Impacts of Rotation Axis and Frequency on Vestibular Perceptual Thresholds

Andrew R. Wagner [1,2]**, Megan J. Kobel** [1,3] **and Daniel M. Merfeld** [1,2,3,4]

[1] Otolaryngology – Head & Neck Surgery, Ohio State University Wexner Medical Center, 915 Olentangy River Rd, Columbus, OH 43212, USA

[2] Health and Rehabilitation Sciences, Ohio State University, Columbus, OH 43210, USA

[3] Speech and Hearing Science, Ohio State University, Columbus, OH 43210, USA

[4] Biomedical Engineering, Ohio State University, Columbus, OH 43210, USA

*Corresponding author; e-mail: andrew.wagner@osumc.edu

ORCID iDs: Wagner: 0000-0002-1833-766X; Kobel: 0000-0001-5067-8520
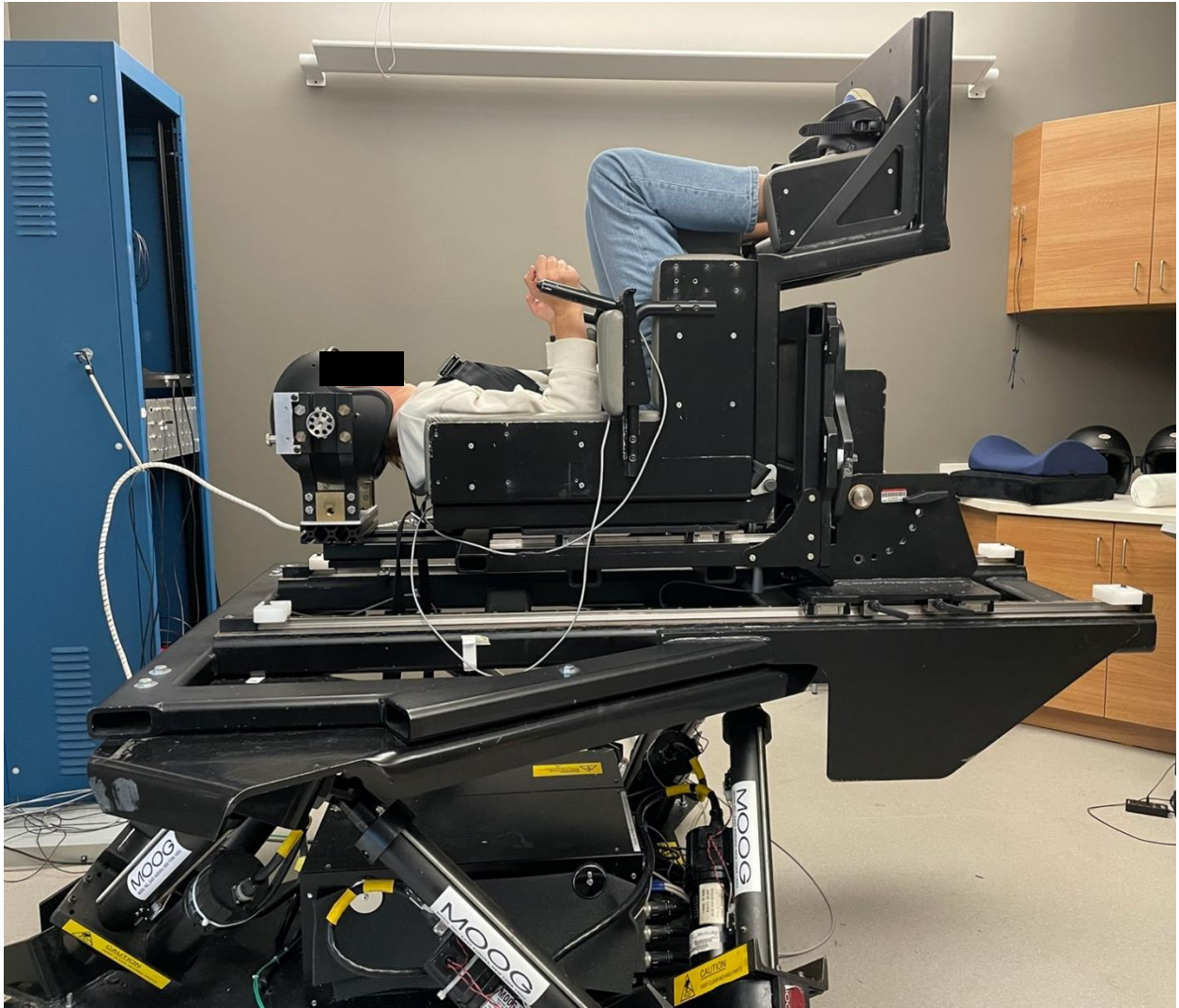
Supplementary Material

Figure S1. Chair is positioned in a supine orientation. Earth vertical roll rotations were delivered by rotating the subject about an earth vertical axis aligned at the level of the vestibular labyrinths (i.e., head-centered).

Figure S2. Chair is tilted backward 90 degrees and rotated 45 degrees to the left of supine. Earth vertical LARP rotations were delivered by rotating the subject about an earth vertical axis aligned at the level of the vestibular labyrinths (i.e., head-centered).

Figure S3. Chair is tilted backward 90 degrees and rotated 90 degrees to the right of supine. Earth vertical pitch rotations were delivered by rotating the subject about an earth vertical axis aligned at the level of the vestibular labyrinths (i.e., head-centered).

Figure S4. Chair is tilted backward 90 degrees and rotated 45 degrees to the right of supine. Earth vertical RALP rotations were delivered by rotating the subject about an earth vertical axis aligned at the level of the vestibular labyrinths (i.e., head-centered).

Figure S5. Chair remains upright for each of the Earth-Horizontal rotation (i.e., tilt) conditions. The MOOG 6DOF motion platform simulates the respective axes to permit head centered tilts in each of the respective motion planes.

Table S1.

Average (i.e., geometric mean) vestibular perceptual displacement thresholds ($n = 14$) for each motion condition (with 95% confidence interval).

	0.2 Hz		0.5 Hz		1 Hz		2 Hz	
	EH	EV	EH	EV	EH	EV	EH	EV
Roll	1.152	6.253	0.602	1.371	0.358	0.484	0.141	0.108
	(0.869 to 1.527)	(4.816 to 8.12)	(0.432 to 0.837)	(1.054 to 1.782)	(0.239 to 0.537)	(0.387 to 0.605	(0.09 to 0.22)	(0.085 to 0.136)
Pitch	1.431	6.895	0.729	1.44	0.401	0.422	0.157	0.139
	(1.185 to 1.728)	(4.805 to 9.895)	(0.577 to 0.921)	(1.149 to 1.805)	(0.328 to 0.491)	(0.327 to 0.544)	(0.124 to 0.199)	(0.115 to 0.167)
RALP	1.47	6.706	0.594	1.462	0.361	0.498	0.158	0.165
	(1.165 to 1.856)	(4.919 to 9.144)	(0.457 to 0.771)	(1.027 to 2.081)	(0.276 to 0.473)	(0.353 to 0.704)	(0.137 to 0.182)	(0.123 to 0.2220
LARP	1.333	7.17	0.699	1.635	0.395	0.518	0.151	0.178
	(1.110 to 1.600)	(5.216 to 9.855)	(0.545 to 0.898)	(1.297 to 2.062)	(0.319 to 0.489)	(0.42 to 0.64)	(0.119 to 0.193)	(0.142 to 0.223)

EH = earth horizontal (tilt); EV = earth.

Table S2.

Average (i.e., geometric mean) vestibular perceptual acceleration thresholds ($n = 14$) for each motion condition (with 95% confidence interval).

	0.2 Hz		0.5 Hz		1 Hz		2 Hz	
	EH	EV	EH	EV	EH	EV	EH	EV
Roll	0.289	1.572	0.945	2.153	2.252	3.038	1.767	1.352
	(0.218 to 0.384)	(1.21 to 2.041)	(0.679 to 1.315)	(1.656 to 2.799)	(1.503 to 3.373)	(2.430 to 3.7990)	(1.128 to 2.767)	(1.071 to 1.707)
Pitch	0.36	1.733	1.145	2.262	2.523	2.649	1.975	1.741
	(0.298 to 0.434)	(1.208 to 2.487)	(0.906 to 1.447)	(1.805 to 2.835)	(2.063 to 3.085)	(2.054 to 3.416)	(1.561 to 2.499)	(1.448 to 2.094)
RALP	0.37	1.685	0.933	2.296	2.269	3.132	1.984	2.073
	(0.293 to 0.466)	(1.236 to 2.298)	(0.718 to 1.211)	(1.613 to 3.269	(1.734 to 2.969)	(2.218 to 4.424)	(1.718 to 2.292)	(1.542 to 2.785)
LARP	0.335	1.802	1.098	2.569	2.482	3.256	1.901	2.240
	(0.279 to 0.402)	(1.311 to 2.477)	(0.855 to 1.41)	(2.038 to 3.239)	(2.006 to 3.072)	(2.637 to 4.020)	(1.491 to 2.423)	(1.789 to 2.805)

EH = earth horizontal (tilt); EV = earth vertical, LARP = left anterior right posterior; RALP, right anterior left posterior.

Table S3.

Mean vestibular bias ($n = 14$) in the displacement domain for each motion condition (with 95% confidence interval).

	0.2 Hz		0.5 Hz		1 Hz		2 Hz	
	EH	EV	EH	EV	EH	EV	EH	EV
Roll	−0.048	−0.540	−0.066	−0.055	0.005	−0.035	0.008	−0.007
	(−0.229 to 0.133)	(−1.589 to 0.509)	(−0.209 to 0.077)	(−0.286 to 0.175)	(−0.055 to 0.065)	(−0.126 to 0.057)	(−0.032 to 0.047)	(−0.036 to 0.022)
Pitch	−0.461	−0.805	−0.242	−0.322	−0.179	−0.33	−0.039	−0.046
	(−0.72 to −0.201)	(−1.46 to −0.15)	(−0.361 to −0.122)	(−0.597 to −0.046)	(−0.15 to −0.029)	(−0.247 to −0.084)	(−0.062 to −0.017)	(−0.074 to −0.019)
RALP	−0.065	−0.343	−0.108	−0.231	−0.13	−0.287	−0.083	−0.046
	(−0.344 to 0.214)	(−1.626 to 0.941)	(−0.245 to 0.029)	(−0.461 to −0.002)	(−0.13 to 0.001)	(−0.218 to −0.069)	(−0.083 to 0.004)	(−0.087 to −0.005)
LARP	−0.199	1.01	−0.12	0.409	−0.064	0.216	−0.011	0.009
	(−0.44 to 0.049)	(−0.158 to 2.179)	(−0.257 to 0.018)	(0.033 to 0.785	(−0.103 to 0.039)	(0.016 to 0.201)	(−0.045 to 0.023)	(−0.015 to 0.034)

EH = earth horizontal (tilt); EV = earth vertical, LARP = left anterior right posterior; RALP = right anterior left posterior.

Table S4.

Mean vestibular bias ($n = 14$) in the acceleration domain for each motion condition (with 95% confidence interval).

	0.2 Hz		0.5 Hz		1 Hz		2 Hz	
	EH	EV	EH	EV	EH	EV	EH	EV
Roll	−0.012	−0.136	−0.103	−0.087	0.029	−0.217	0.097	−0.089
	(−0.058 to 0.033)	(−0.399 to 0.128)	(−0.328 to 0.121)	(−0.449 to 0.275)	(−0.348 to 0.406)	(−0.793 to 0.358)	(−0.396 to 0.591)	(−0.456 to 0.277)
Pitch	−0.116	−0.202	−0.38	−0.505	−0.562	−1.038	−0.494	−0.579
	(−0.181 to −0.051)	(−0.367 to −0.038)	(−0.567 to −0.192)	(−0.938 to −0.073)	(−0.941 to −0.182)	(−1.055 to −0.525)	(−0.776 to −0.212)	(−0.926 to −0.233)
RALP	−0.016	−0.086	−0.17	−0.363	−0.41	−0.9	−0.5	−0.574
	(−0.086 to 0.054)	(−0.409 to 0.237)	(−0.384 to 0.045)	(−0.724 to −0.003)	(−0.818 to −0.001)	(−1.367 to −0.434)	(−1.046 to 0.045)	(−1.088 to −0.06)
LARP	−0.05	0.254	−0.188	0.642	−0.2	0.68	−0.138	0.117
	(−0.112 to 0.012)	(−0.04 to 0.548)	(−0.404 to 0.028)	(0.052 to 1.233)	(−0.645 to 0.244)	(0.099 to 1.261)	(−0.56 to 0.285)	(−0.189 to 0.423)

EH = earth horizontal (tilt); EV = earth vertical, LARP = left anterior right posterior; RALP, right anterior left posterior.