Multisensory Integration in Heading and Scene-Relative Object Motion Perception

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STARDUST – Study to Assess and Reduce Dizziness Using Sensory Theory

UKRI Medical Research Council

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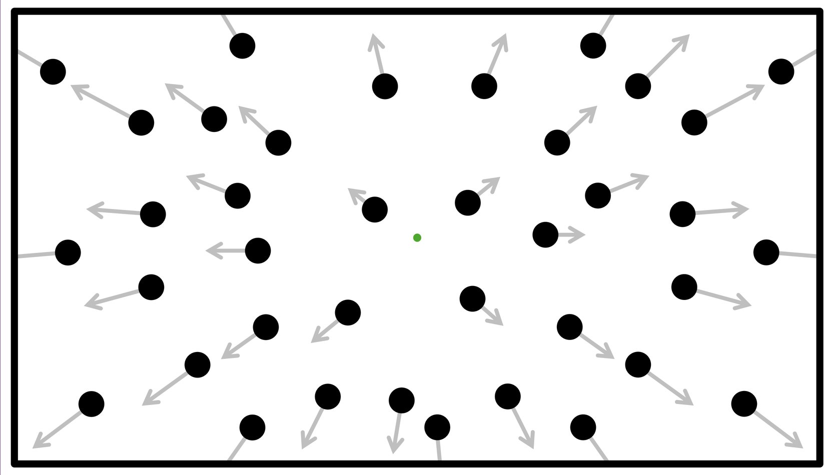
Background

Heading Estimation

Estimate direction of self-movement

Multisensory process (visual, vestibular etc.), optimal integration should follow Maximum Likelihood Estimation (Ernst & Banks, 2002)

There is previous evidence for optimal integration (e.g., Gu et al., 2007; Yakubovich et al., 2020)



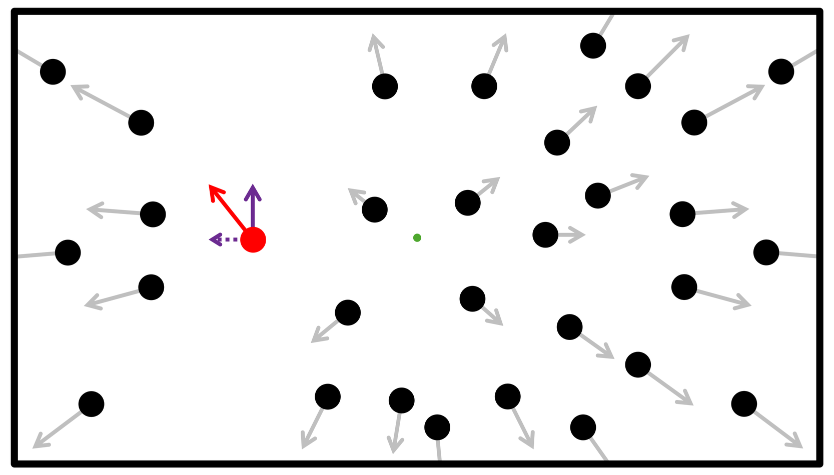
Scene-Relative Object Motion (S-ROM)

Estimate motion of an object within a visual scene

Need to distinguish between retinal motion due to observer movement and S-ROM

Another multisensory process, so should involve optimal integration

Improvement to S-ROM when visual and vestibular info together implies integration (MacNeilage et al., 2012)



Similar Processes?

One way to recover S-ROM would be to estimate heading first, and use that estimate of motion due to observer movement to recover S-ROM

If we solve SROM by first estimating heading, the processes would be linked, and integration should be similar within participants

Design

Participants

23 participants (13F, 10M) aged 20-72

Normal vision and no balance disorders

Stimuli

Visual: static observer, optic flow of field in Head-Mounted Display

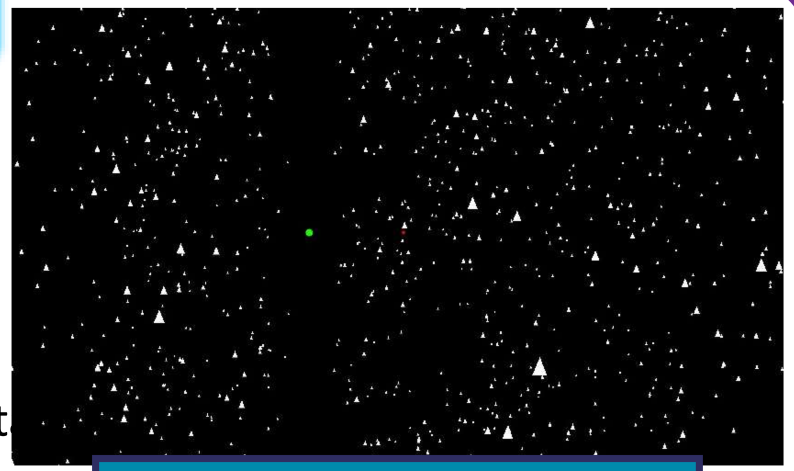
Vestibular: moving observer on motion platform (no optic flow)

Multisensory: moving observer + optic flow

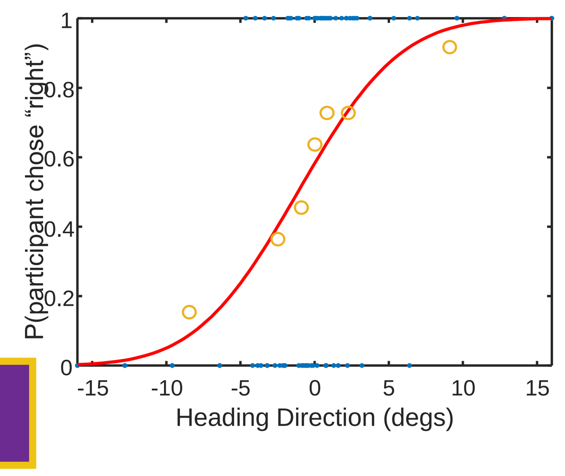
Linear forward movement with Gaussian speed profile (1s, max speed 0.31m/s)

Max heading direction +/-16degs

Max SROM +/-16degs/s, vertical



Example Stimulus from SROM task



Method

Visual, Vestibular, and Multisensory conditions

In the heading task, two multisensory conditions had $\Delta \pm 6$ degs of bias added to the unisensory information

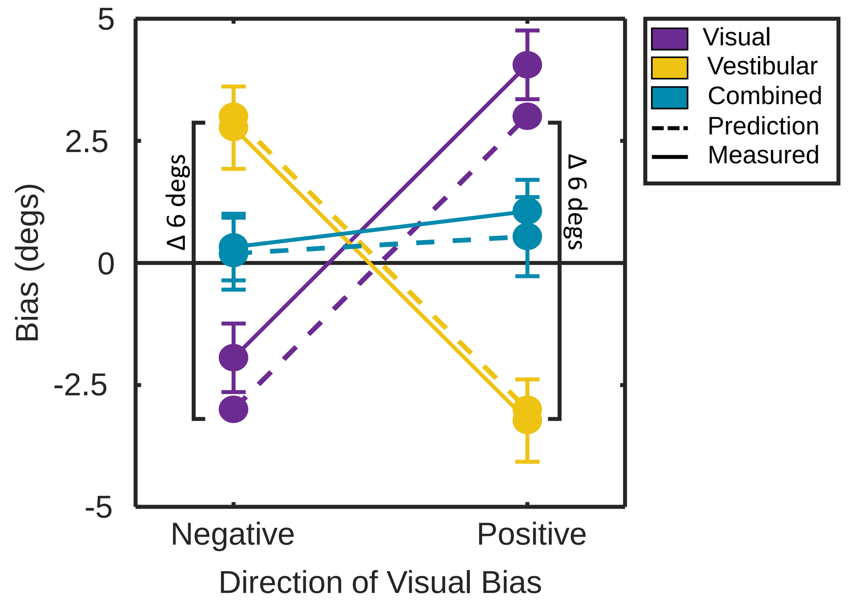
80 trials (4x interleaved Kesten staircases) in each

Psychometric functions (PMFs) fitted (Cumulative Normal). Bias and Threshold statistics recovered

Optimal biases and precisions calculated from unisensory conditions and compared to measured multisensory conditions

Results

Heading Task



Bias data for the two multisensory conditions and the underlying unisensory information that they contain (unisensory data taken from unbiased unisensory conditions with Δ added as shown)

For bias analysis in integration, we need multisensory conditions that have differently biased unisensory information, to recover which biased signal is higher weighted

Biases are not significantly different from predictions in any condition

Visual: $t(22) = 1.50, p = 0.59$

Vestibular: $t(22) = -0.27, p = 3.15$

Multi (vis-): $t(22) = -0.26, p = 3.19$

Multi (vis+): $t(22) = 0.99, p = 1.33$

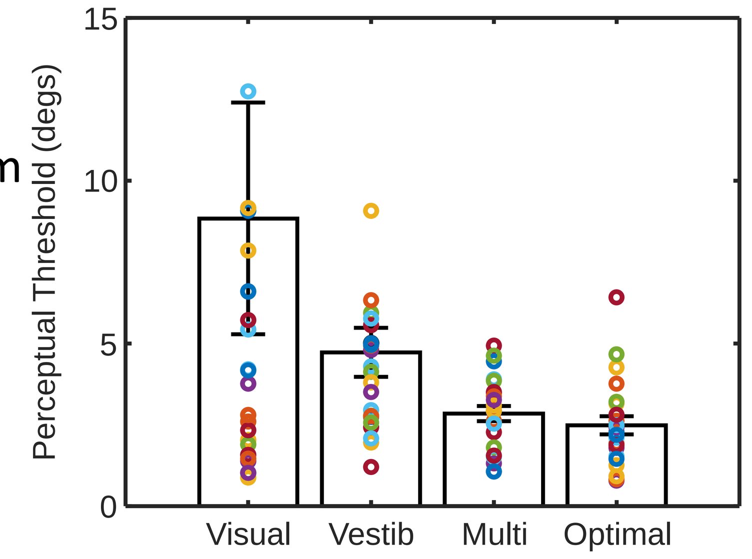
Perceptual thresholds in the multisensory condition are not significantly different from the optimal prediction

Optimal: $t(22) = 2.2, p = 0.12$

But are also not significantly different from the unisensory conditions (due to high variability in unisensory)

Visual: $t(22) = 1.64, p = 0.35$

Vestibular: $t(22) = 2.01, p = 0.17$



Some individual data is off the scales

SROM Task

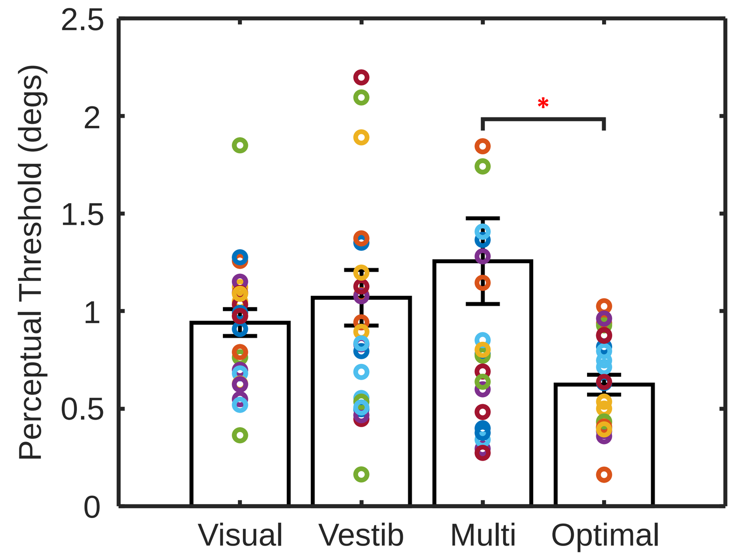
Thresholds in the multisensory condition are significantly different from the optimal prediction

Optimal: $t(22) = 3.02, p = 0.02$*

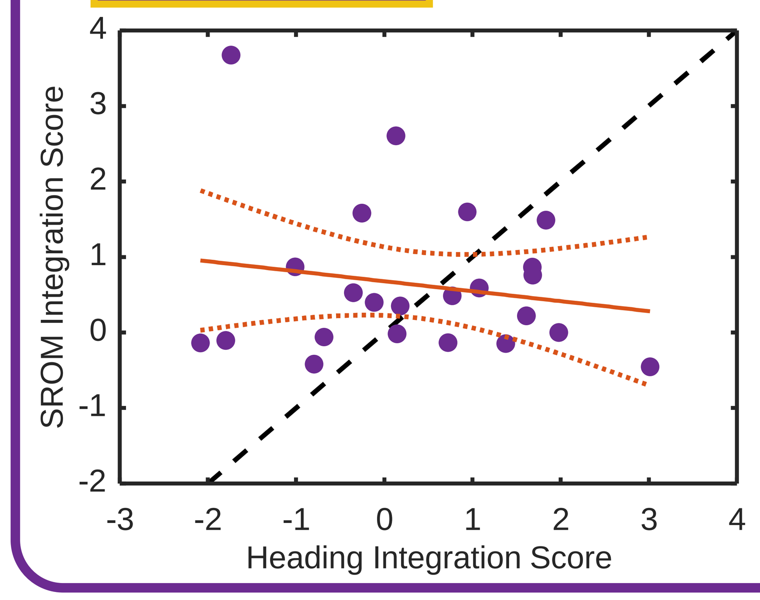
And not significantly different from the unisensory conditions

Visual: $t(22) = -1.47, p = 0.47$

Vestibular: $t(22) = -0.86, p = 1.2$



Correlation



Difference between prediction and measurement used as an integration score for individual participants on each task

Non-significant, negative correlation between the Integration scores in the SROM and Heading tasks

Correlation: $R(21) = -0.18, p = 0.42$

All T-tests are Bonferroni corrected

STARDUST

We are investigating the motion perception of people with Persistent Postural Perceptual Dizziness (PPPD) to better understand the mechanisms of PPPD and reduce symptoms through tailored VR therapy

The mechanisms of PPPD are not well understood. They may even vary across patients, with different symptom presentations hinting at subtypes of PPPD

If you know of anyone with PPPD in the UK who may be interested in participating, please contact Dr Joshua Haynes or scan the QR code to the right to view this poster, the poster presented yesterday by Dr Paul Warren, and our participant advert.

Email: joshua.haynes@manchester.ac.uk

Summary and Conclusions

Some evidence for MLE integration in heading task (not significantly different from MLE prediction)

No evidence for integration in S-ROM task (significantly different from MLE prediction)

No evidence for correlation between integration in the two tasks which suggests that tasks are based on different processing

Results consistent with Warren et al (2012) who suggest that visual S-ROM recovery (Flow Parsing) does not depend on previously obtained heading estimate