

# Mathematics and Neuroscience

John S Butler

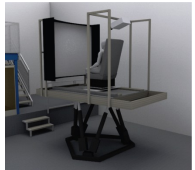
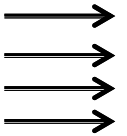
School of Mathematical Sciences

Dublin Institute of Technology

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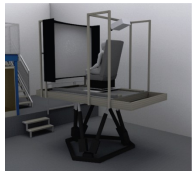
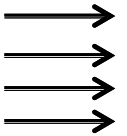
# My background

- Numerical Analysis (Trinity College Dublin, PhD work)
  - Robust Numerical methods of Prandtl Boundary Layer Problems
- Self-motion Perception (Max Planck Institute for Biological Cybernetics)
  - Walking
  - Driving
- Unisensory and Multisensory processing
  - Developmental Disorders (Albert Einstein College of Medicine)
    - Autism Spectrum Disorder, Niemann Pick Type C
  - Movement Disorders (Trinity Centre for Bioengineering)
    - Parkinson's Disease
    - Dystonia



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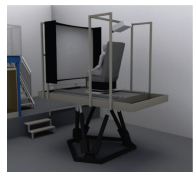
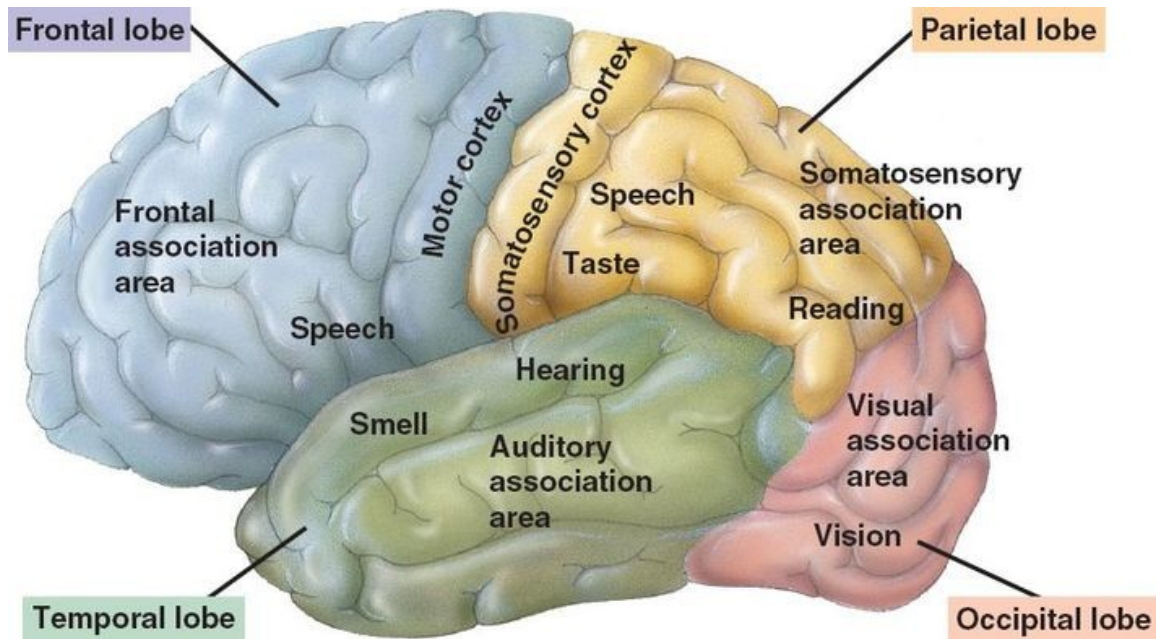
# Mathematics and Neuroscience

- Analyse and Model
  - Chemical reactions (micro)
  - Neuronal Activity (micro)
  - Cortical Activity (mezzo)
  - Behaviour (macro)
- Goal to understand
  - Development
  - Combination of sensory signals
  - Learning
  - Disease

# Mathematics and Neuroscience

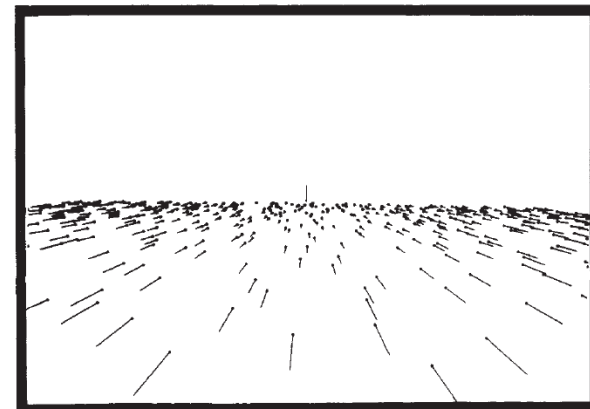
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# Combination of Senses



# Self-motion

- Self-motion
  - Walking
  - Driving
- Cues for Self-motion
  - Visual
  - Vestibular
  - Touch
  - Audio
  - Etc.



# Optic flow (visual)

## Behavioural

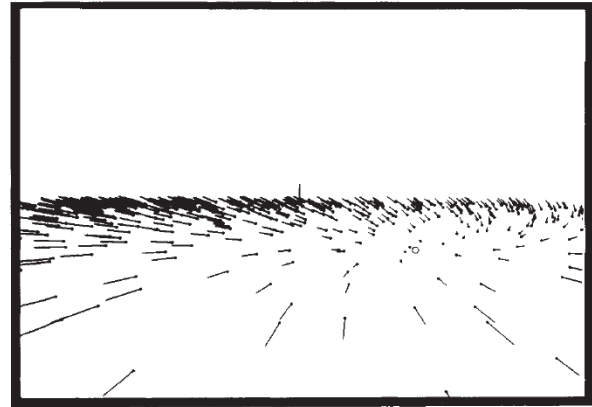
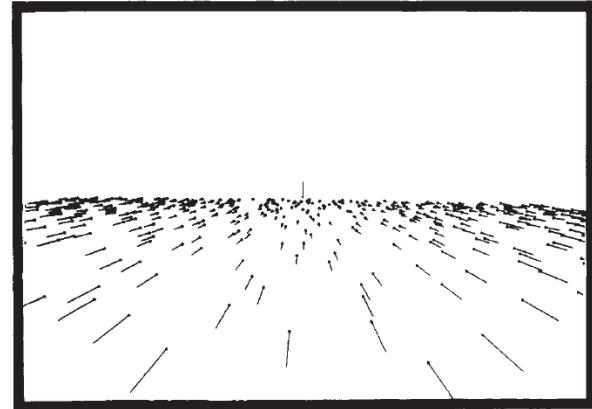
- Relative distance perception
- Heading
- Speed

## Function

- Balance
- Object motion
- Self-motion

## Disorders

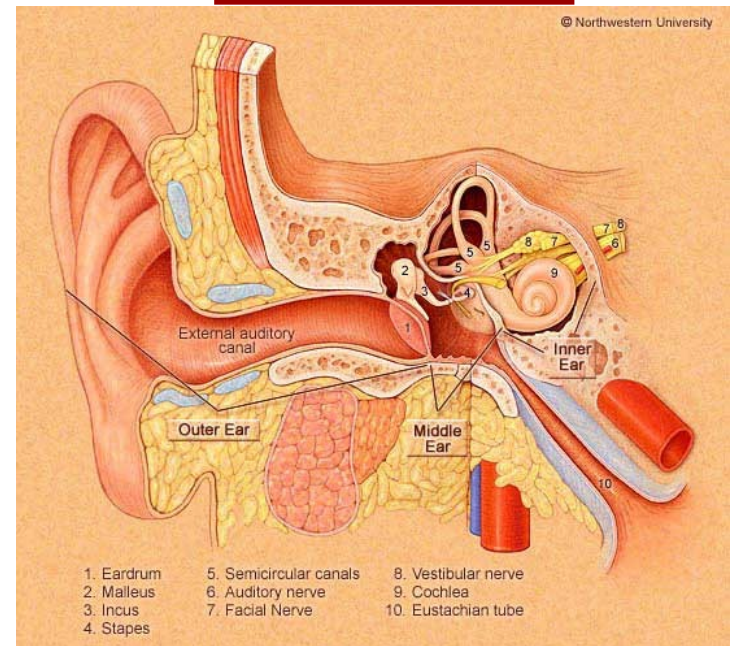
- Monopic vision





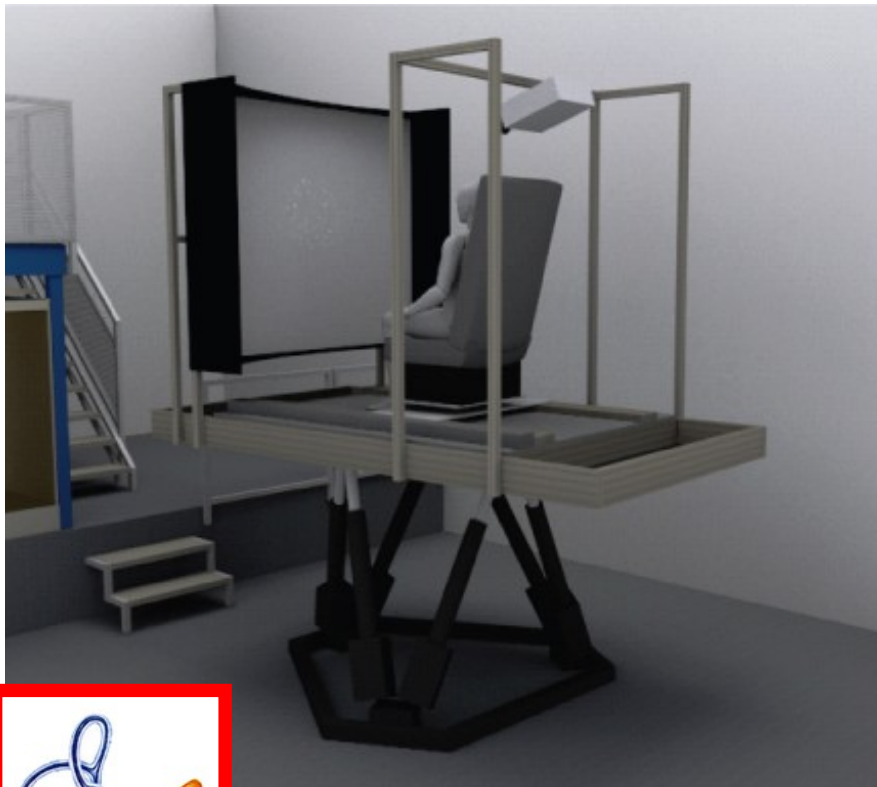
# Inertial (vestibular)

- Otoliths
  - Linear acceleration
- Semi-circular Canals
  - Rotational velocity
- Function
  - Eye movements
  - Heading
- Disorders
  - Vertigo
  - Motion sickness
  - Falls

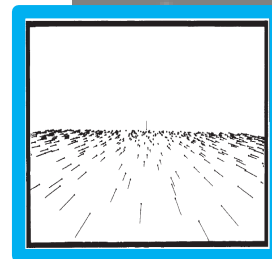


# Virtual reality setup and stimuli

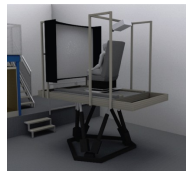
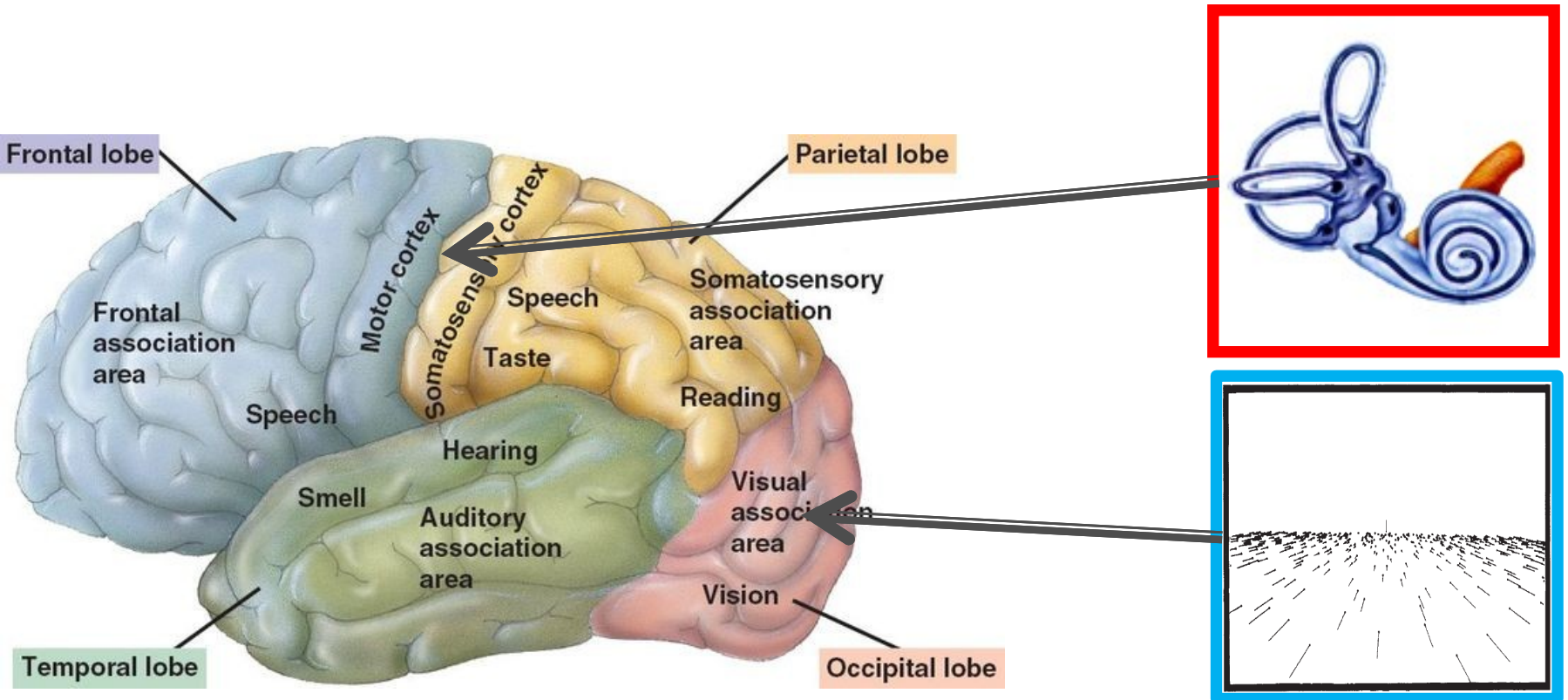
Motion Platform



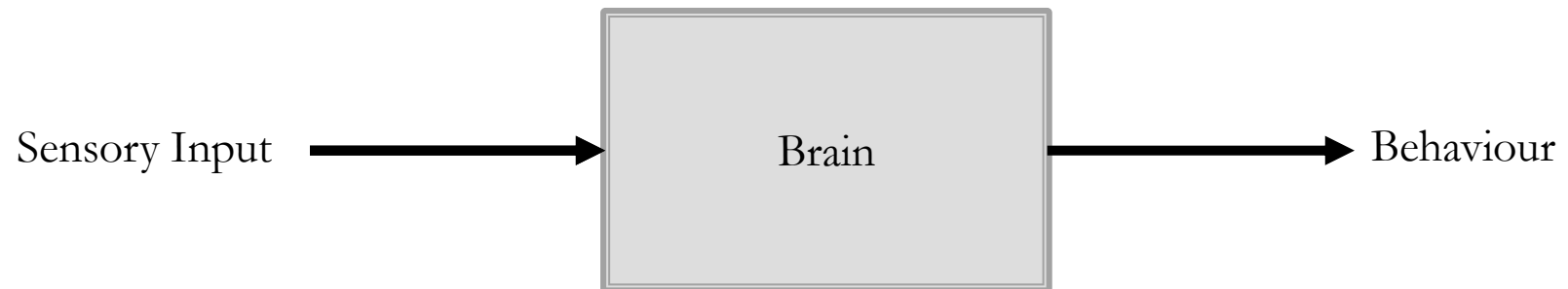
Visual



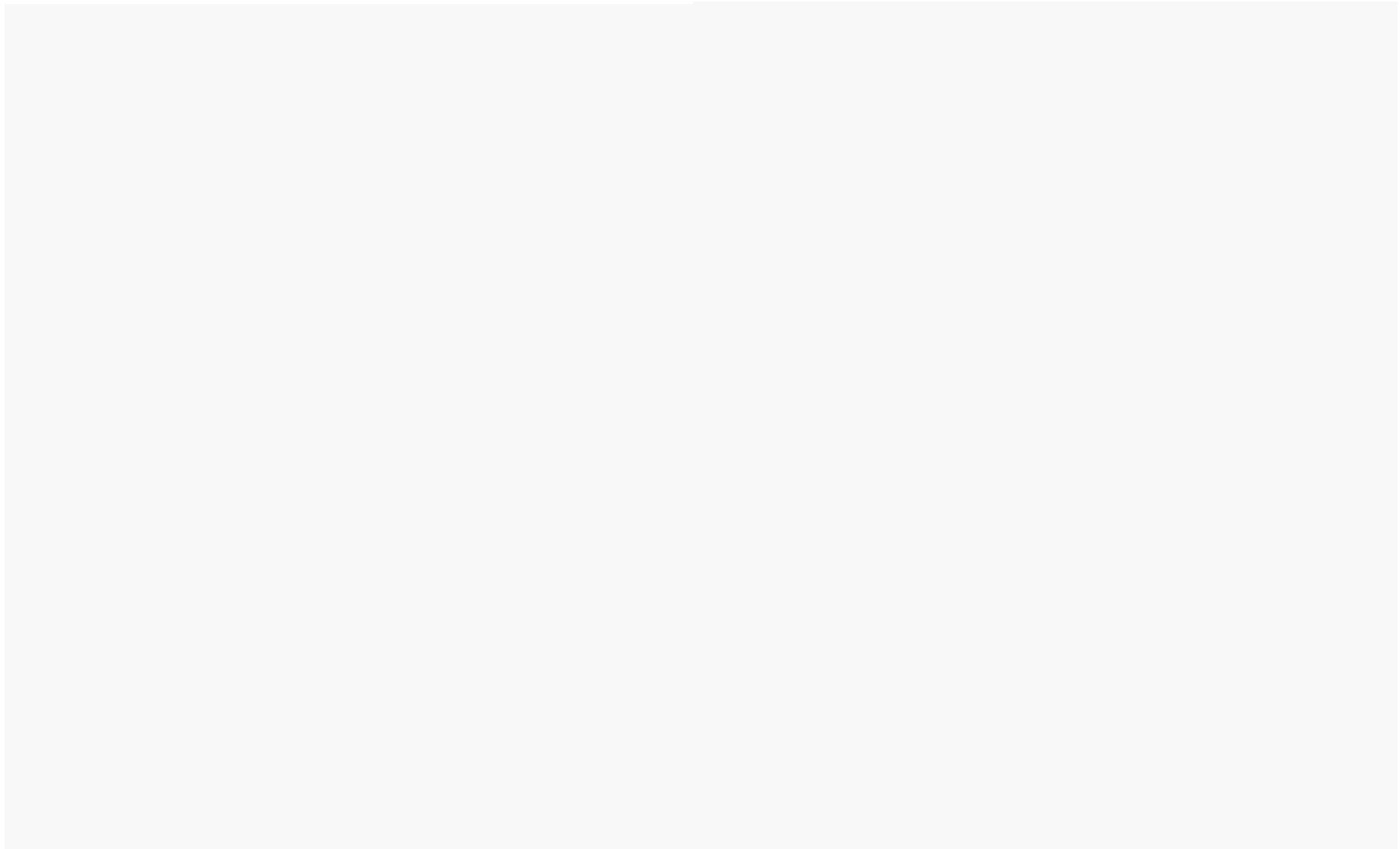
# Combination of Senses



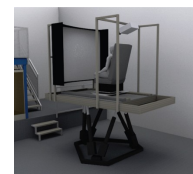
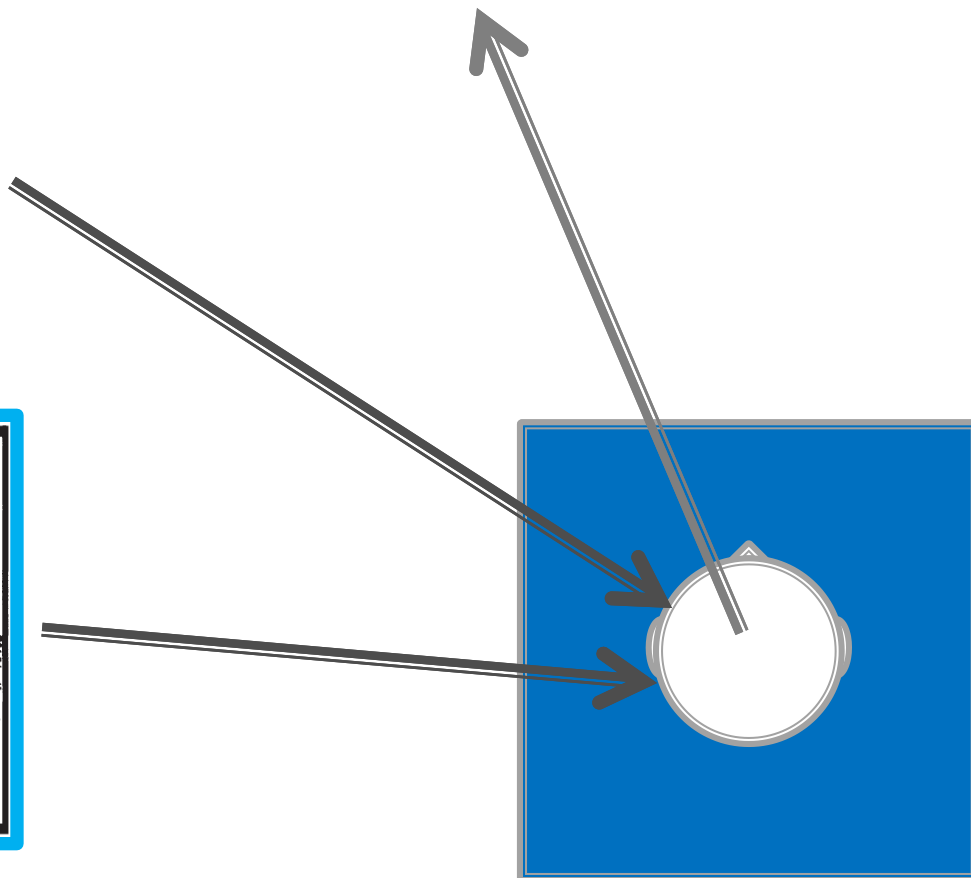
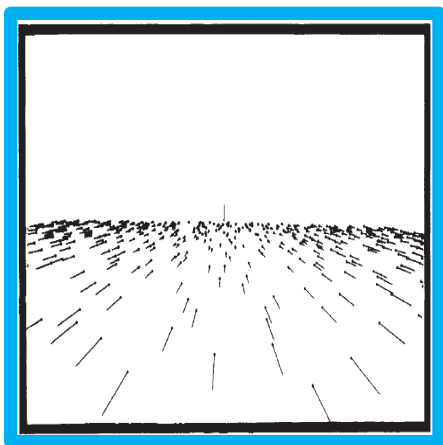
# How a Mathematician starts with the Brain



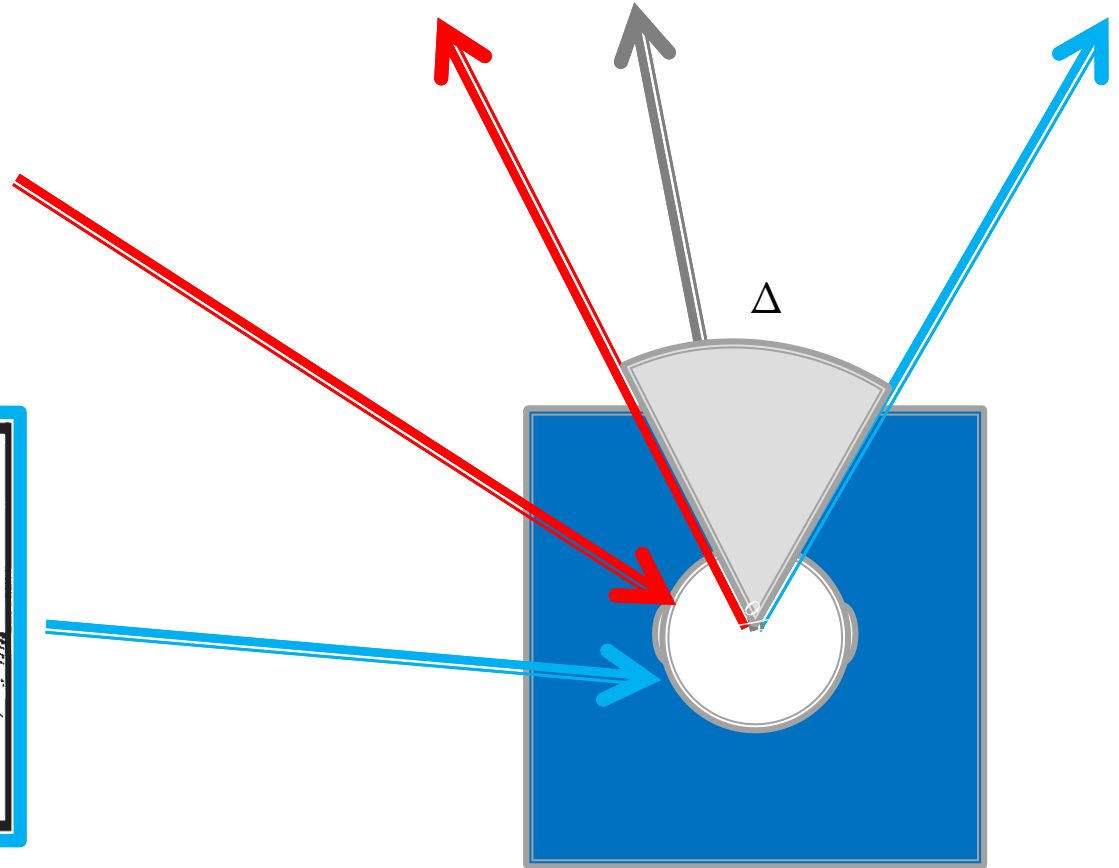
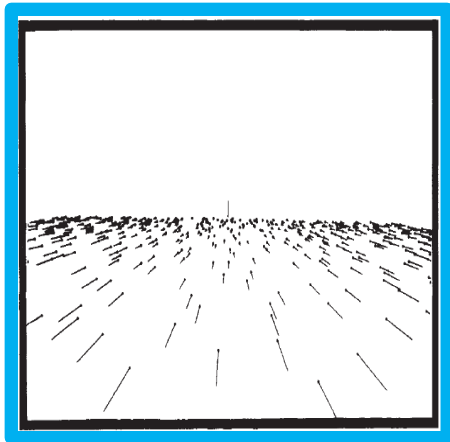
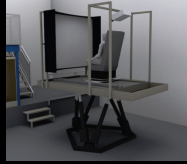
# Possible Models



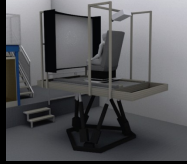
# Visual-Vestibular Integration for Heading



# Visual-Vestibular Integration for Heading (conflict)



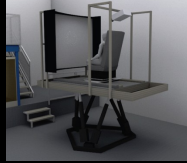
# Why introduce a conflict?



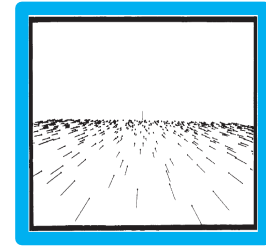
- By introducing a conflict we can see if there is a breakdown of the combination of sense
- We can calculate the weights given to each cue
- To model the observed combined response from the visual and vestibular response



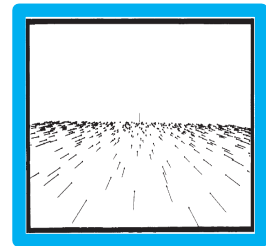
# The logic of conflicts



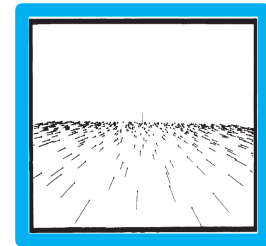
Equally weighted



Vestibular weighted more



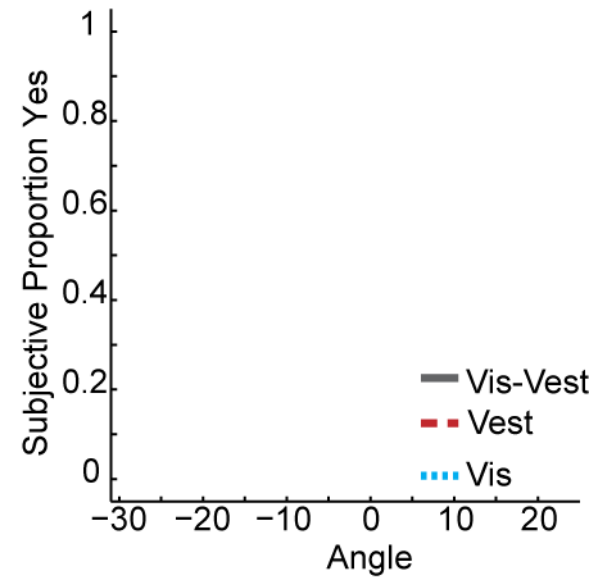
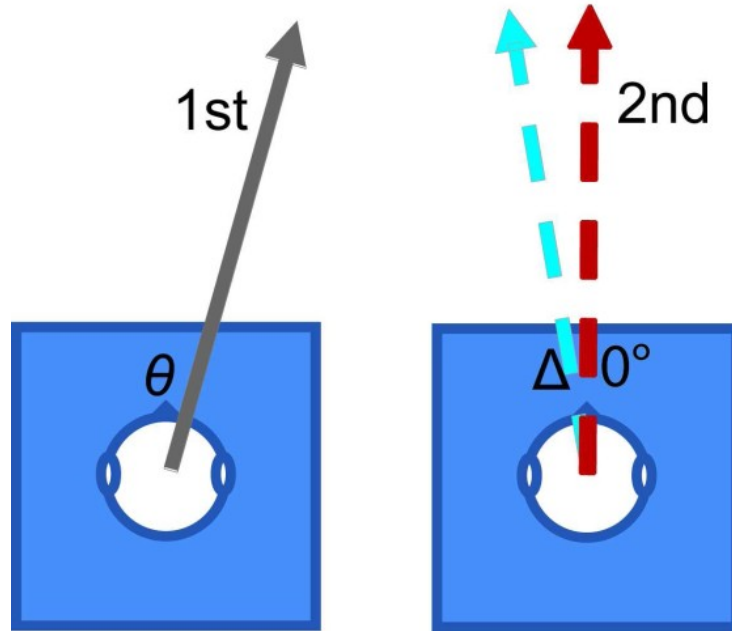
Vision weighted more



# Individual participant analysis



Incongruent

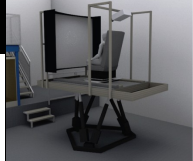


Vis-Vest

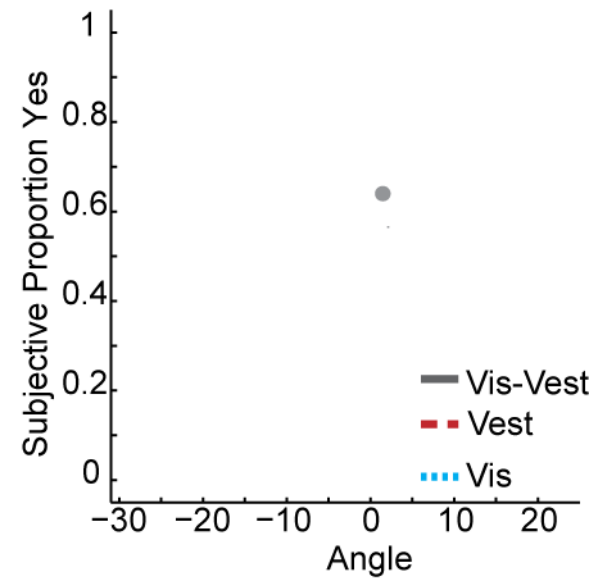
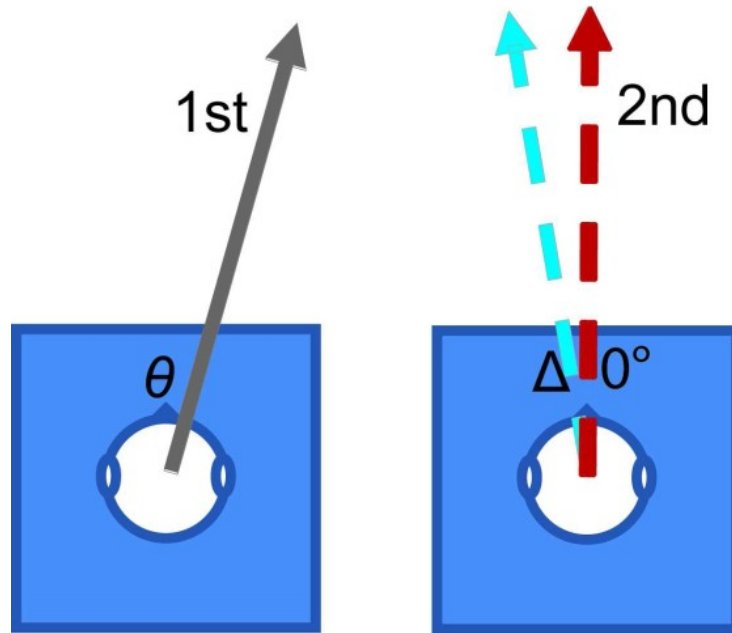
Vestibular

Visual

# Individual participant analysis



Incongruent



— Vis-Vest

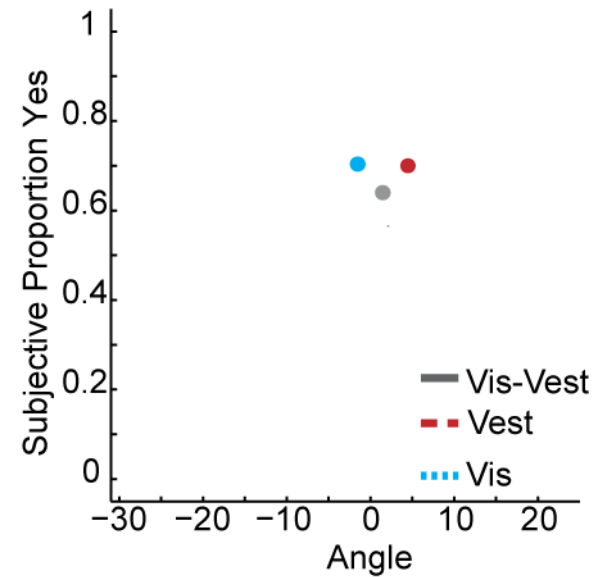
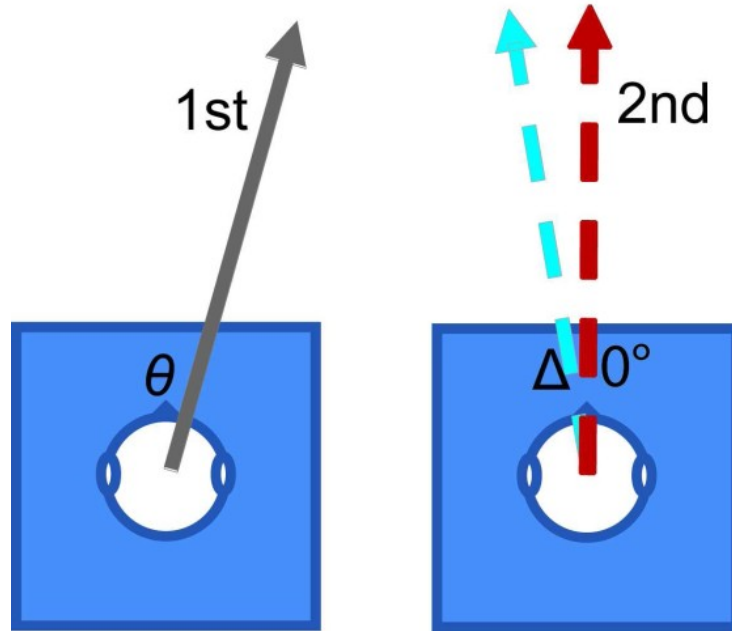
— Vestibular

— Visual

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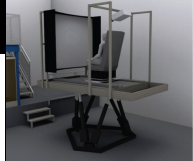


— Vis-Vest

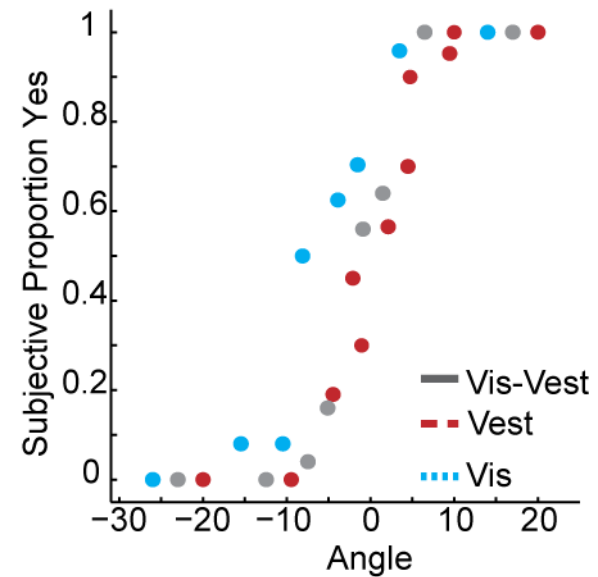
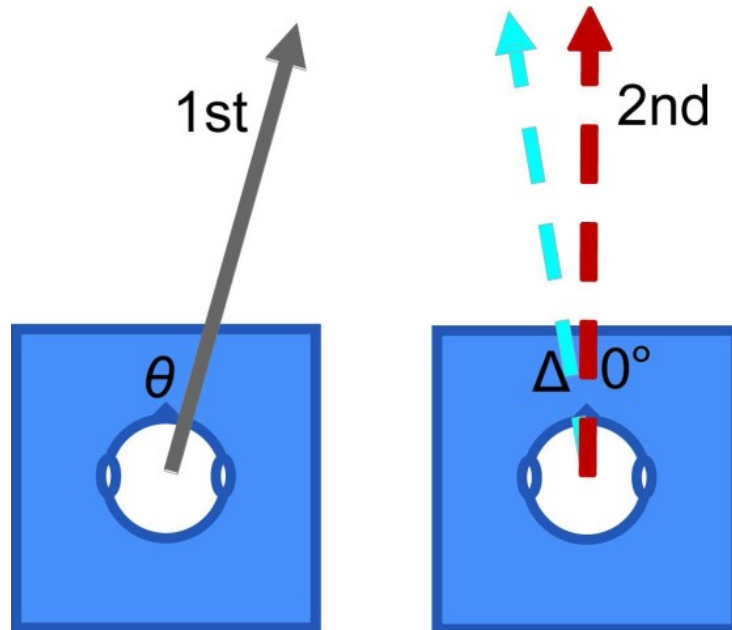
— Vestibular

— Visual

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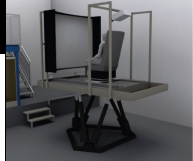


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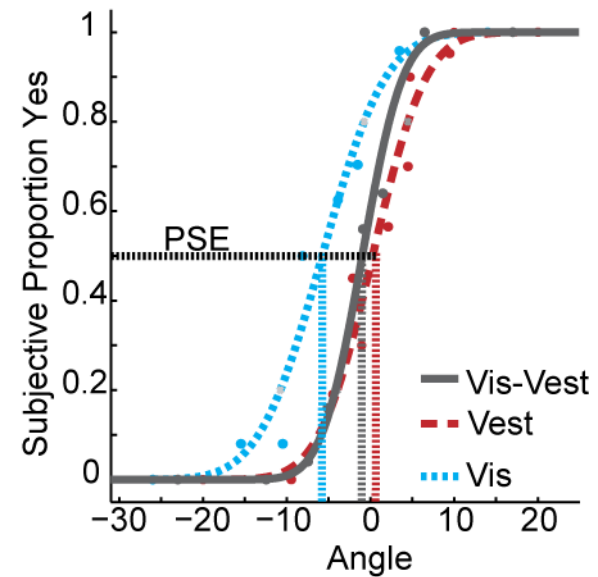
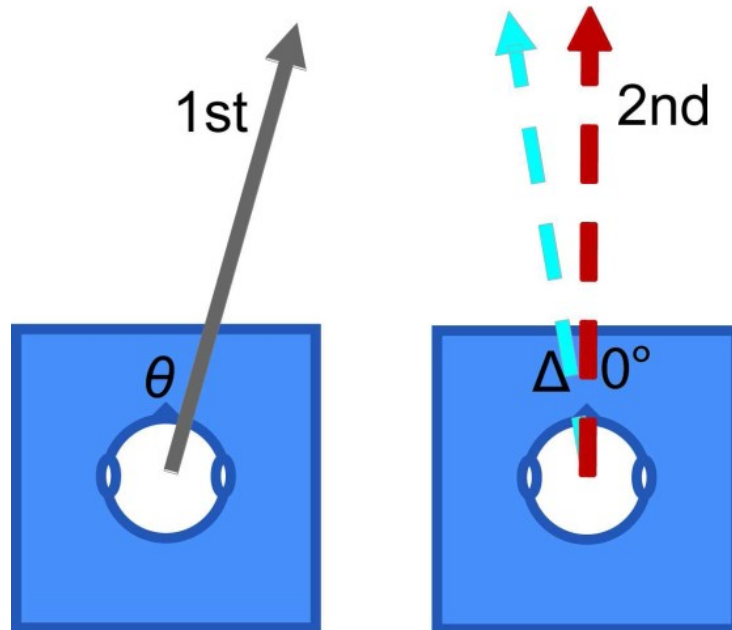
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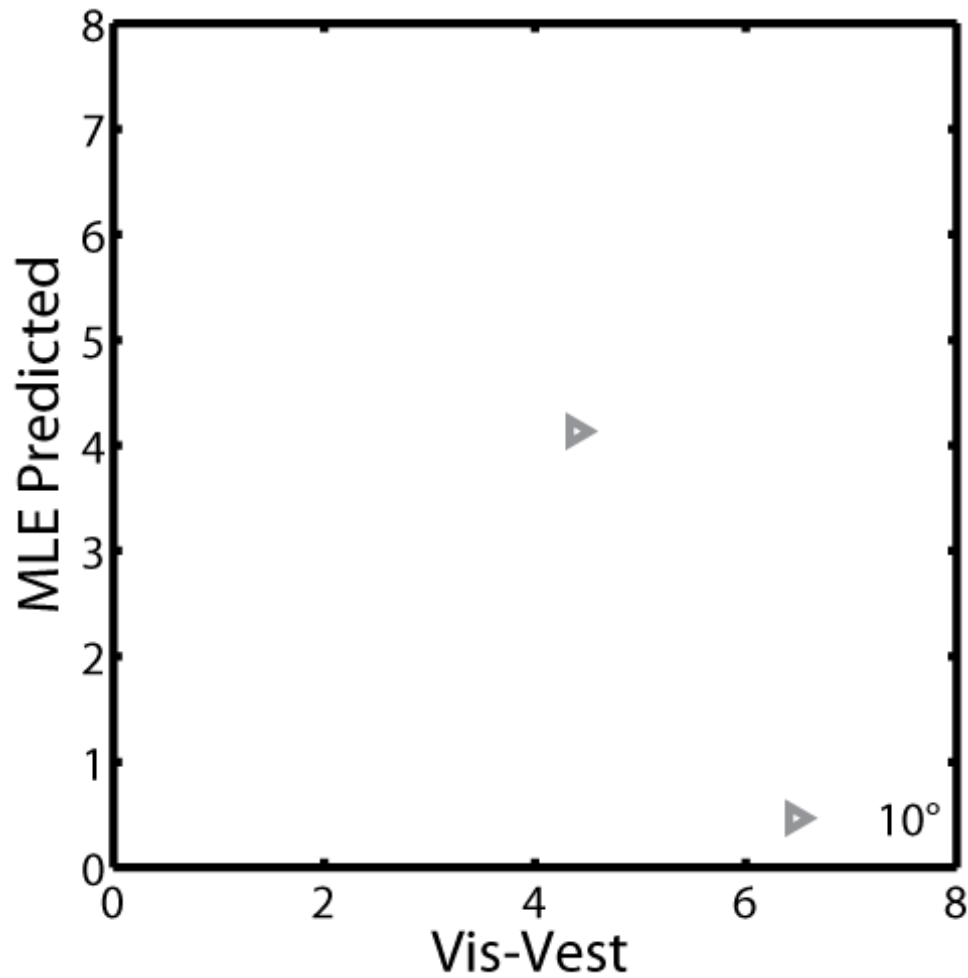


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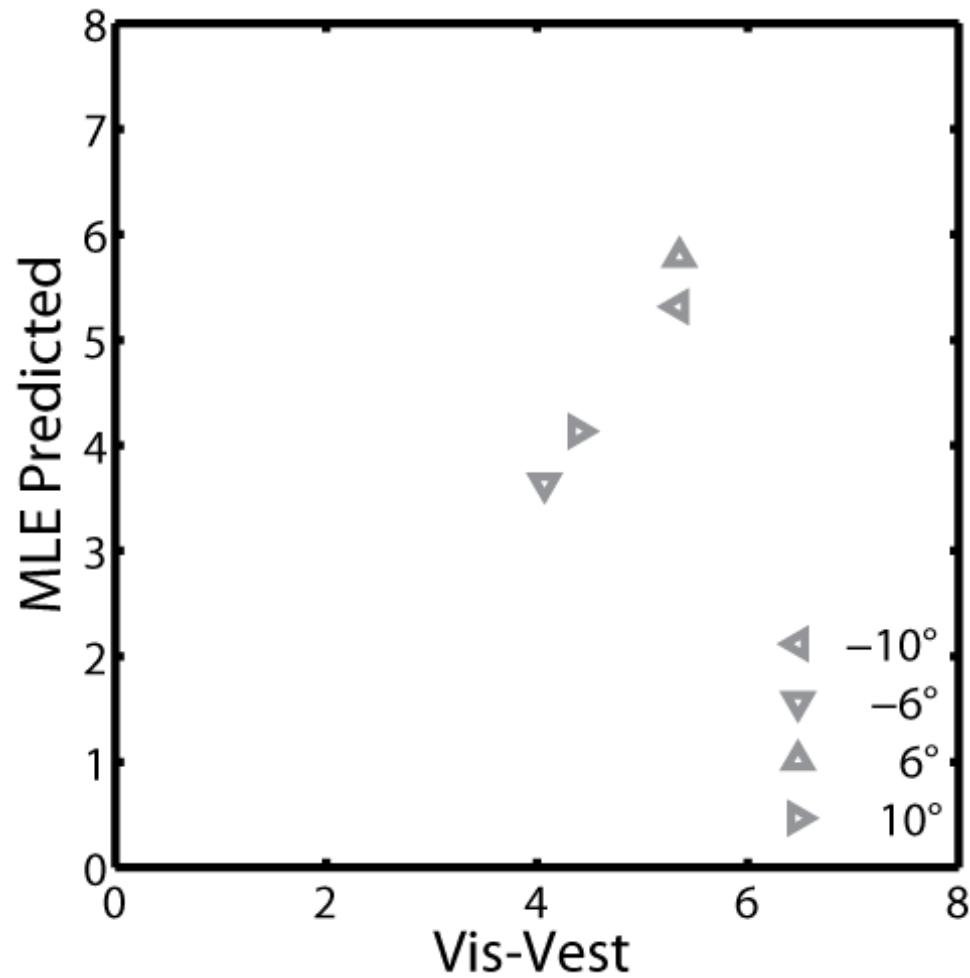
— Vestibular

— Visual

# Observed vs Predicted

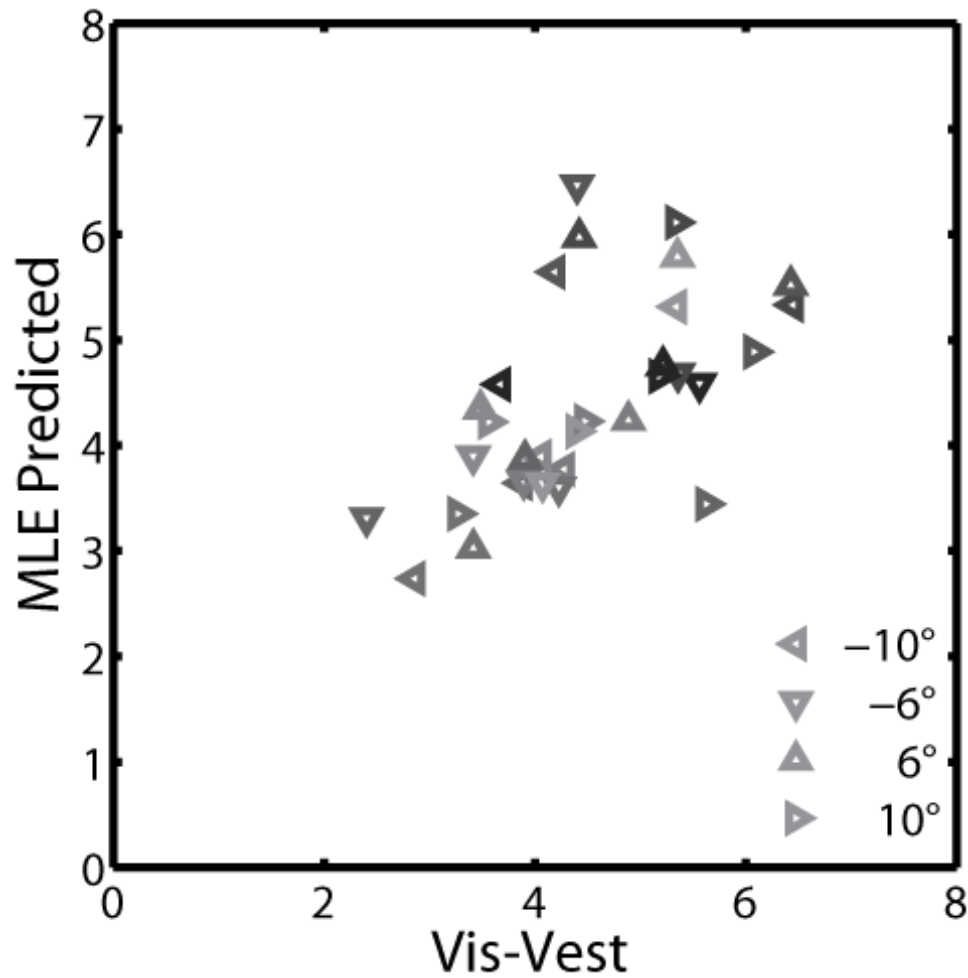


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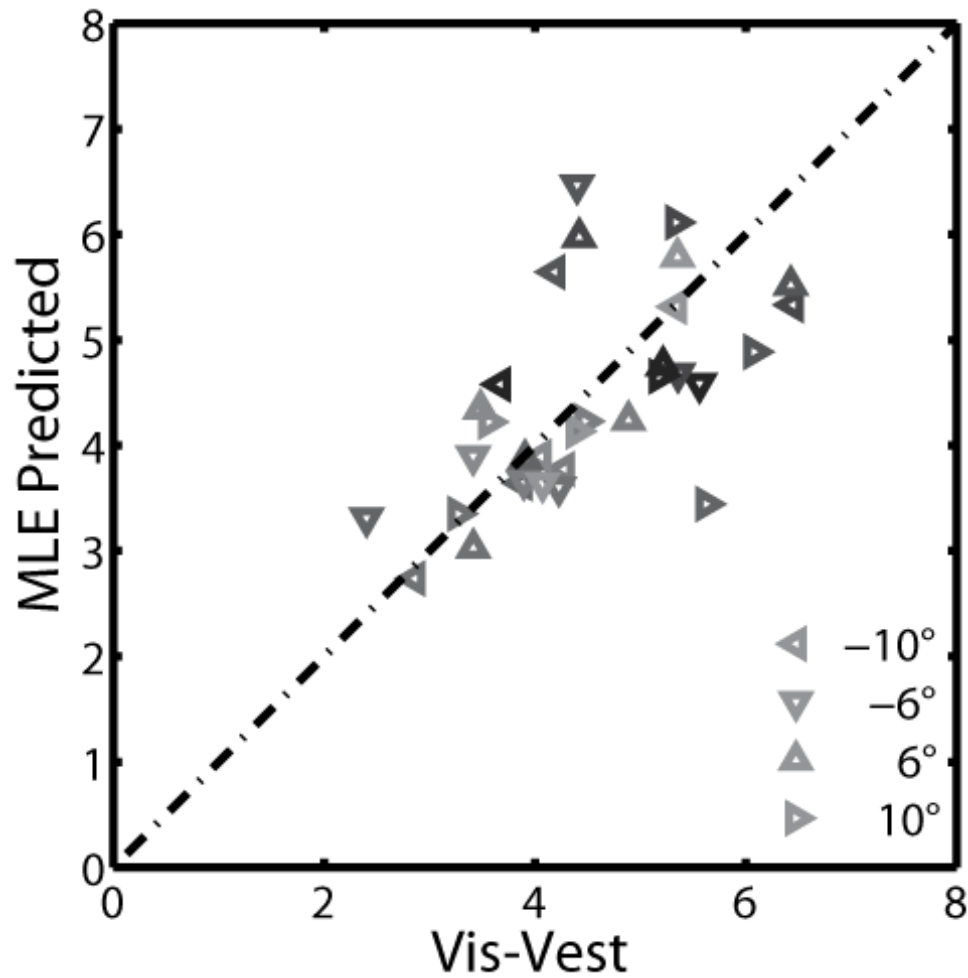




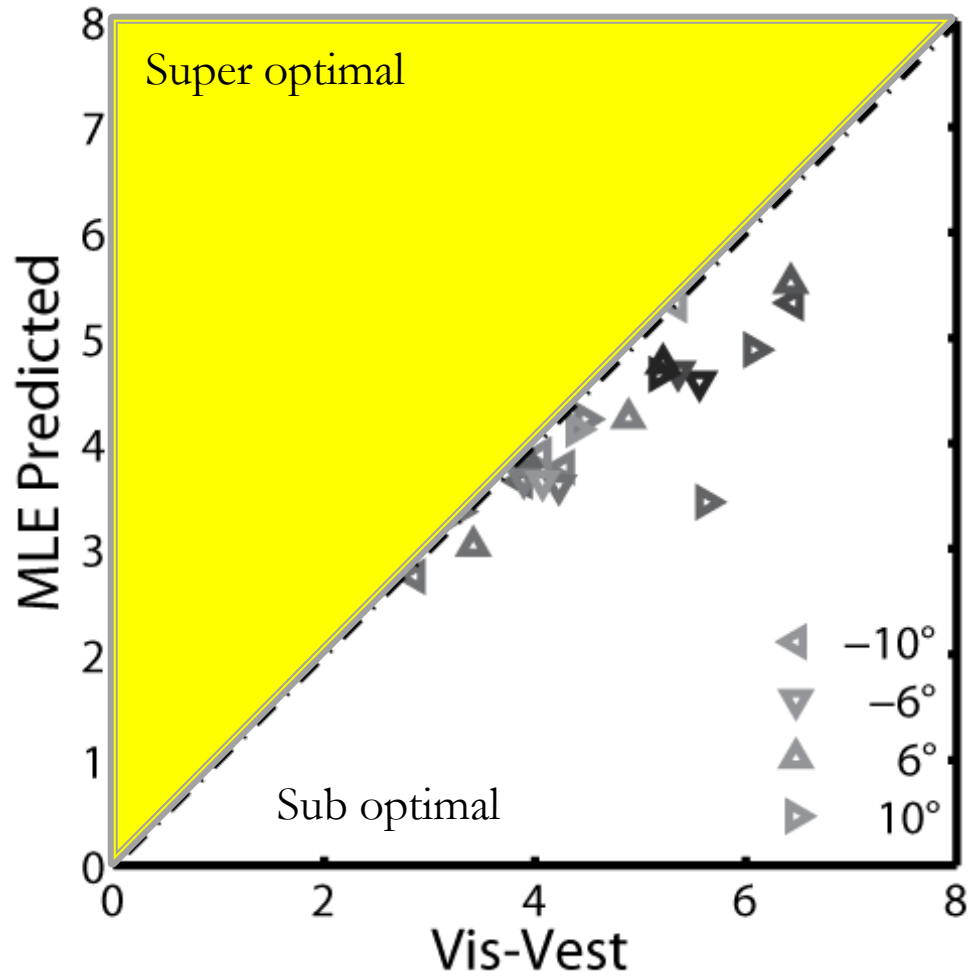
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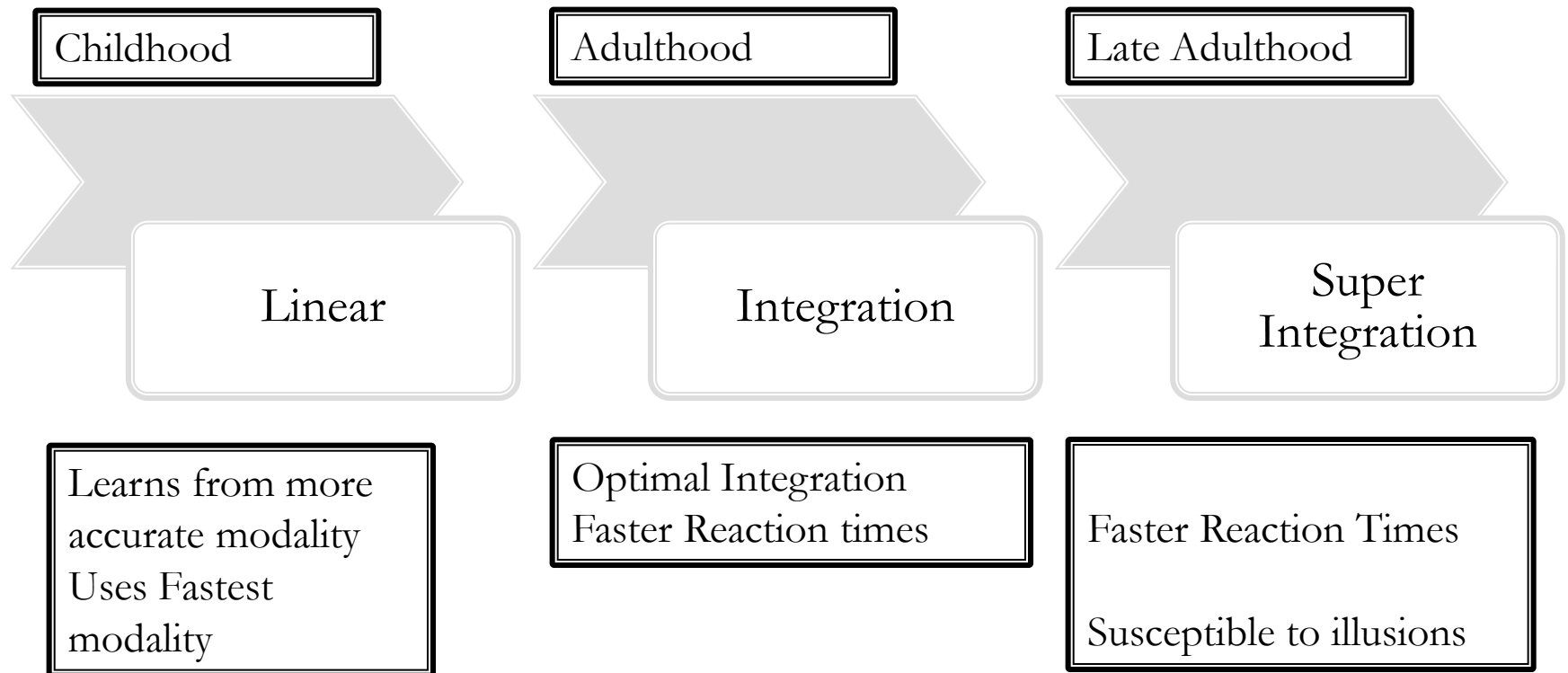


# Summary



- The vestibular system is useful
- Sensory information combines in an optimal fashion
- This has also been shown at the neuronal level
- This model extends to most sensory combinations
  - Audio-visual
  - Visual-touch
  - Audio-touch
- Helps explain possible reasons for falls in the elderly

# The Development Trajectory of Multisensory Integration



# Any questions



Institiúid Teicneolaíochta Bhaile Átha Cliath  
Dublin Institute of Technology

**Scoil na nEolaíochtaí Matamaiticiúla**  
**School of Mathematical Sciences**

Thank you

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MPI FOR BIOLOGICAL CYBERNETICS