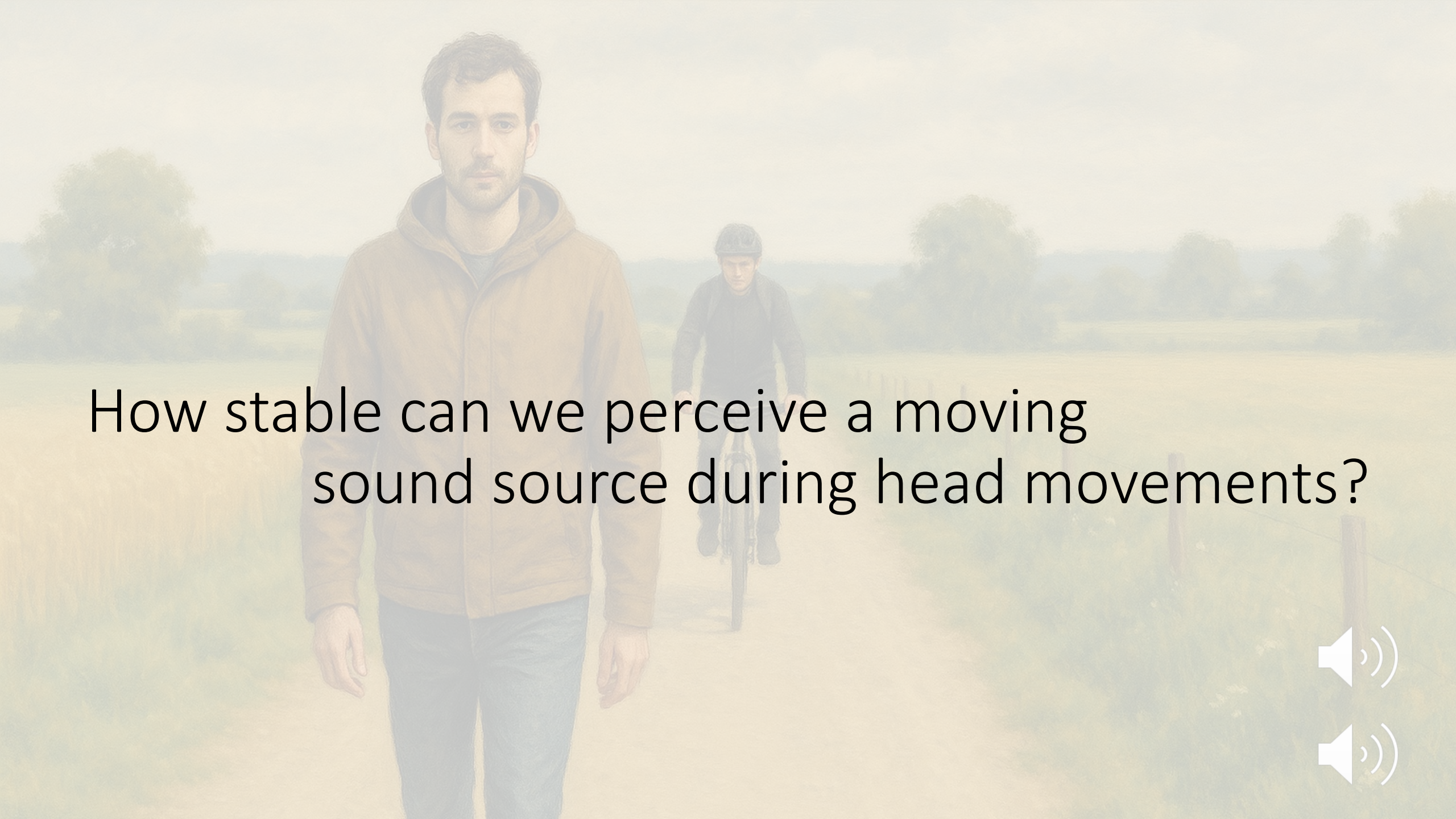
Auditory parsing

The effect of head movement on the perceived direction of a moving sound source

Timo Oess, Marc O. Ernst, Laurence Harris



How stable can we perceive a moving sound source during head movements?

When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]

When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

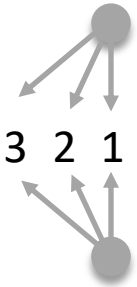
→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]

When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]

When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]



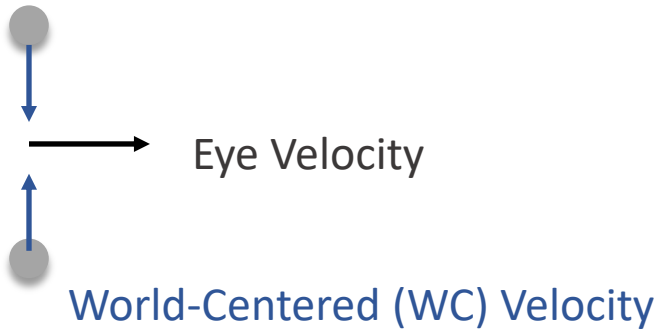
When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]

World-Centered (WC) Velocity

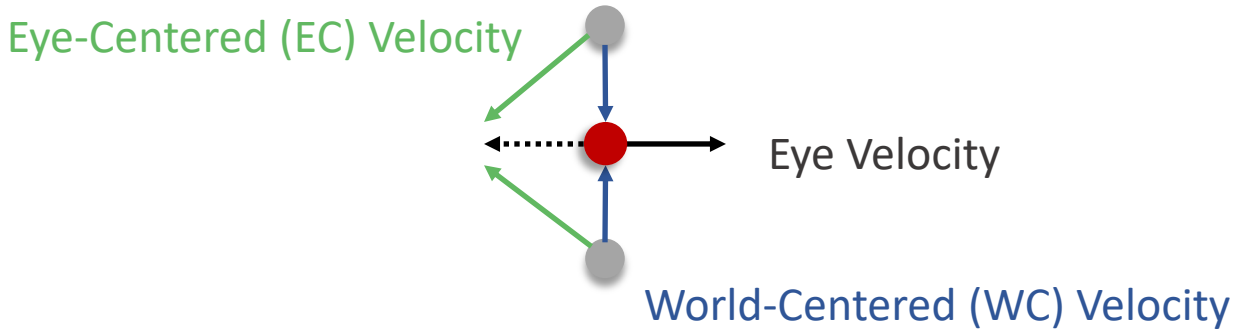
When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]



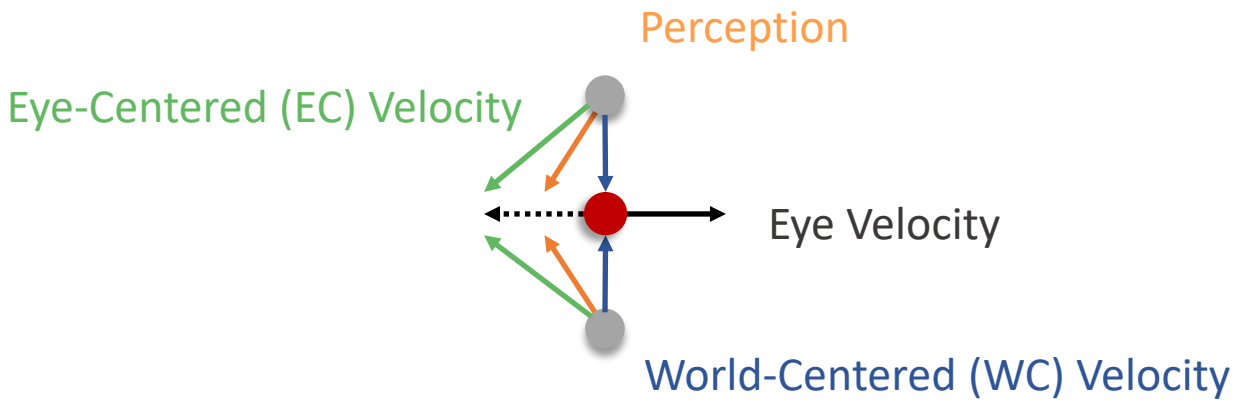
When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]



When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

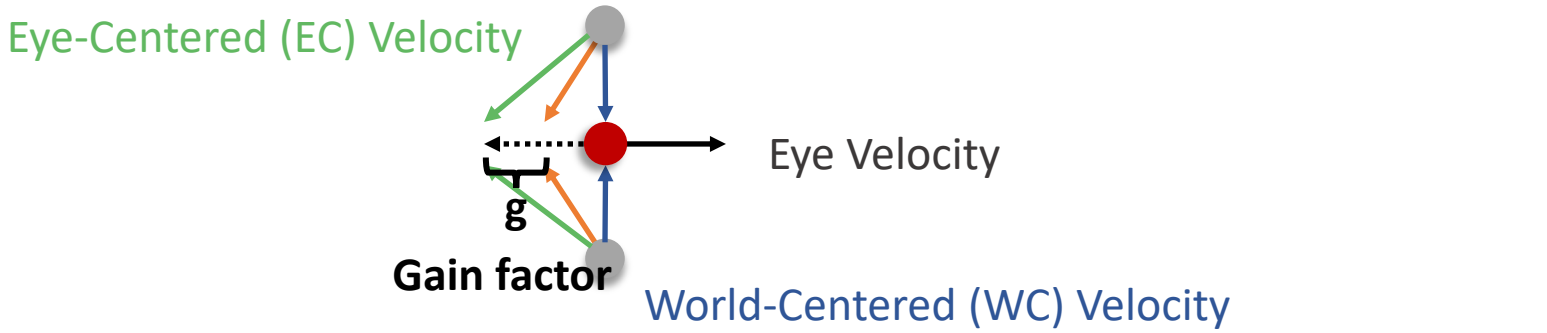
→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]



When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]

Perception = WC Velocity – (1-**g**) × Eye Velocity

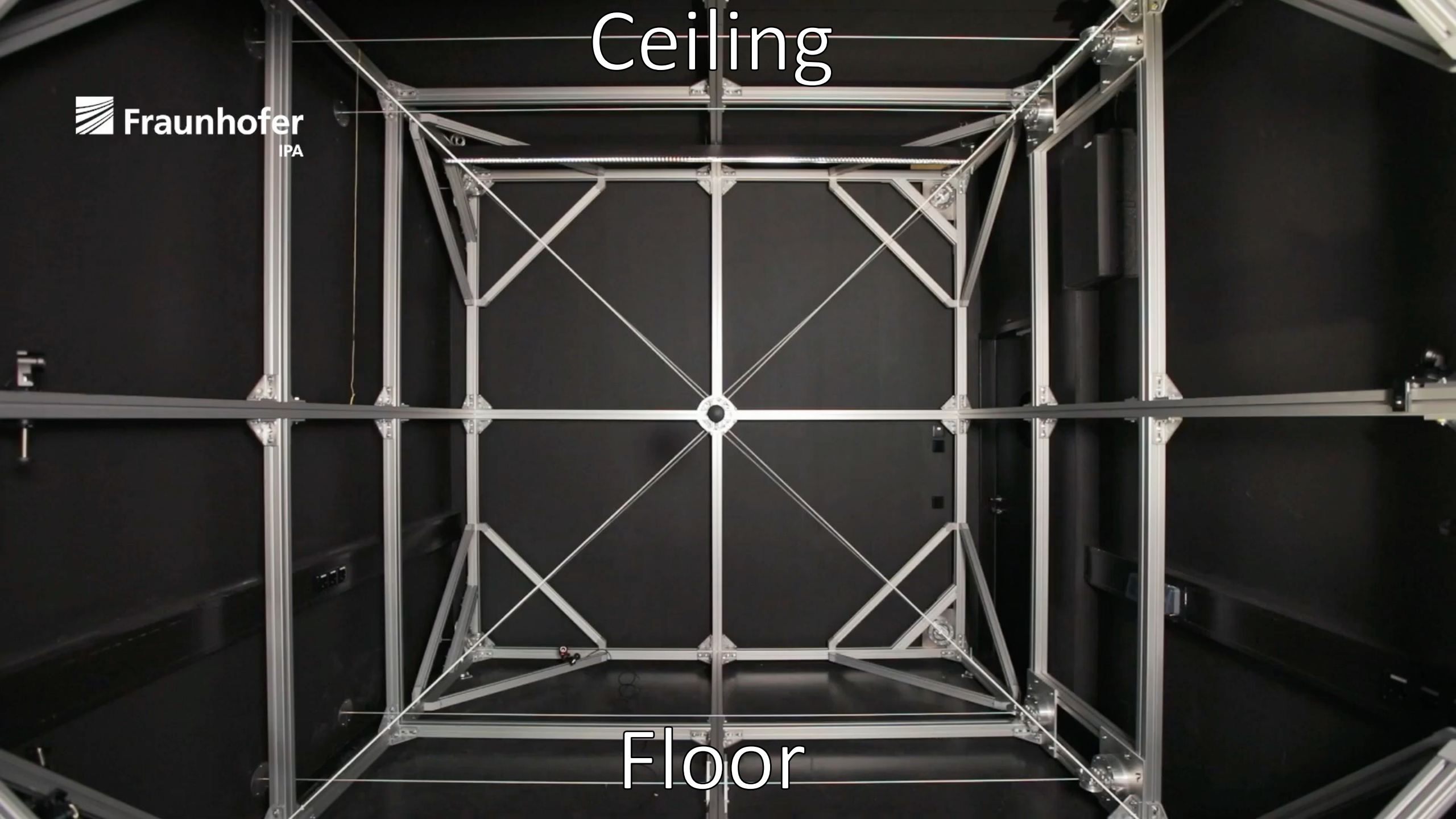


When we make a smooth eye movement to track a moving object, the **visual system** estimates the eye motion and then subtracts it from the observed retinal motion [Wertheim 1994]

→ allows for stable percept of visual image, but not always [Filehne 1922, Fleischl 1882, Aubert 1886]

Previous Work (in Audition)

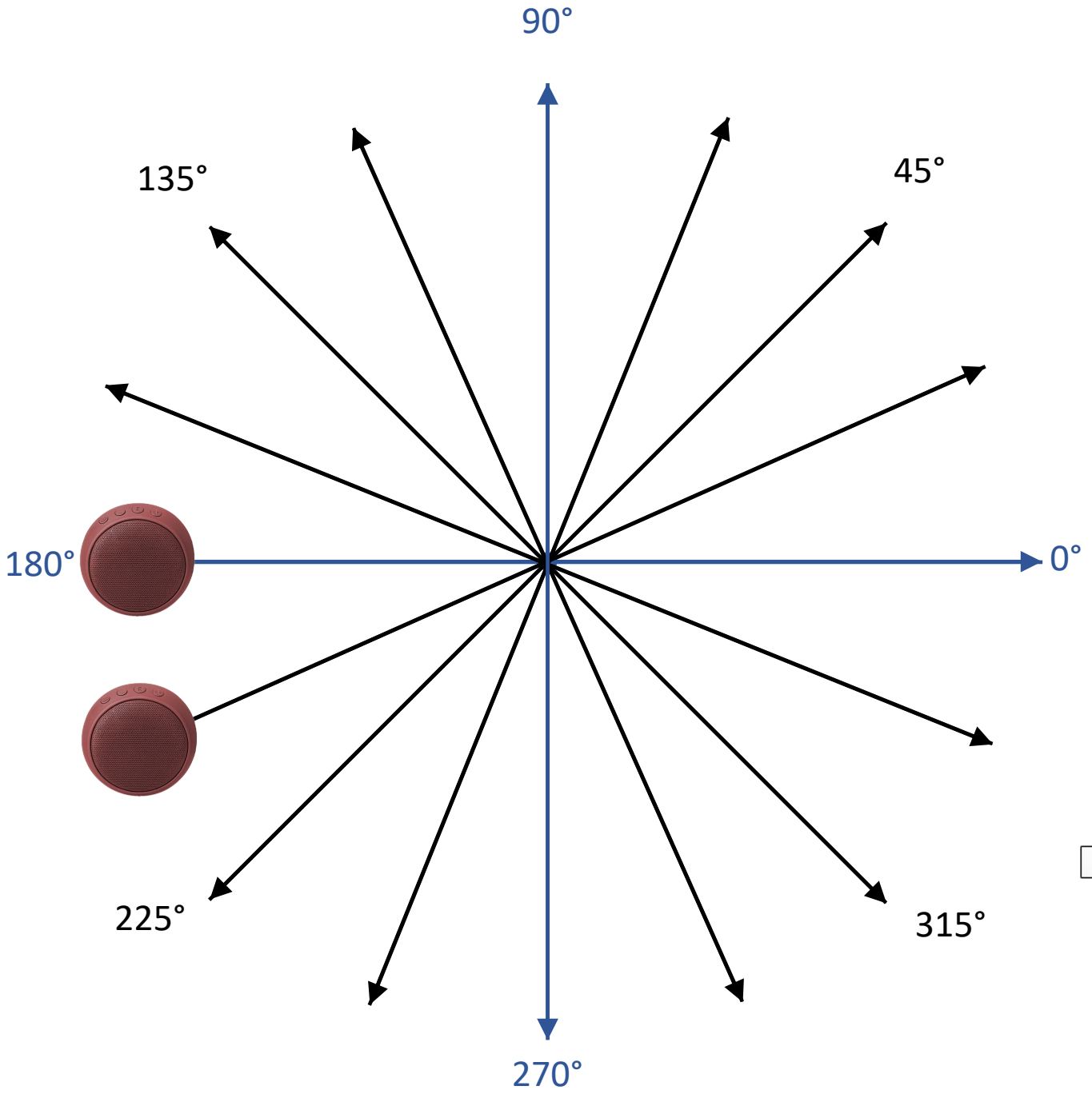
Participants underestimate head speed conistently and do not compensate fully for their head motion and speaker motion in **the horizontal plane.** [Freeman et al. 2017]


Ceiling
Fraunhofer
IPA
Floor

Experiment

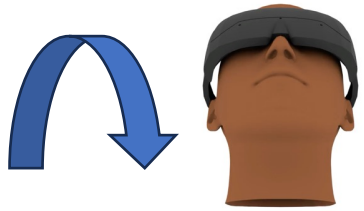
- 16 speaker movement directions
- 1.5s white noise stimulus
- 13 participants
  - (10 female, 26.15 ± 5.1 years)
- 5 Conditions (160 trials each)
  - In 2 Sessions (each 90min)

Task: Indicate direction of moving sound with a joystick

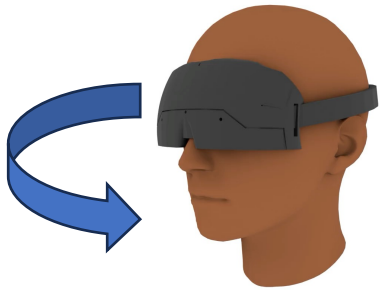


Conditions

Up to Down

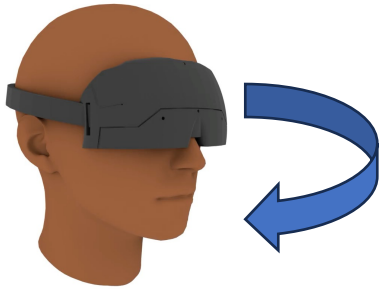


Right to Left

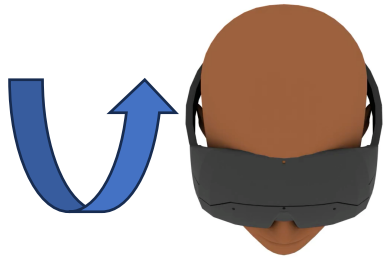


Stationary

Left to Right

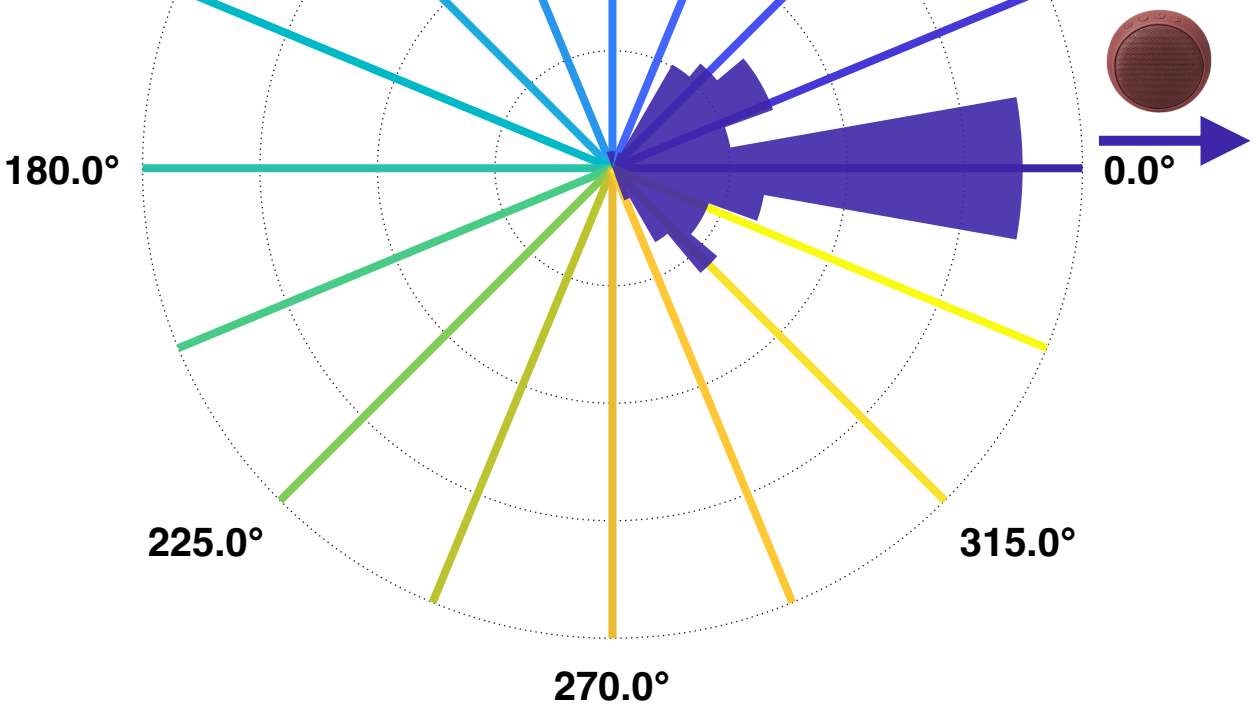


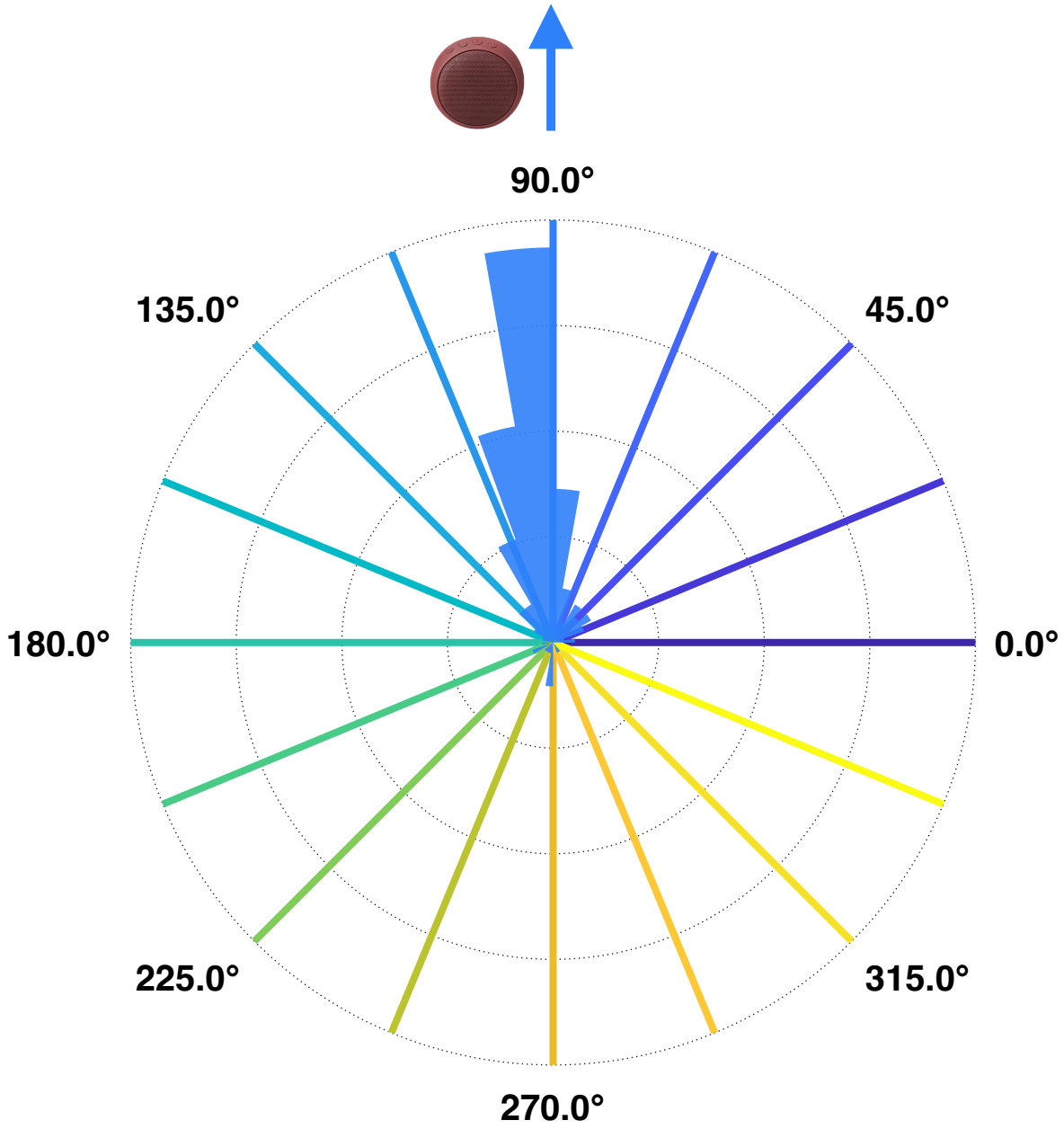
Down to Up



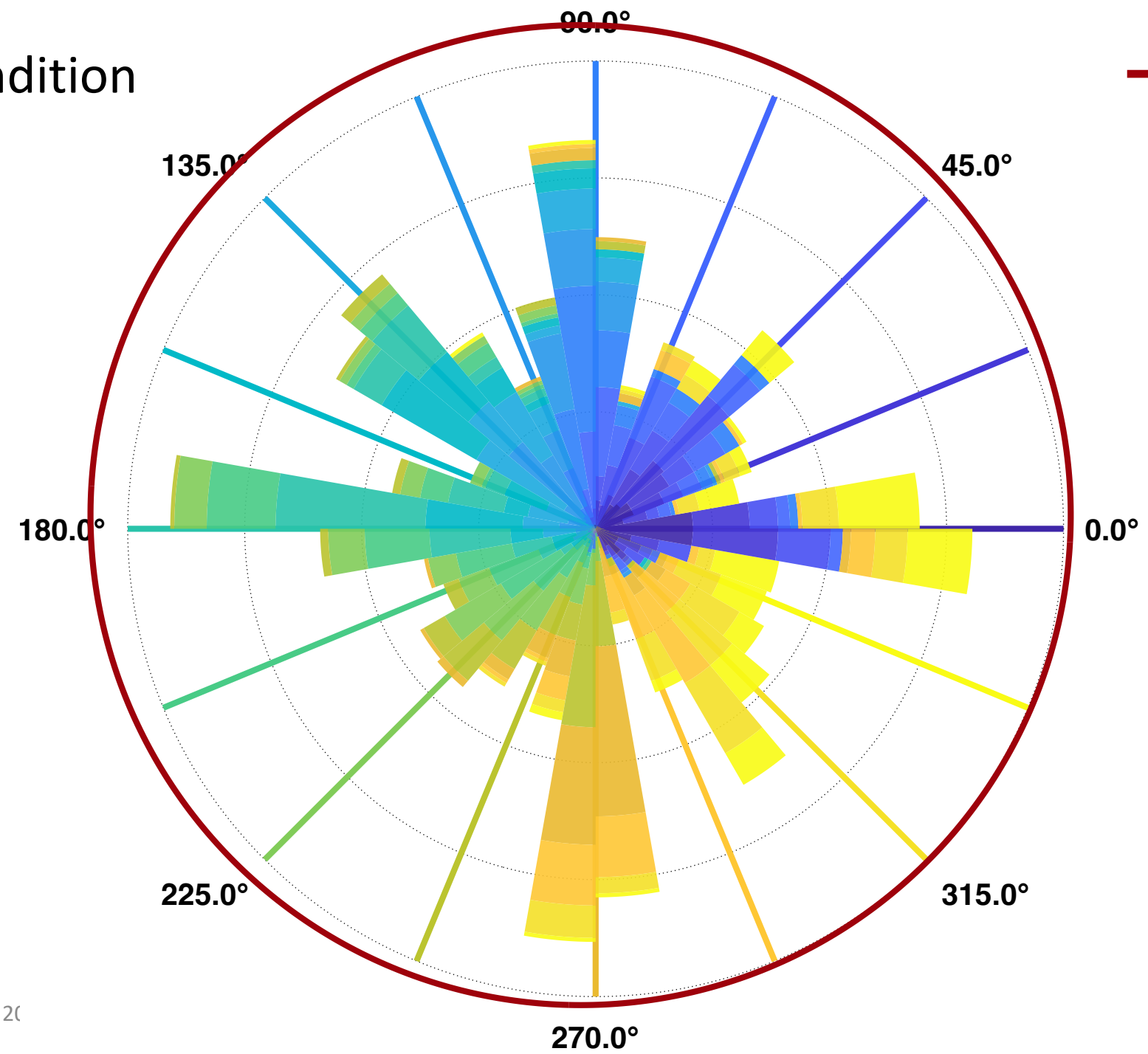

Down to Up Condition

Stationary Condition

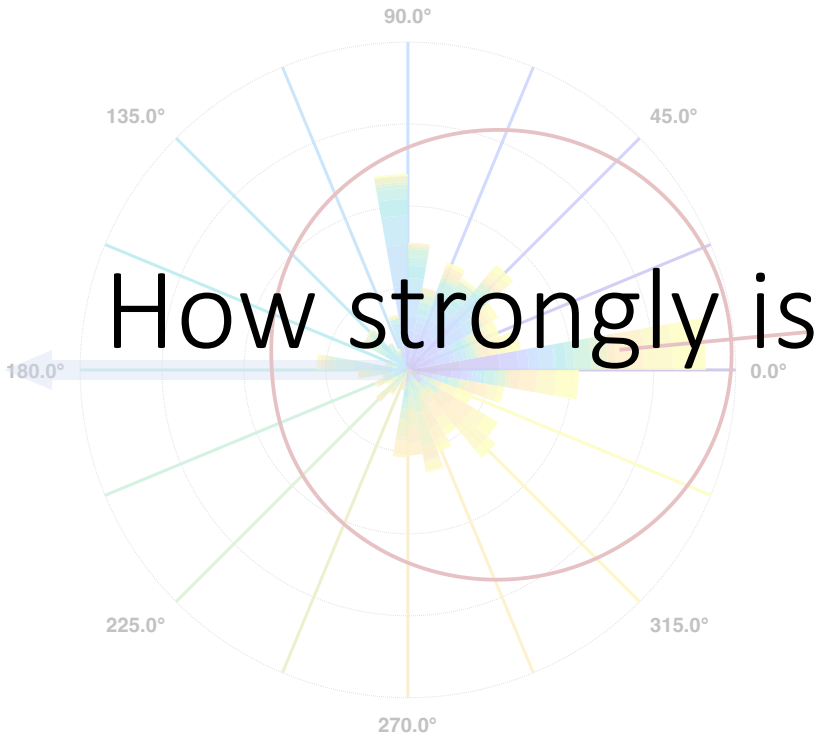




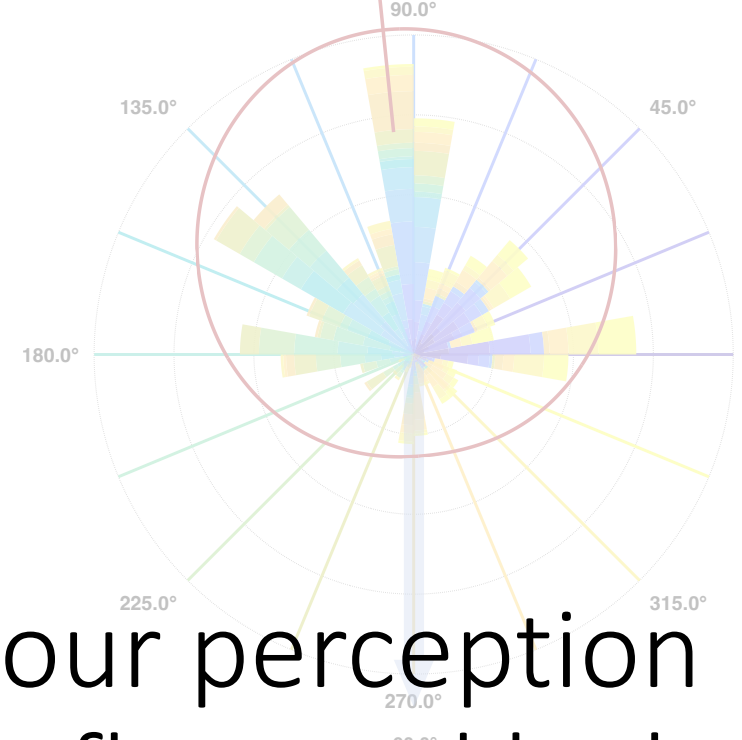
Stationary Condition



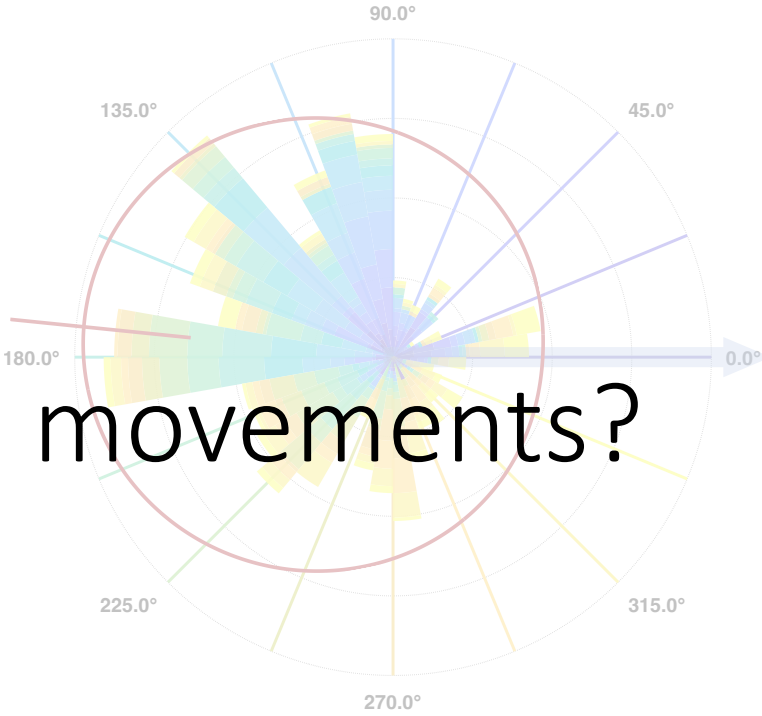
Von Mises Fit
μ = 7.5°
σ^2 = 1.46



Von Mises Fit
Peak: 92.9°
σ^2 = 1.64

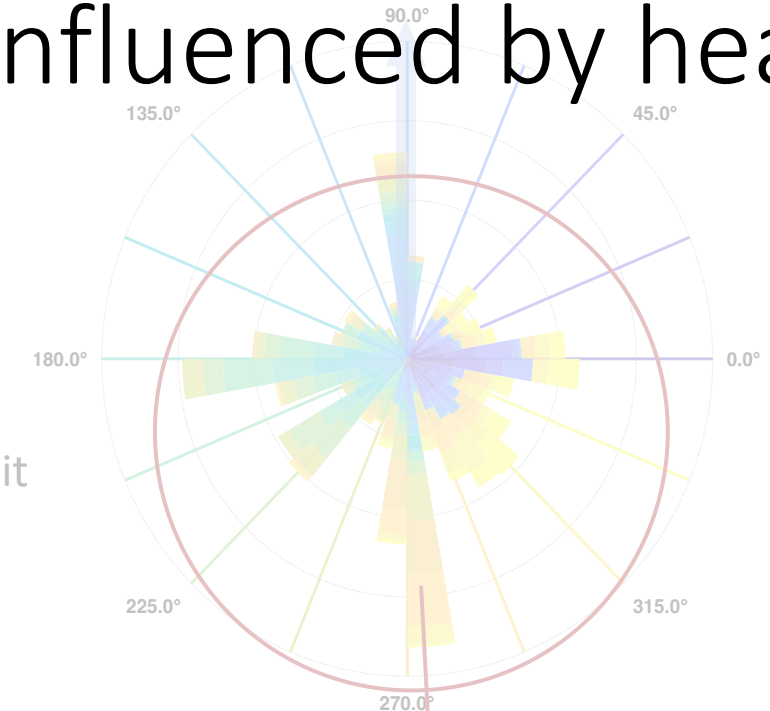


Von Mises Fit
μ = 176.9°
σ^2 = 1.72



How strongly is our perception influenced by head movements?

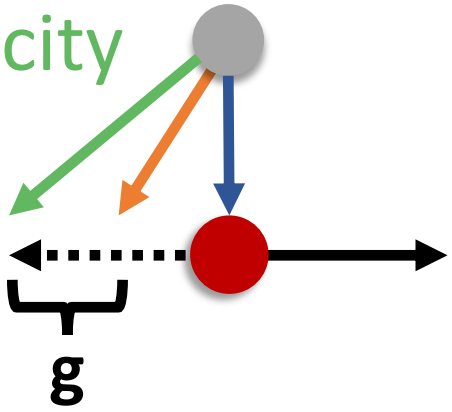
Von Mises Fit
μ = 272.2°
σ^2 = 2.14



Gain Factor

Perception = WC Velocity – (1-**g**) × Head Velocity

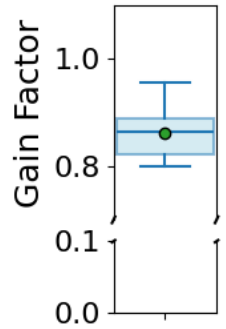
Head-Centered (HC) Velocity



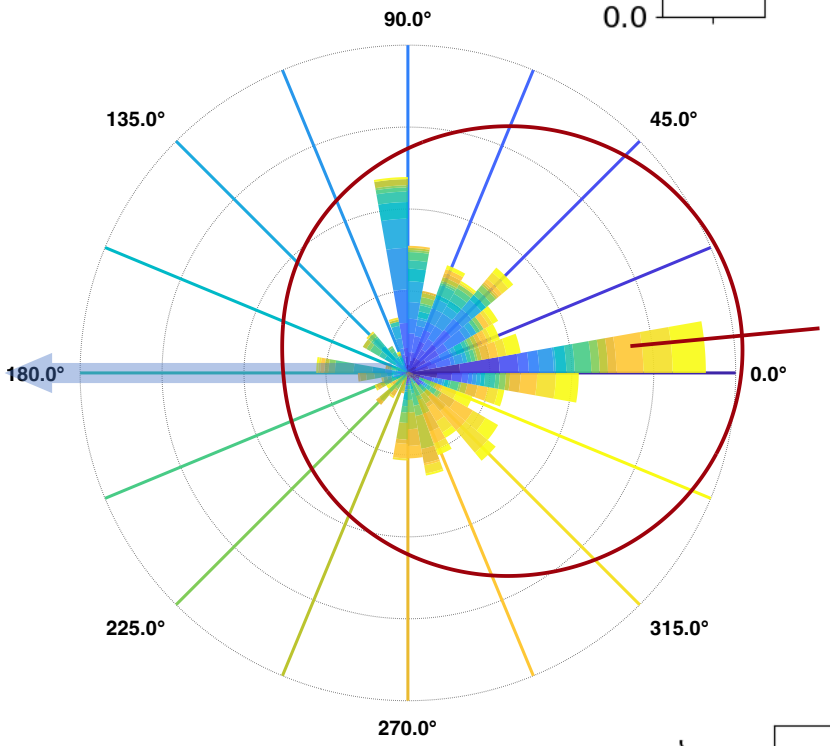
Head Velocity

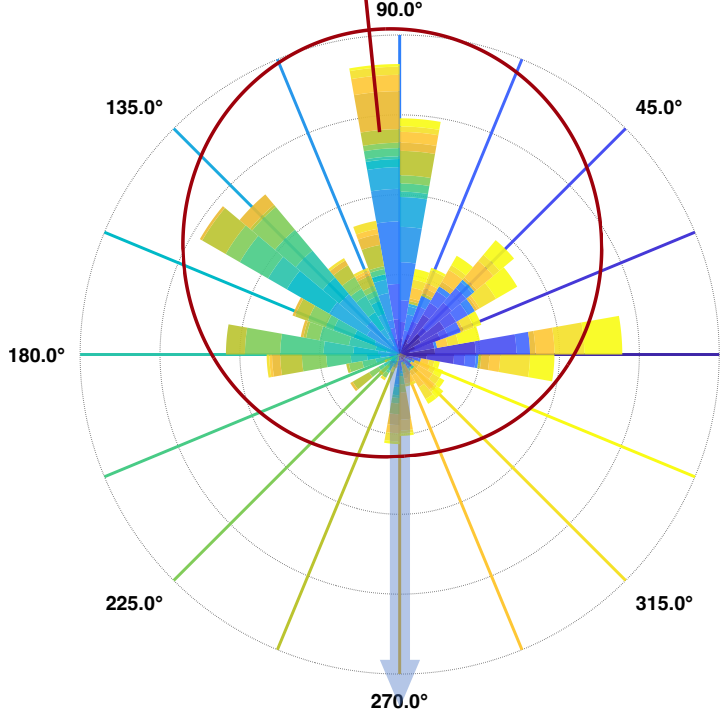
World-Centered (WC) Velocity

Gain Factor

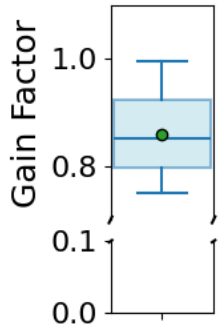


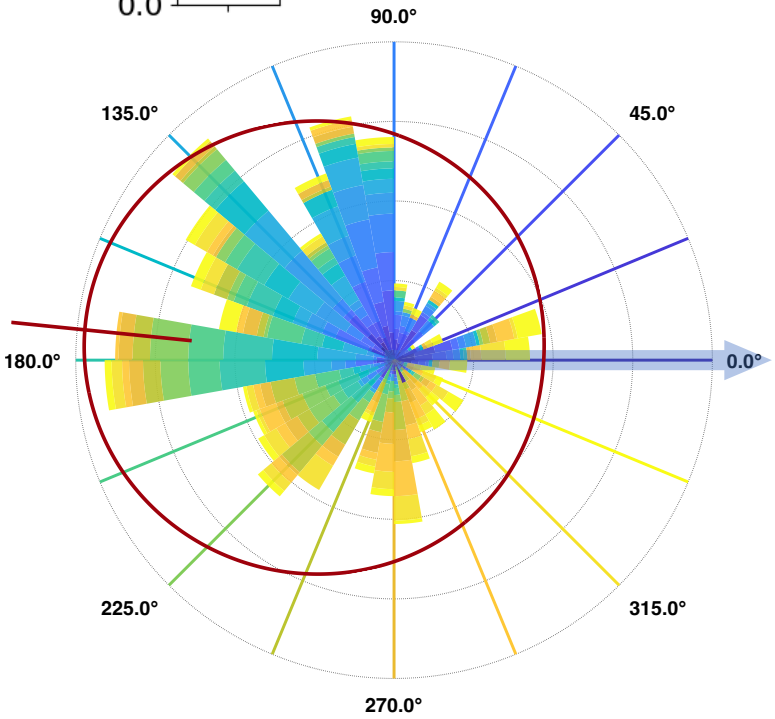
g: 0.86

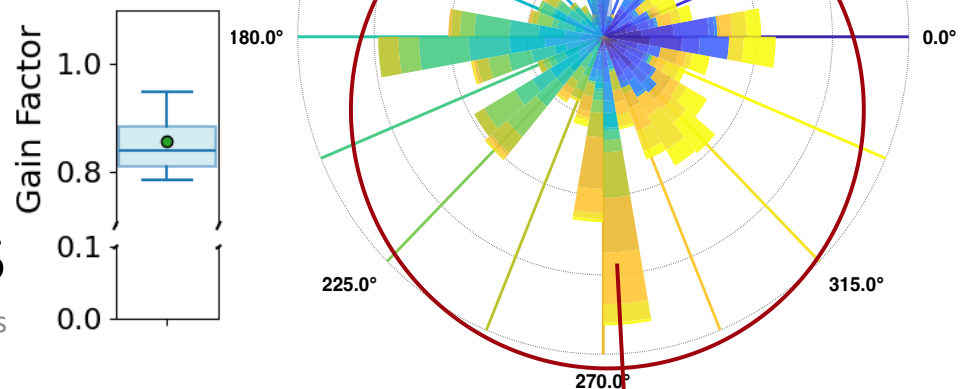




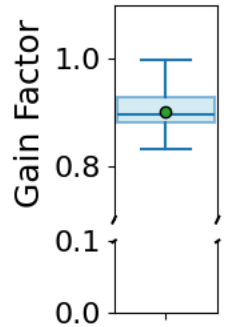
g: 0.86



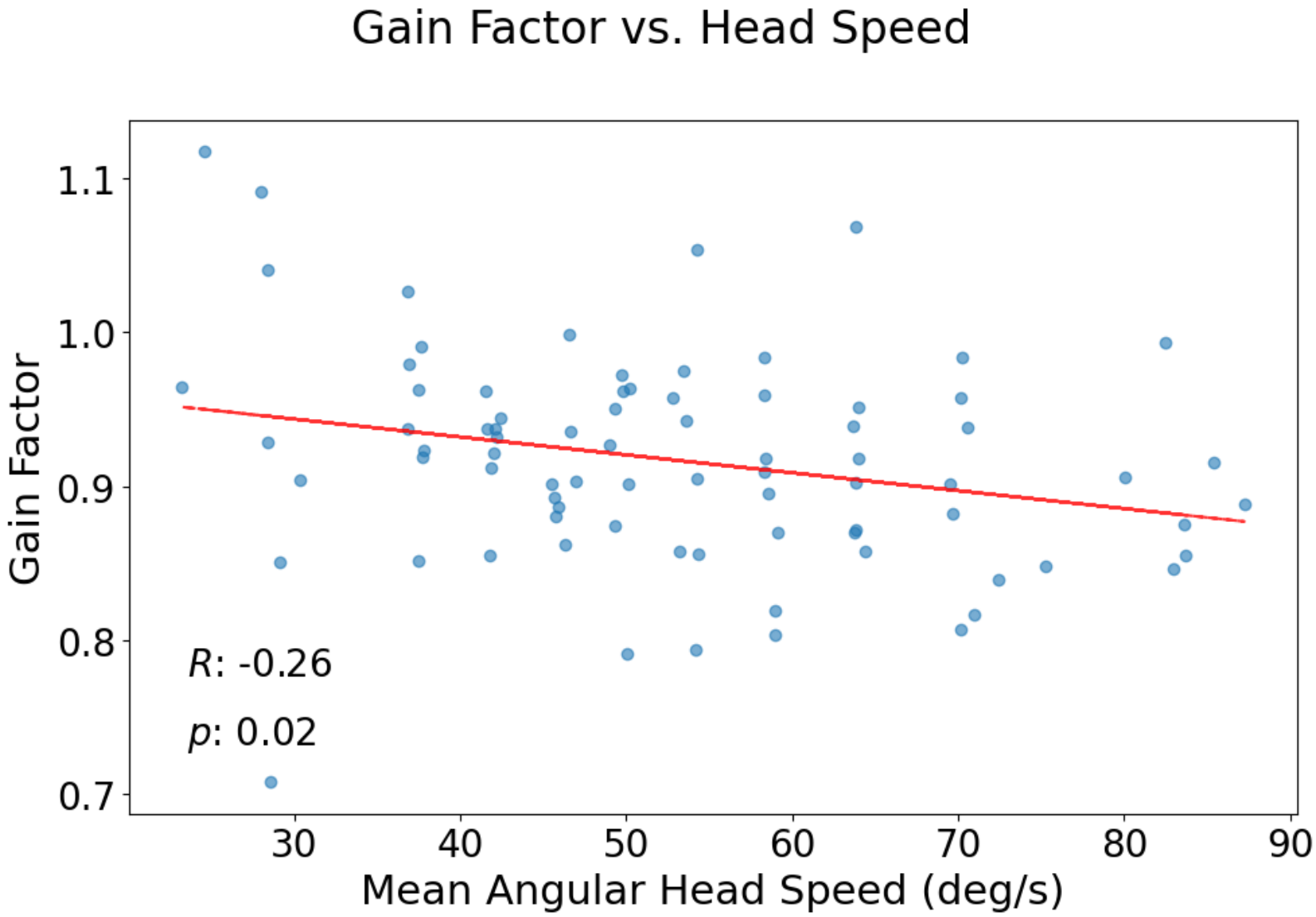




g: 0.85



g: 0.90


Gain Factor vs. Head Speed
Gain Factor
1.1
1.0
0.9
0.8
0.7
30
40
50
60
70
80
90
Mean Angular Head Speed (deg/s)
R: -0.26
p: 0.02

Summary

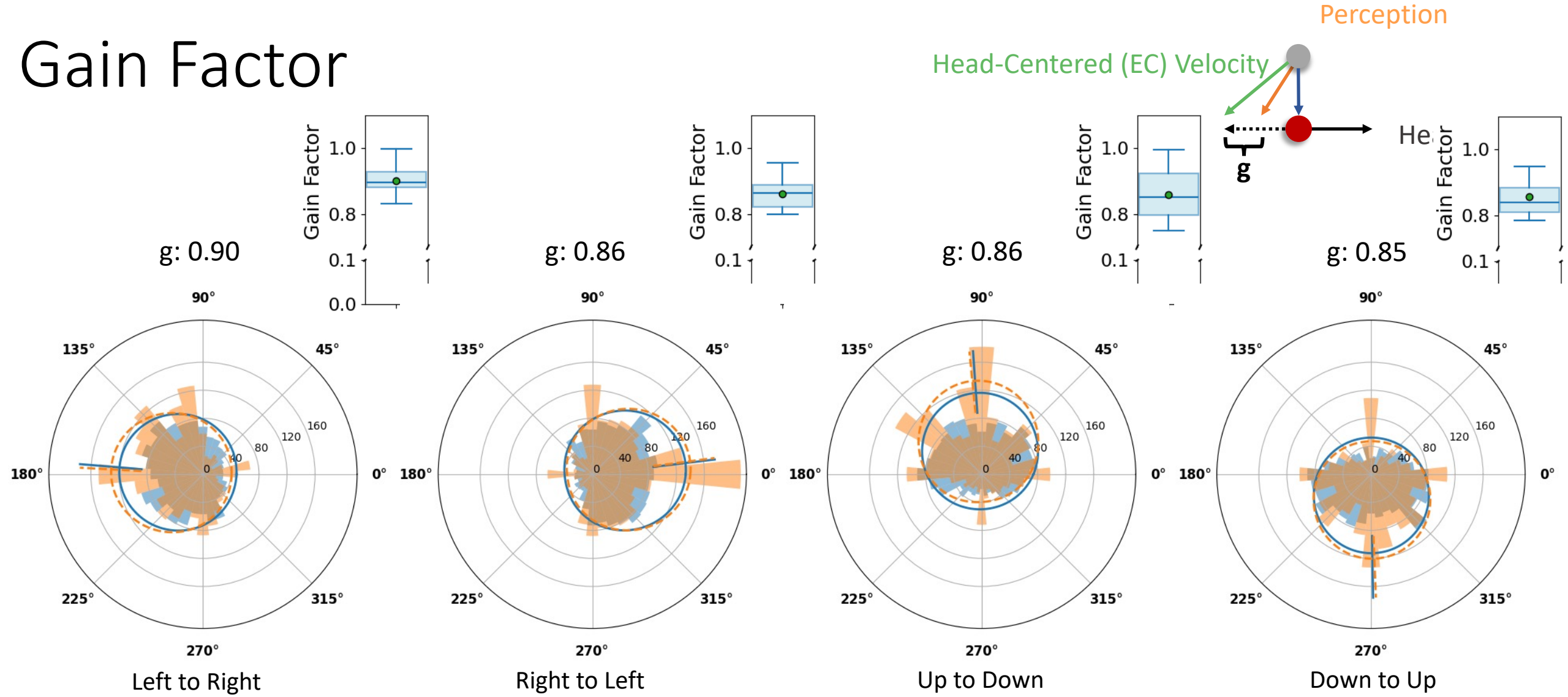
- Perception of auditory motion is **biased** by head motion in any direction
- This bias (gain factor) is constant over head movement **directions**
- Gain factor correlates with head **speed**

Thank you!

Marc Ernst

Laurence Harris

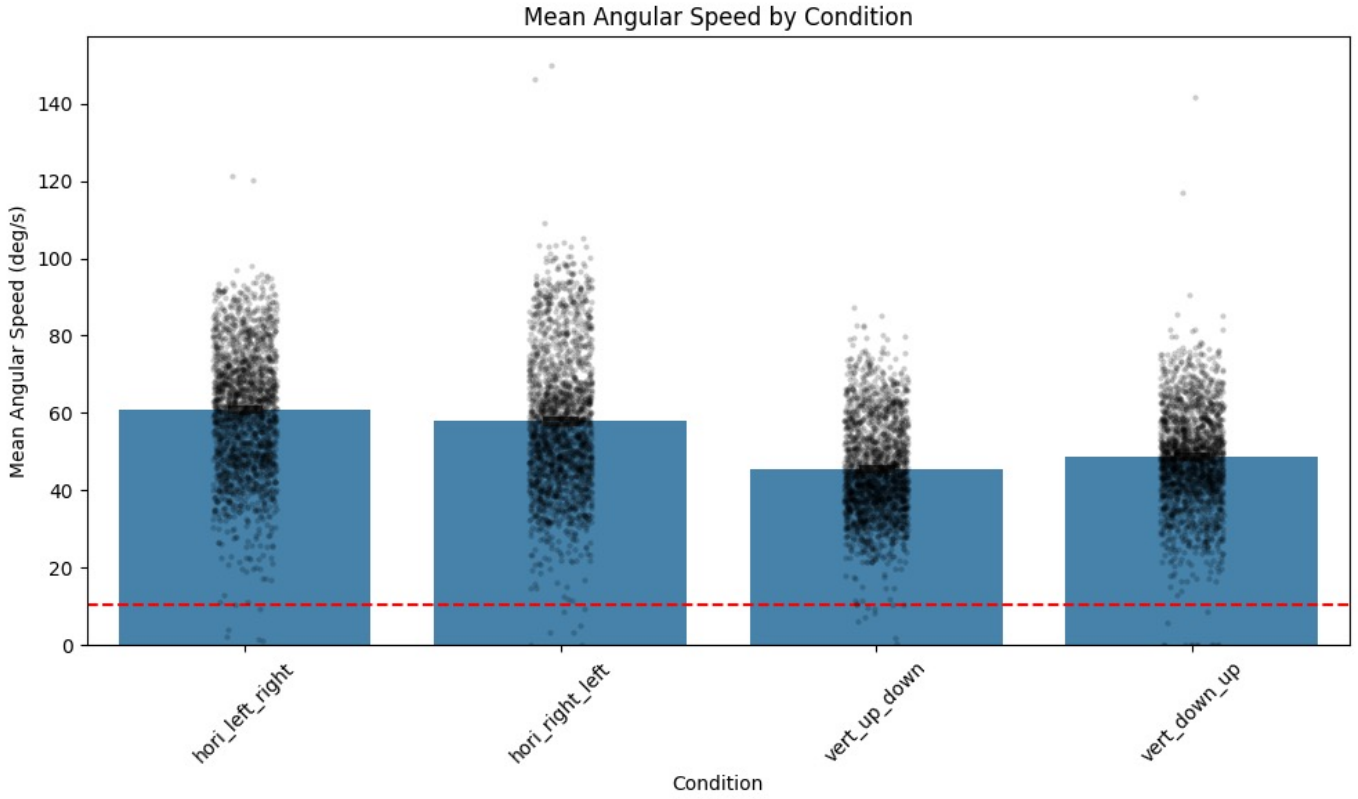
Gain Factor


Perception
Head-Centered (EC) Velocity
g
g: 0.90
g: 0.86
g: 0.86
g: 0.85
Gain Factor
1.0
0.8
0.1
0.0
90°
135°
45°
180°
0°
225°
315°
270°
0
40
80
120
160
Left to Right
Right to Left
Up to Down
Down to Up

Future Work

- Participants **overestimate** their head speed

  → Fixation of head motion speed
- Binaural recordings with dummy head to measure available localization cues



Reference Frame Encoding of Stimulus