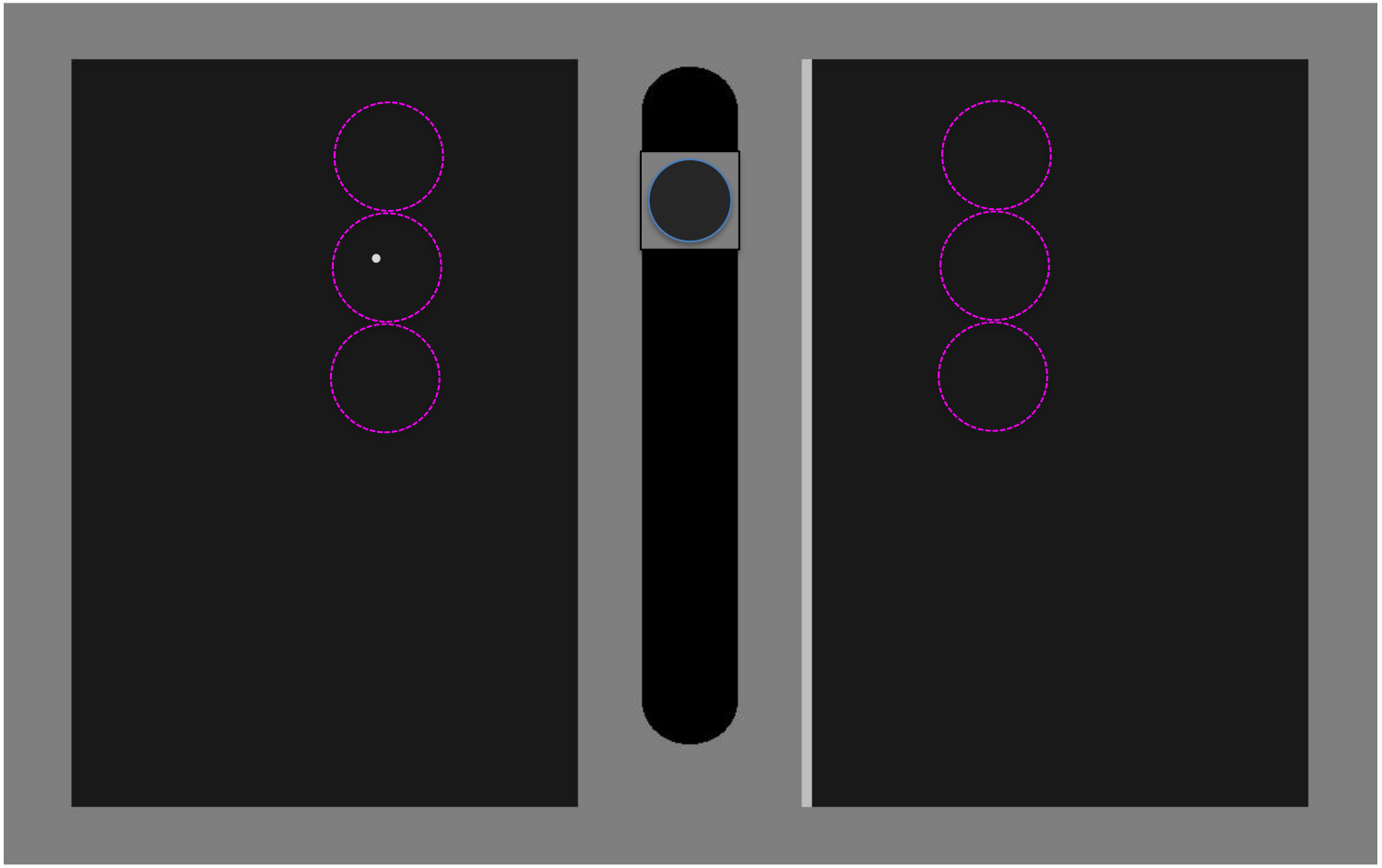
- Apple 30-inch HD Cinema Displays equipped w/ touchscreen
- 2560 X 1600 pixels (vertical X horizontal) per panel
- 100 pixel/inch resolution (30 pixel/deg visual angle)

Pre-Trial Central Fixation LED



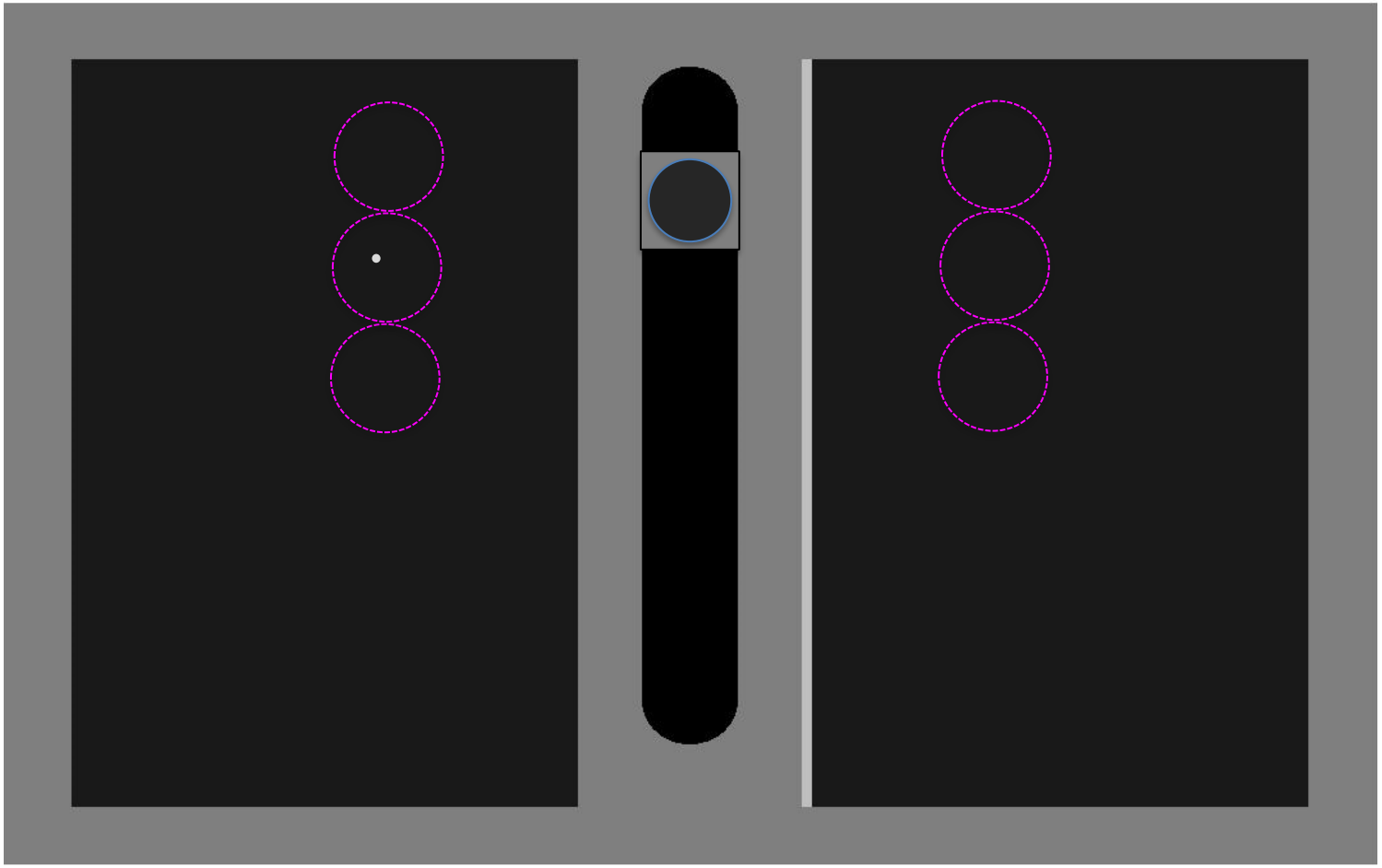
- Central fixation LED illuminated for random unpredictable time
- Continue to hold right hand rest switch while LED is illuminated

Target Spot
(OPEN LOOP)



- Central fixation LED extinguished
- Single target (30-pixel/0.3 inch/1° diam) in 1 of 6 circular zones for 133 ms
- Fixate location where target spot appeared and simultaneously release switch and reach to touch screen with *RIGHT* hand

Target Spot
(CLOSED LOOP)



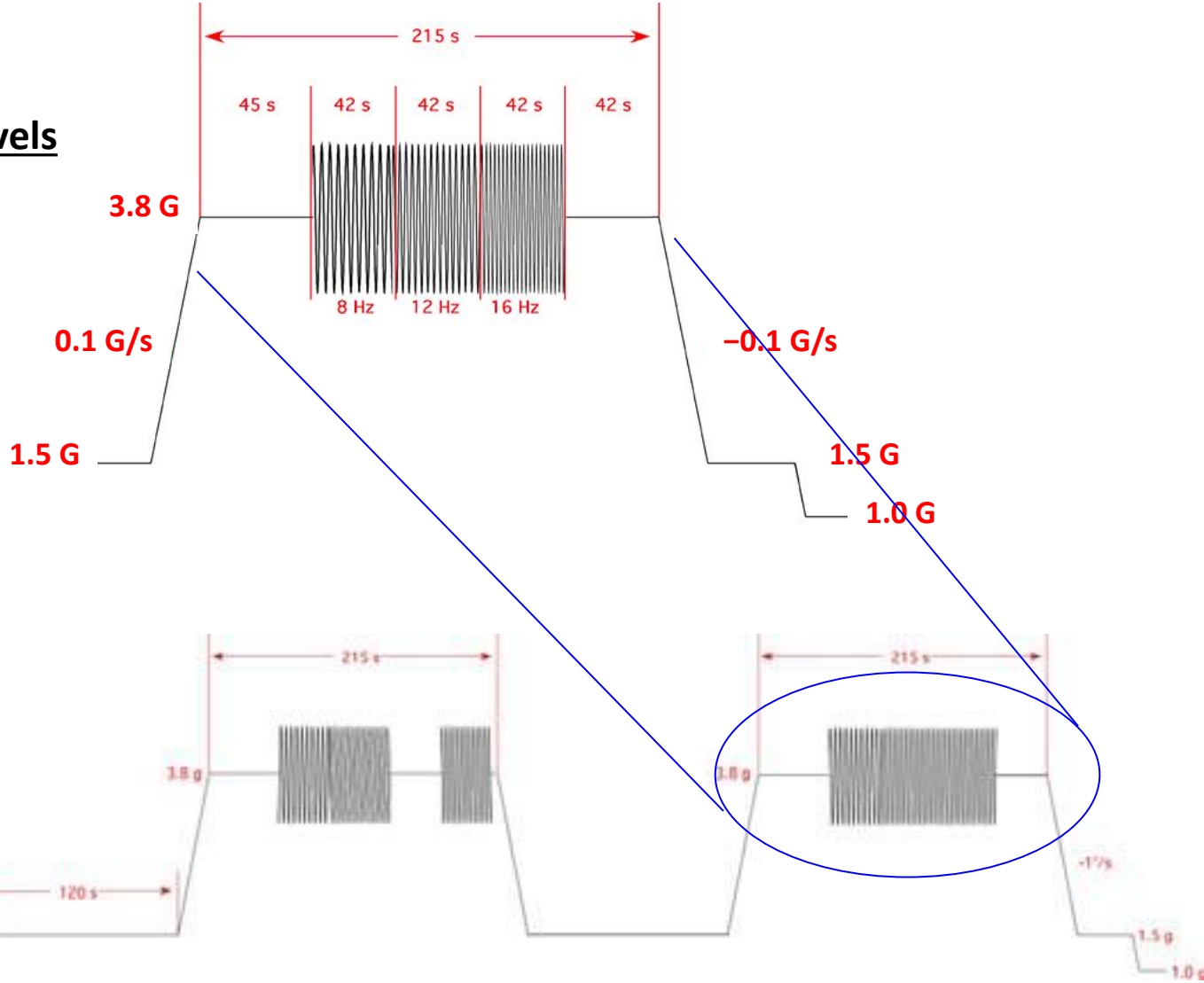
- Central fixation LED extinguished
- Single target (30-pixel/0.3 inch/1° diam) in 1 of 6 circular zones until end of trial
- Fixate location where target spot appeared and simultaneously release switch and reach to touch screen with *RIGHT* hand

Experiment Vibration Plus G Profile (Centrifuge)

(Identical vibration profile and timing for 1.0-G condition)

4 vibration frequency levels

- **Zero**
- **8 Hz @ 0.5 $g_{(zero\text{-}pk)}$**
- **12 Hz @ 0.5 $g_{(zero\text{-}pk)}$**
- **16 Hz @ 0.5 $g_{(zero\text{-}pk)}$**



Resonance of Arm-Hand

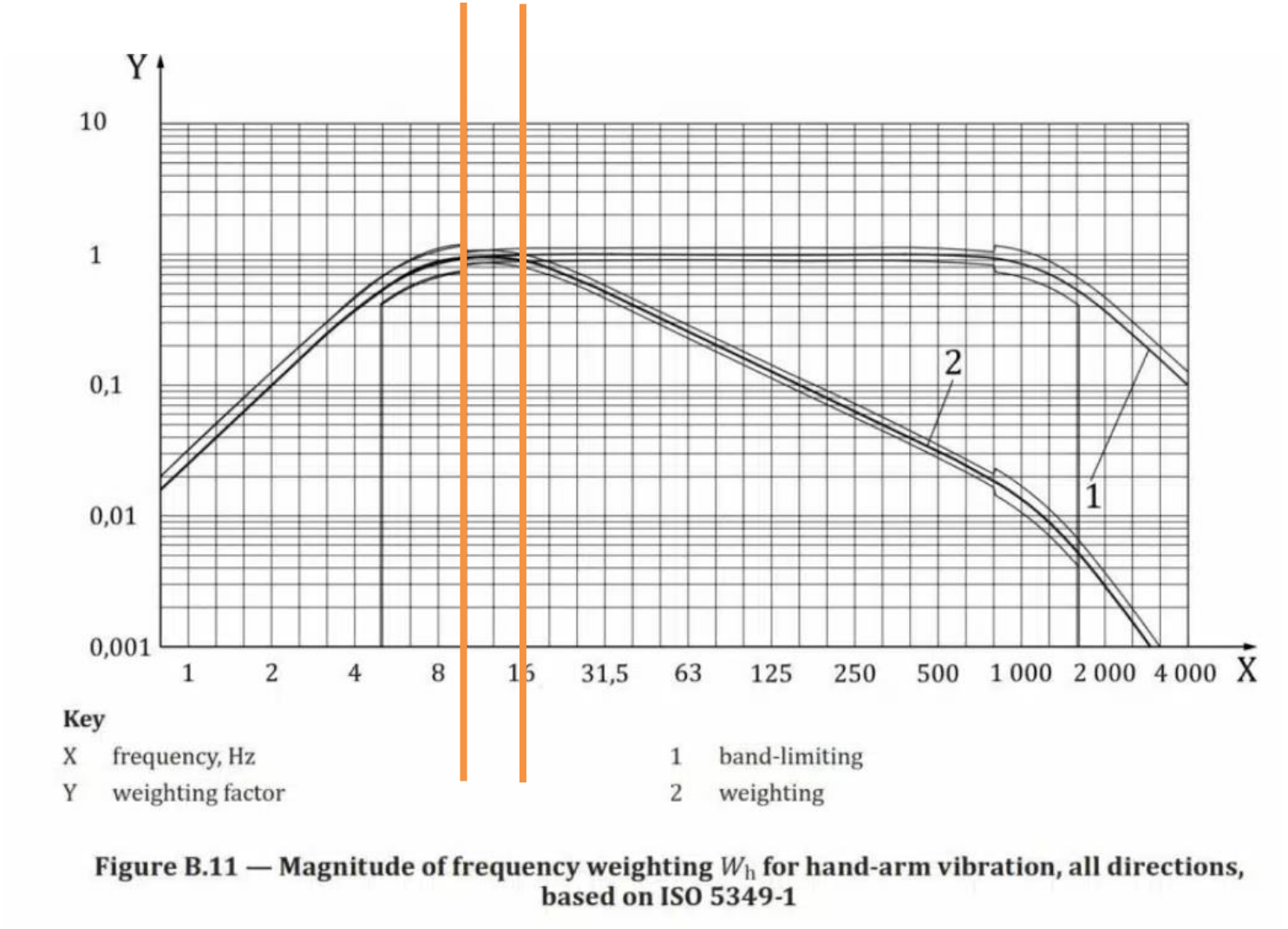
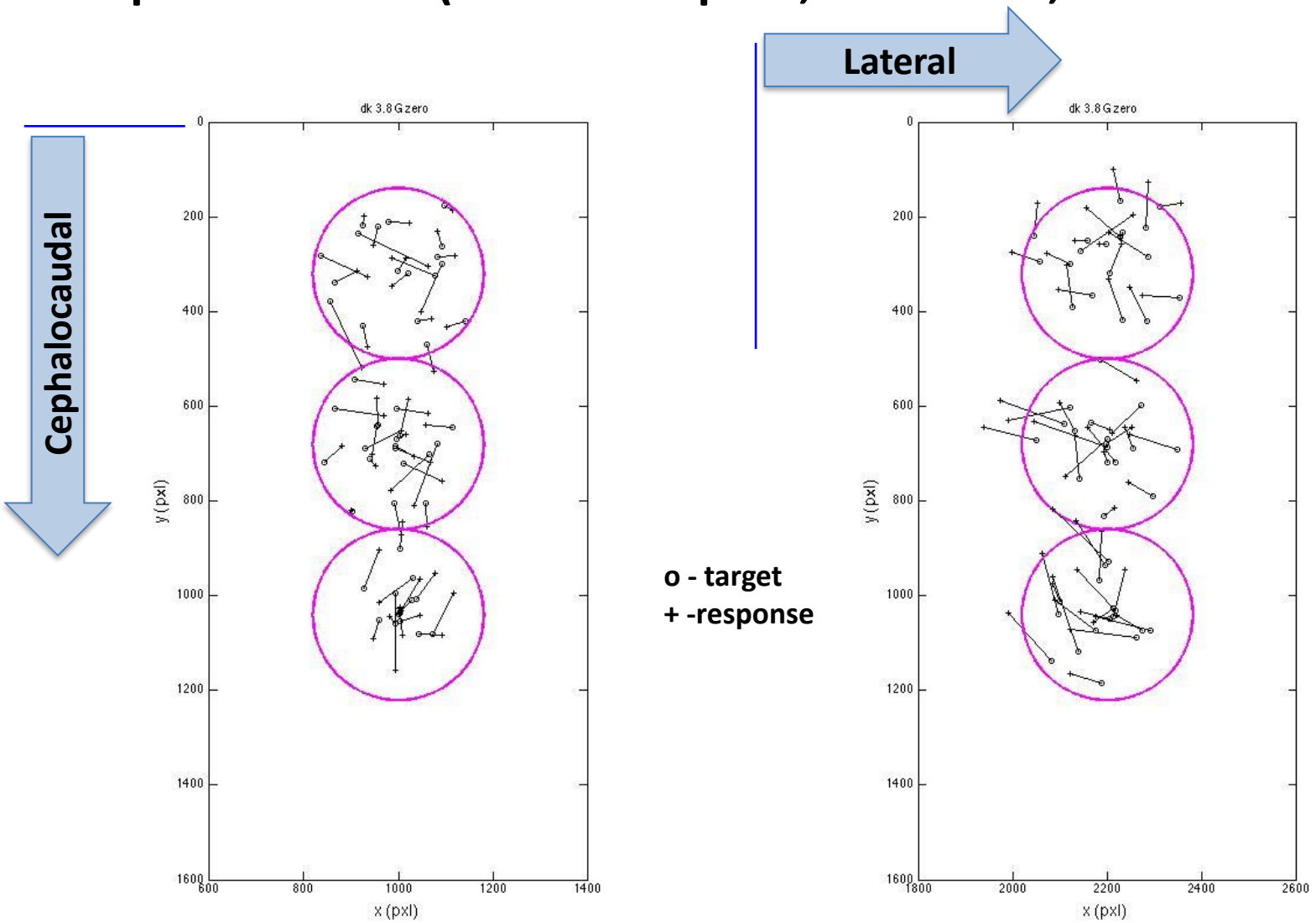


Figure B.11 — Magnitude of frequency weighting W_h for hand-arm vibration, all directions, based on ISO 5349-1

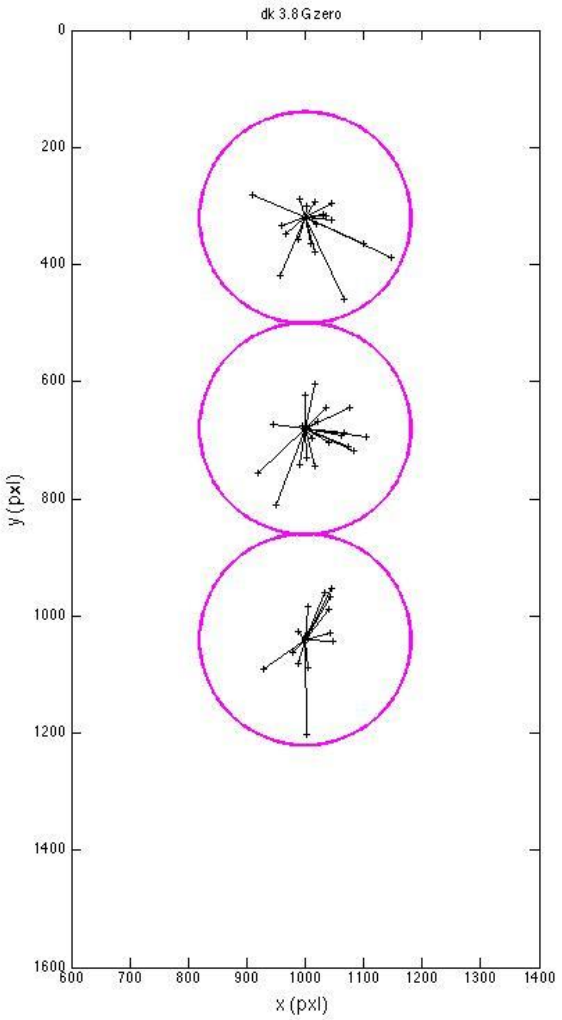
- Arm-Hand system has a resonance between 8 and 16 Hz
- Shoulder-WholeArm system has a lower resonance frequency that was not tested.

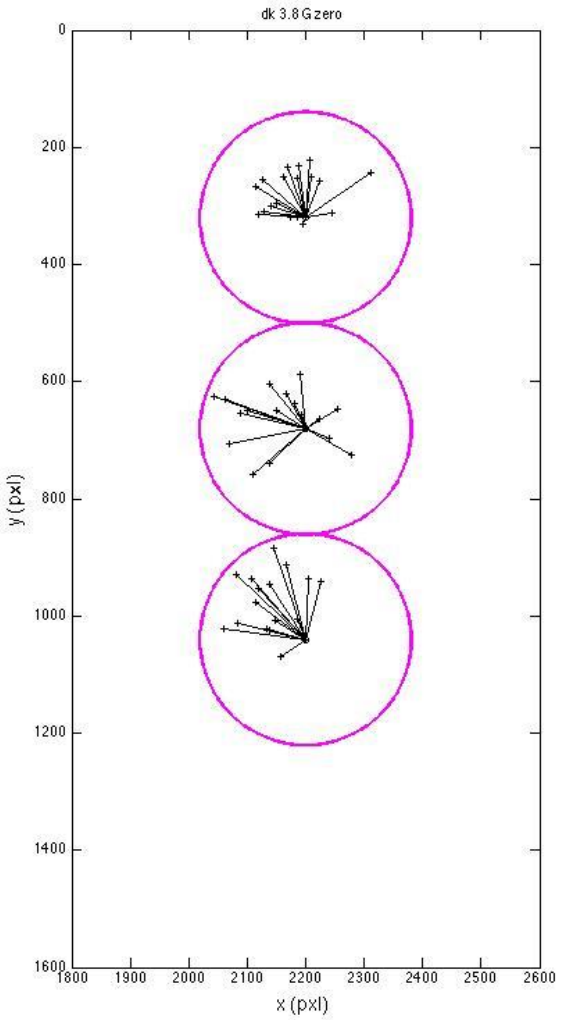
Sample Raw Data (One Participant, 3.8-G Bias, Zero Vibration)



- Three target zones each panel
- Target zone diameter: 3.6 inch (360 pixels)
- Vertical zone separation: 3.6 inch (360 pixels) center-center
- Horizontal zone separation: 19.4 inch center-center (~±30° visual from midline)

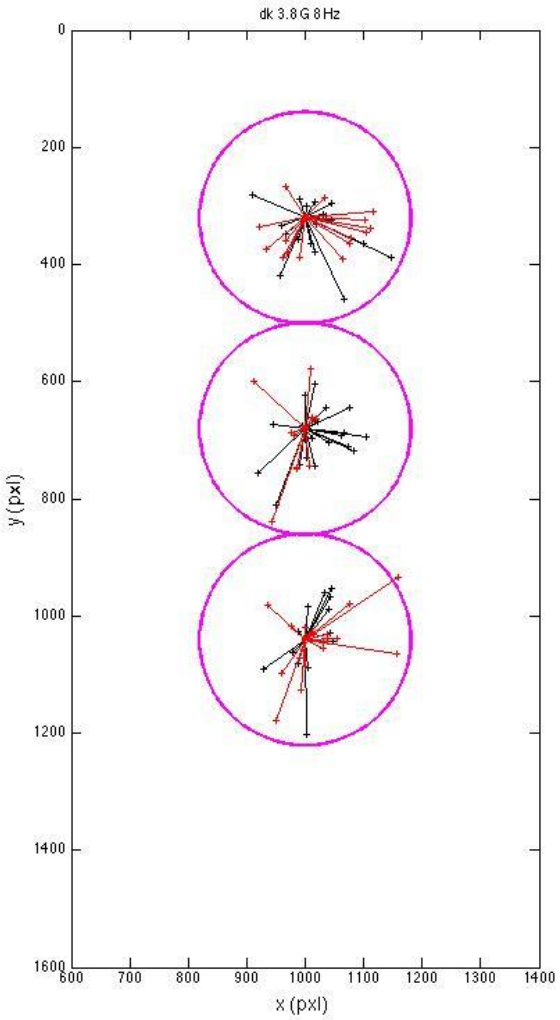
Response Error with Respect to Zone Centers (One Participant, 3.8-G Bias)

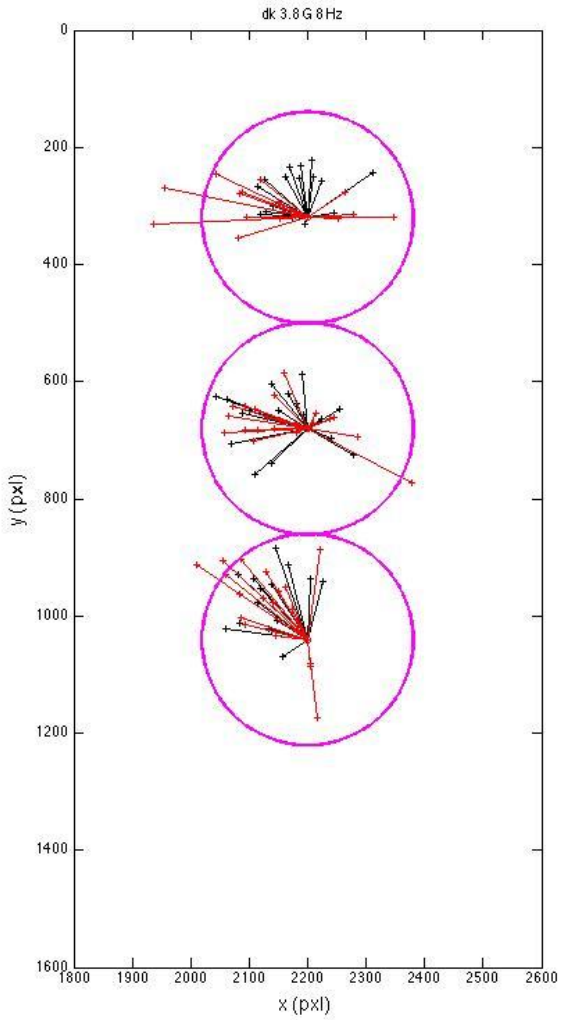




Zero Vibration

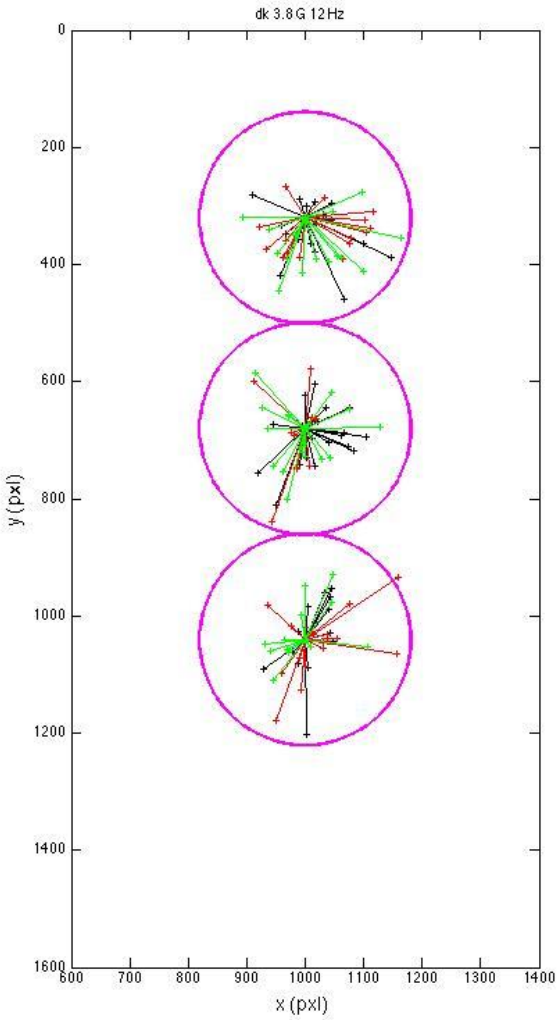
Response Error with Respect to Zone Centers (One Participant, 3.8-G Bias)

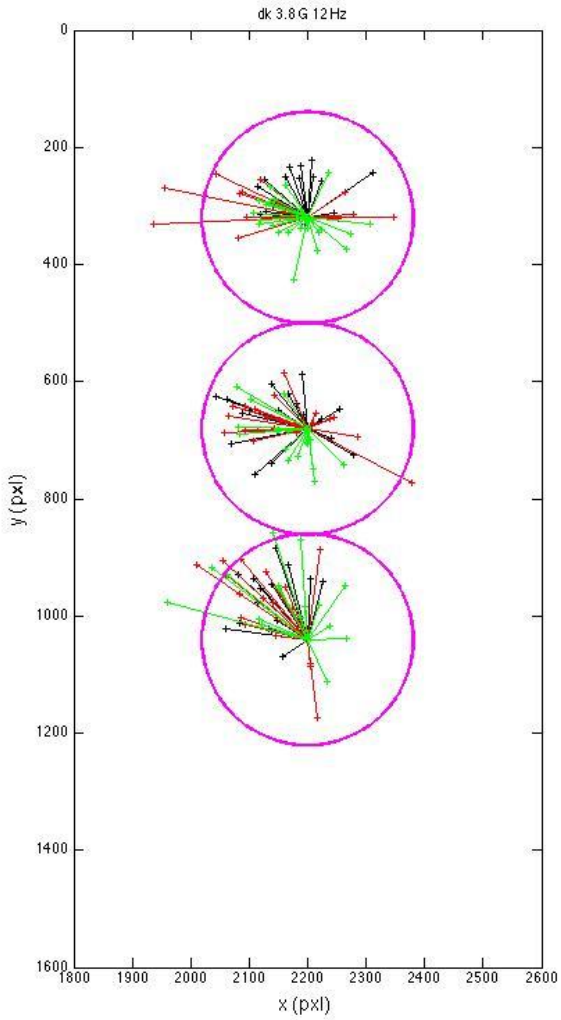




Zero, 8-Hz Vibration

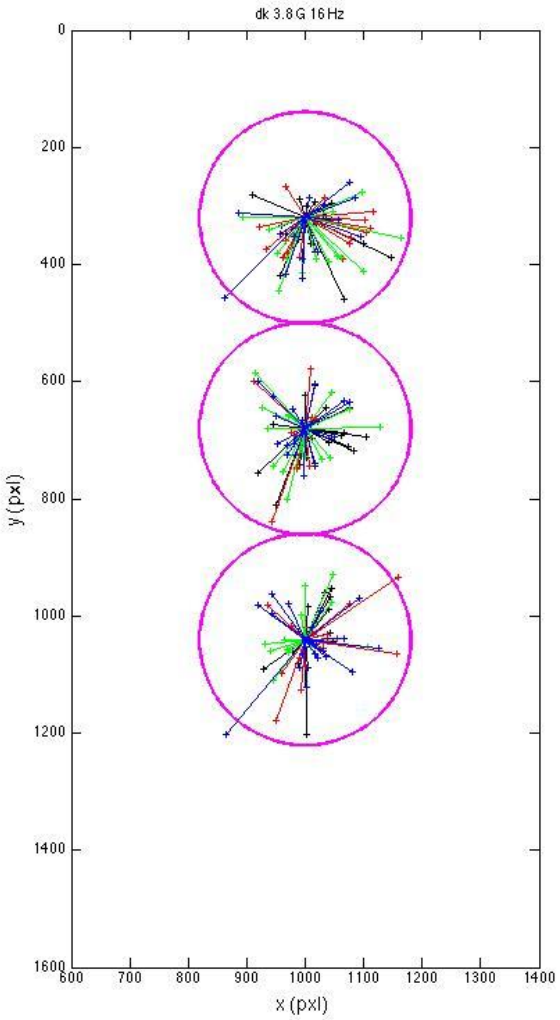
Response Error with Respect to Zone Centers (One Participant, 3.8-G Bias)

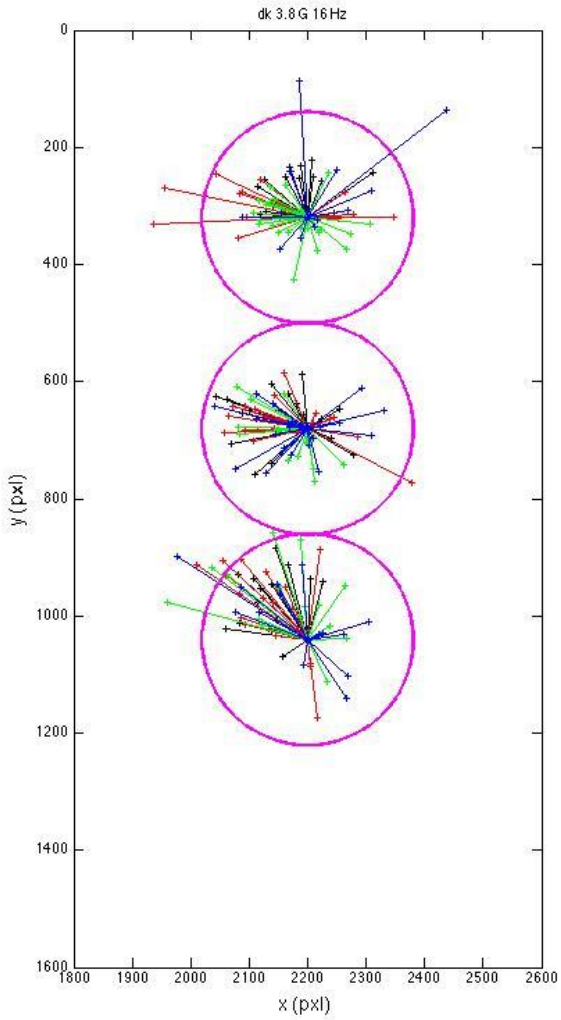




Zero, 8-, 12-Hz Vibration

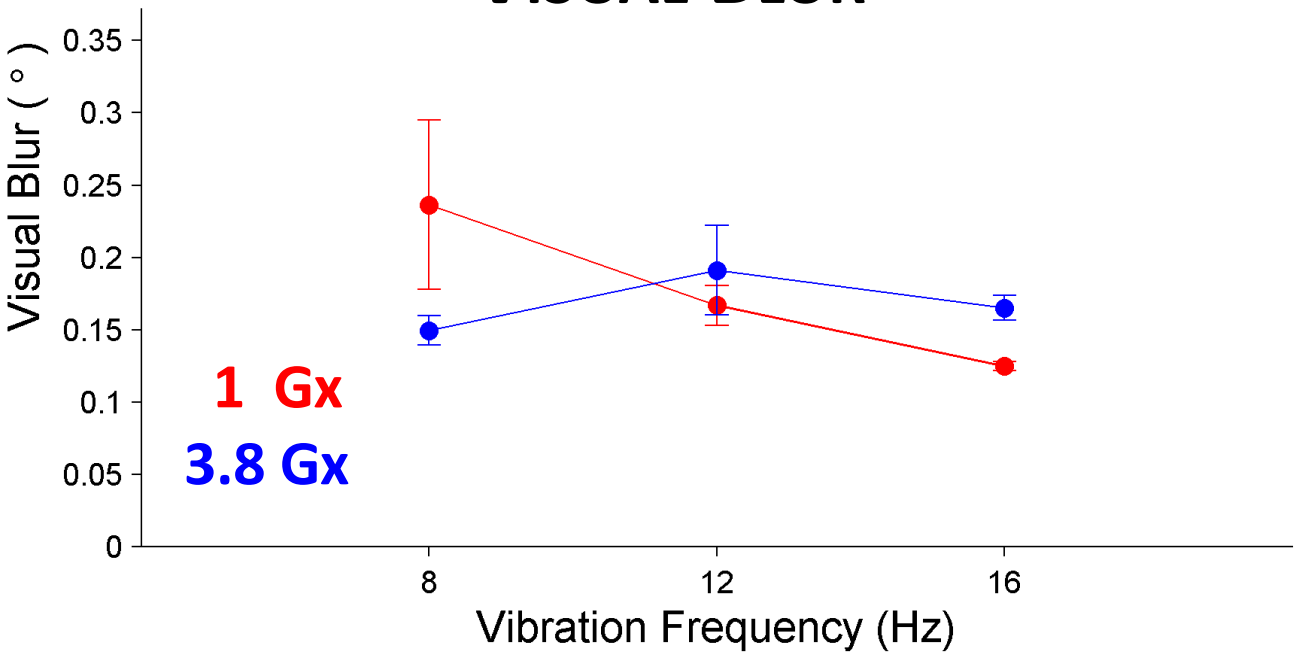
Response Error with Respect to Zone Centers (One Participant, 3.8-G Bias)





Zero, 8-, 12-, 16-Hz Vibration

VISUAL BLUR



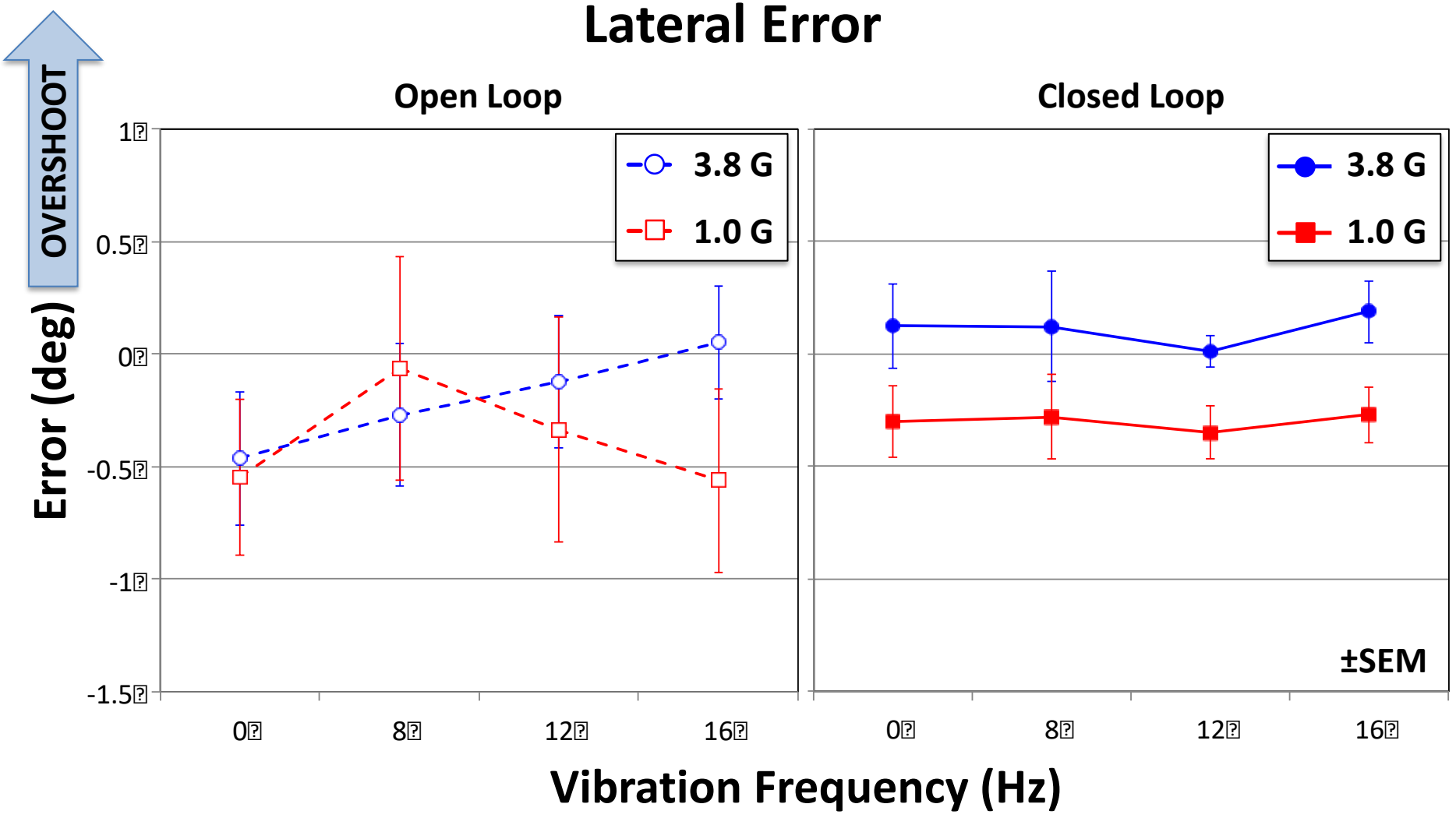
- The human Vestibulo-Ocular Reflex (VOR) was designed to stabilize gaze in response to human head movements (i.e. low frequency motion) and begins to fail at typical spaceflight vibration frequencies (> 8 Hz).

- Gaze stabilization noise (visual blur) is ~0.25 deg for ±0.5g of vibration.

- Thus, vibration affects legibility (Adelstein et al. 2009ab) and adds visual noise at the very beginning of any visuomotor response, regardless of display type, but is likely only a small contributor to reaching errors.

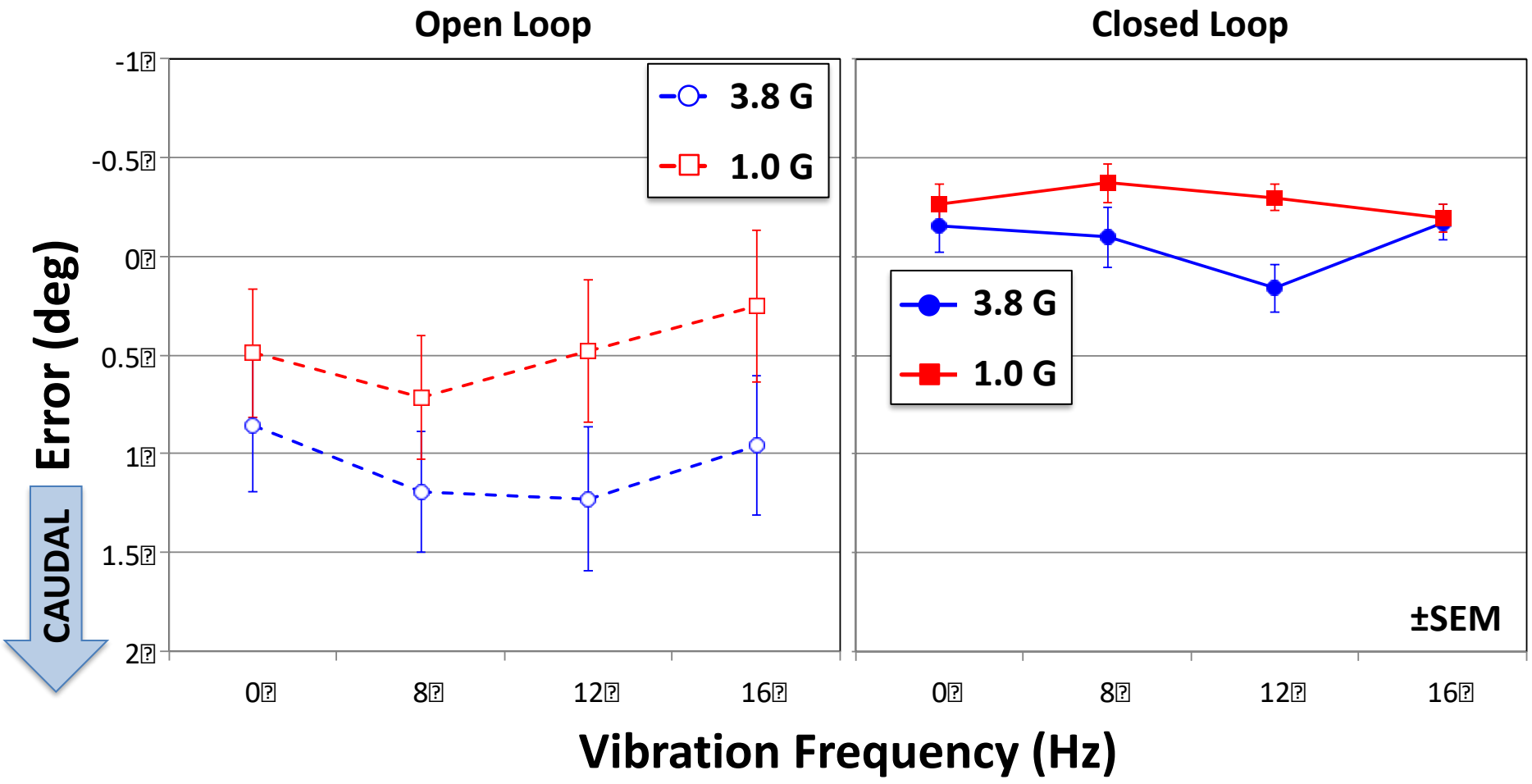
Manual Reaching Endpoint

Lateral Error



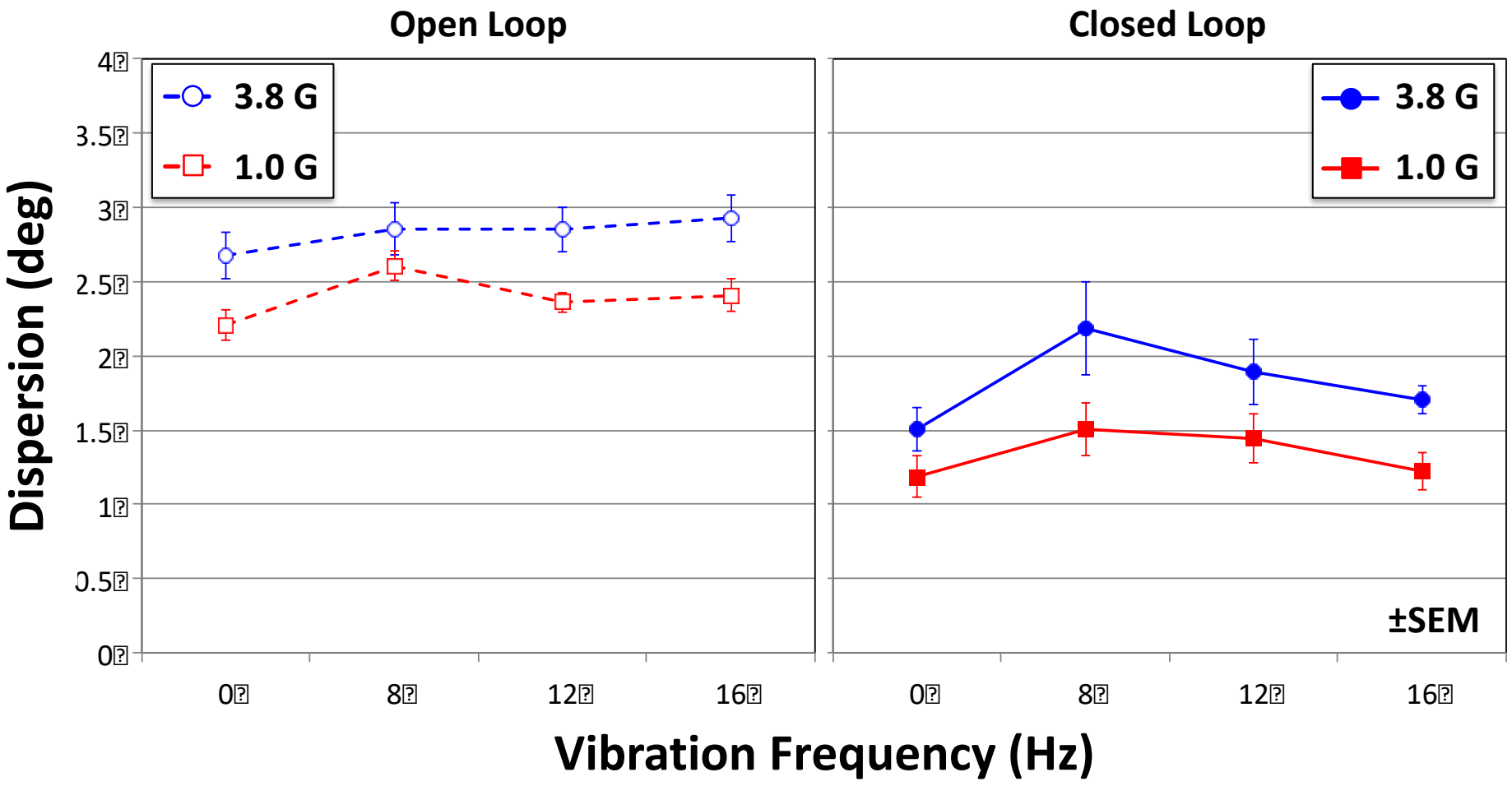
- G-forces generate systematic reaching errors that depend on G direction and target location with respect to the main joint (in this case, the shoulder).
- In our spatial configuration, lateral errors were on average small (< 0.5 deg).

Manual Reaching Endpoint
Cephalocaudal Error



- In our configuration, systematic vertical errors (bias) were larger and could reach ~1 deg (mean bias + 2σ, 95% CI) for the worst-case 1G rapid reaches.
- Visual feedback effectively eliminated this error.

Manual Reaching Endpoint
Radial Dispersion



- Random reaching errors (dispersion, σ) due to biological noise, G-force, and vibration reached ~5 deg (2σ, 95% CI) in worst-case rapid 1G reaches.
- Visual feedback reduced this error to ~3 deg.

SUMMARY

- A ballpark estimate of the worst-case rapid reach error due to biological noise, G-force, and vibration is 6 deg (~2'' for a 19'' reach).
- Visual feedback and slower responses lowers this to 3 deg.

Potential mitigating lunar factors (i.e., likely smaller errors):

- G-force and vibration likely lower than 1G and 0.5g, respectively
- vehicle vibration could be above of the 8-16 Hz band
- crew will know relevant display locations ahead of time
- non-abort actions can be done relatively slowly
- support structures (arm or wrist rests) would reduce these errors
- training (especially under realistic dynamic conditions) would reduce errors

Potential exacerbating lunar factors (i.e., possibly larger errors):

- estimates were from highly practiced reaches under stable G/vibration
- non-deconditioned participants (crews on Gateway for 30 days will be)
- vehicle vibration could be below the 8-16 Hz band affecting the shoulder
- reaches were oblique to Gx-vector (as opposed orthogonal to Gz vector)
- IVA suit and gloves could further hamper reaches
- regolith could interfere with touchscreen function