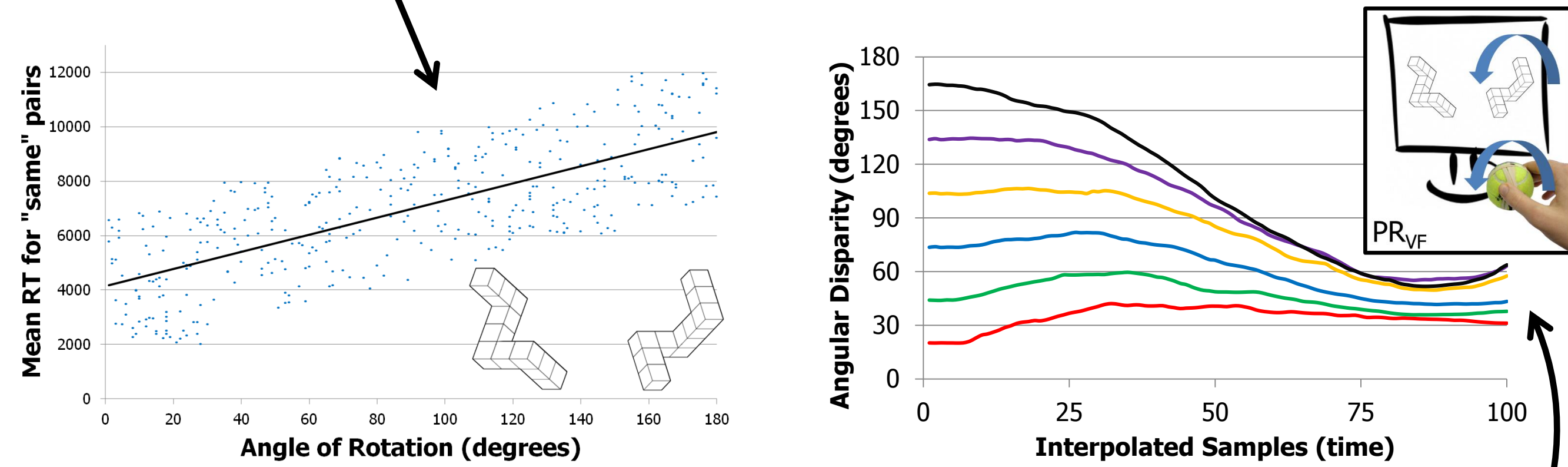


# Mental Rotation Strategies are Optimally Integrated

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## Introduction

- Mental rotation research typically shows the angular disparity effect (ADE), a linear RT function interpreted as **mental rotation to a match**<sup>1</sup>



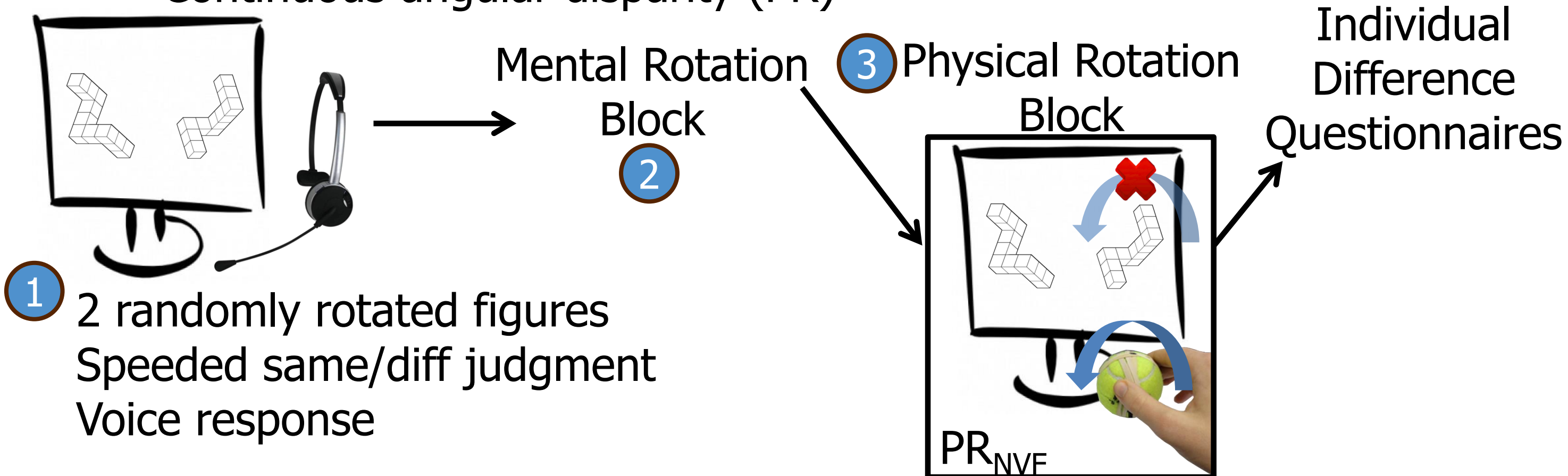
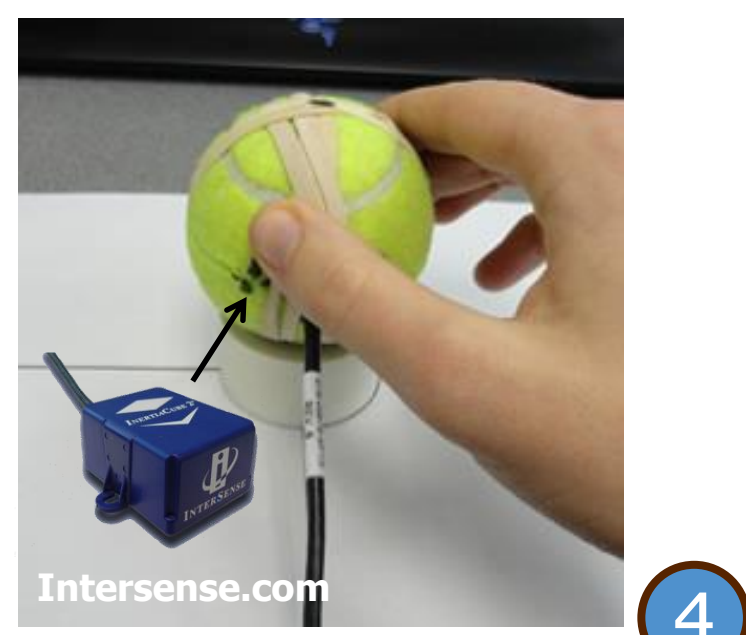
- Mental rotation (MR) akin to physical rotation (PR)
  - but do individuals universally apply this strategy during MR?
- Our recent work<sup>2</sup> suggested:
  - mental rotation to an off-axis difference**, not to match
- Can we similarly use PR to examine MR strategies?
  - Motoric strategy akin to PR and distinct *analytic* strategies

### PRIMARY GOALS

- Identify MR strategies from PR behavior
- Examine MR strategy selection

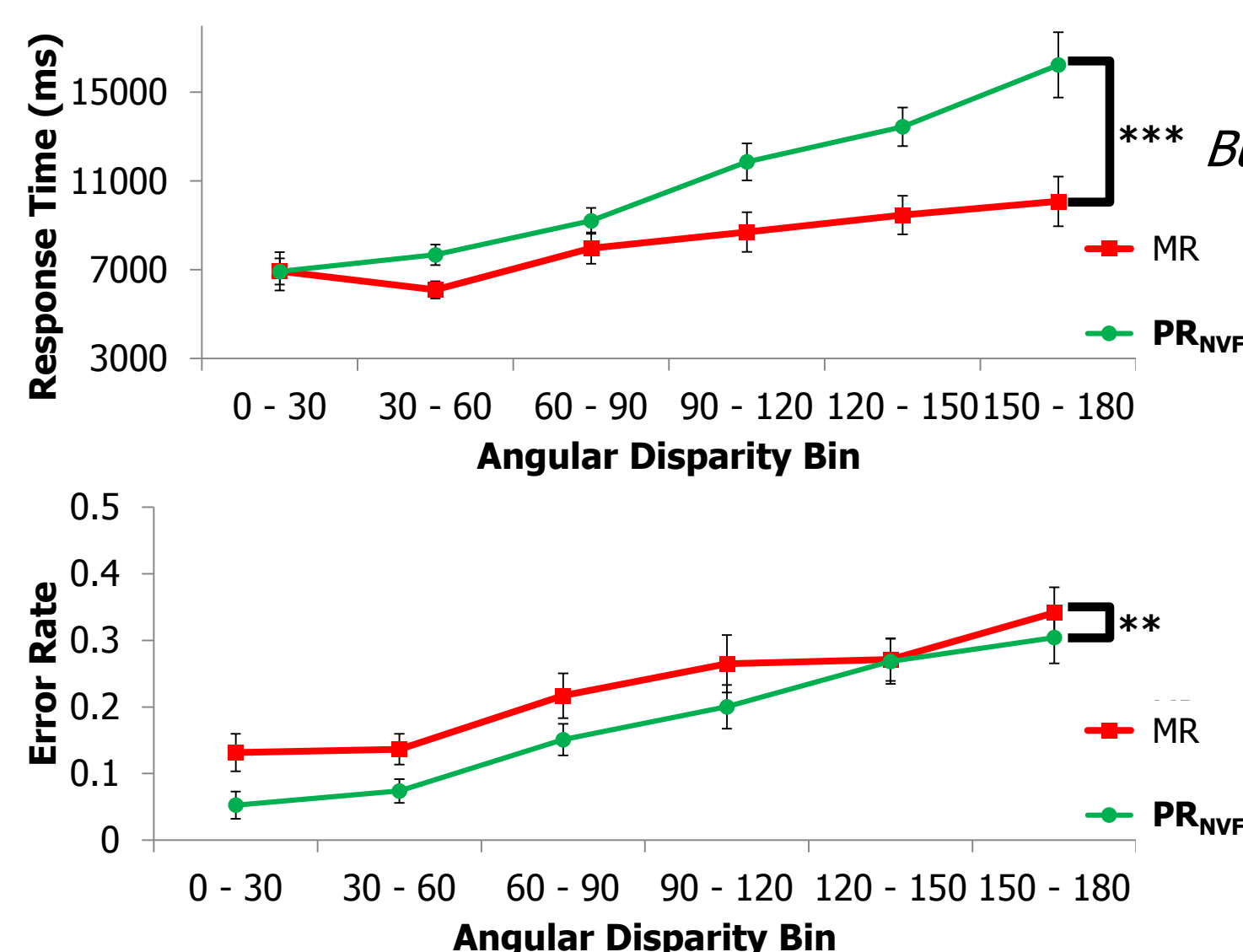
## Methods

- Materials:**
  - 3D models of Shepard-Metzler figures<sup>3</sup>
  - Ran experiment and recorded data with Vizard VR Toolkit
  - Ps physically mirrored MR with handheld Intersense InertiaCube
- Sample, Design, and Procedure:**
  - $n = 32$  undergrads: 16 male
  - All participants completed MR; then completed PR without visual feedback (PR<sub>NVF</sub>)
  - Measurements
    - Response time, error rate
    - Continuous angular disparity (PR)

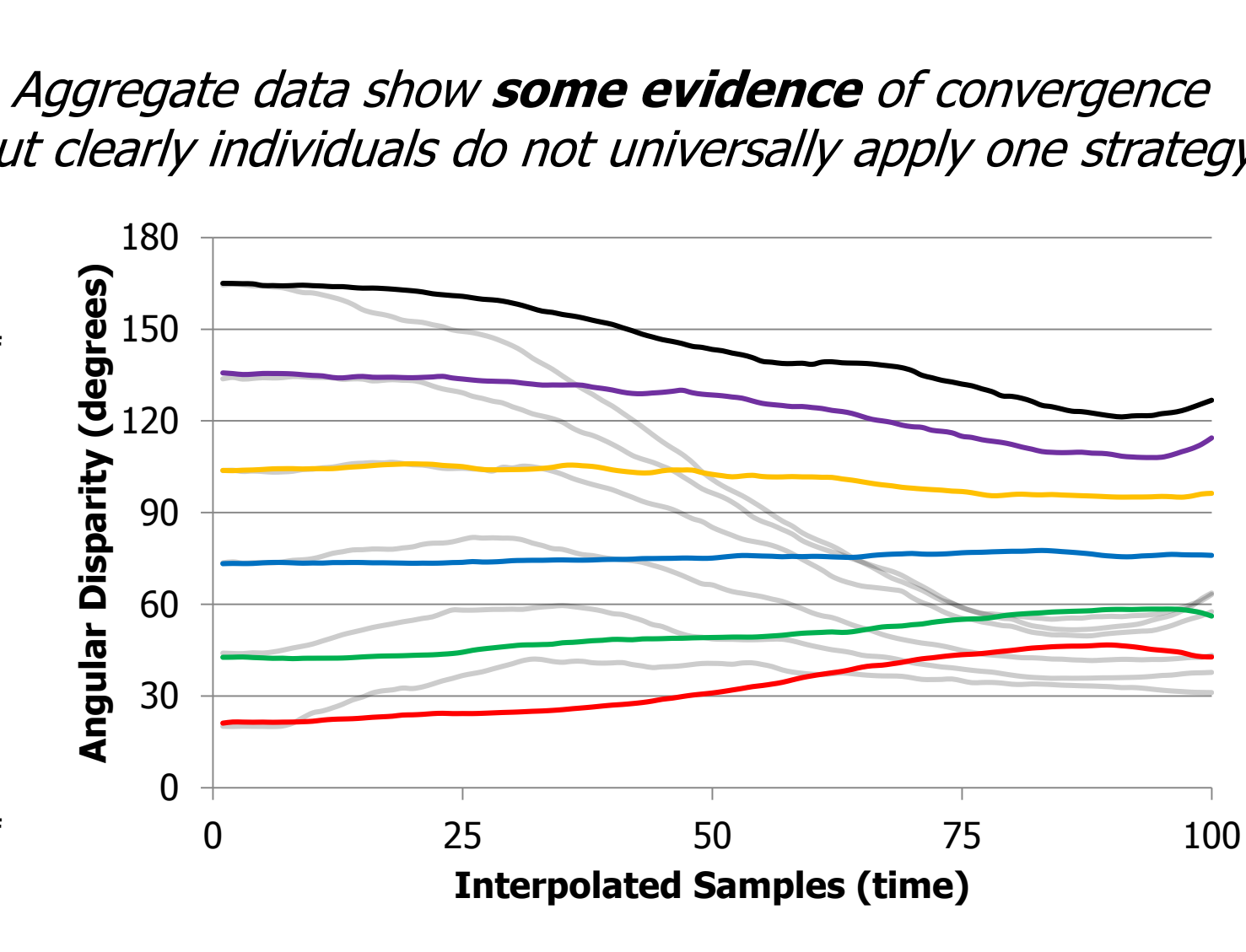


## Results: Response Time & Error Rate

### 1 ADEs & S/A trade-off



### 2 Rotational convergence



Aggregate data show **some evidence** of convergence  
 But clearly individuals do not universally apply one strategy

Data from Gardony et al., 2014 depicted in grey

## Extracting Strategies with Data Mining

### 3-Step procedure

- Filter data
- Compute distance matrices from PR data
- Cluster analysis

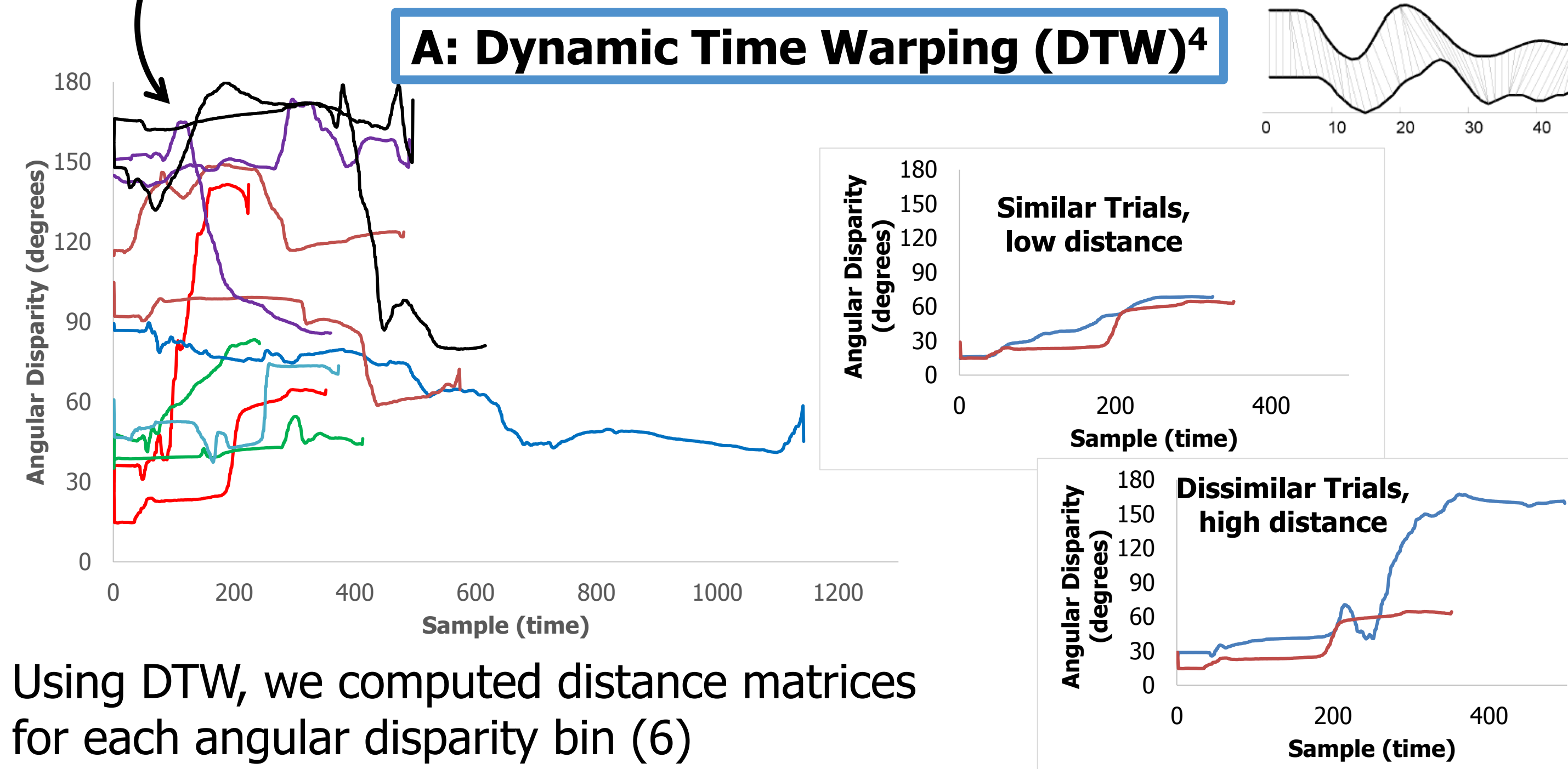
### Step 1: Filter Data

- Rule 1: Remove erroneously truncated trials (< 2 samples)  
1.7% trials removed
- Rule 2: Remove sensor reset error trials (2<sup>nd</sup> sample - 1<sup>st</sup>) > 15°  
6.4% trials removed

### Step 2: Compute Distance Matrices

Continuous angular disparity data look like this!

Q: How do we compute distance/dissimilarity b/w such trials?

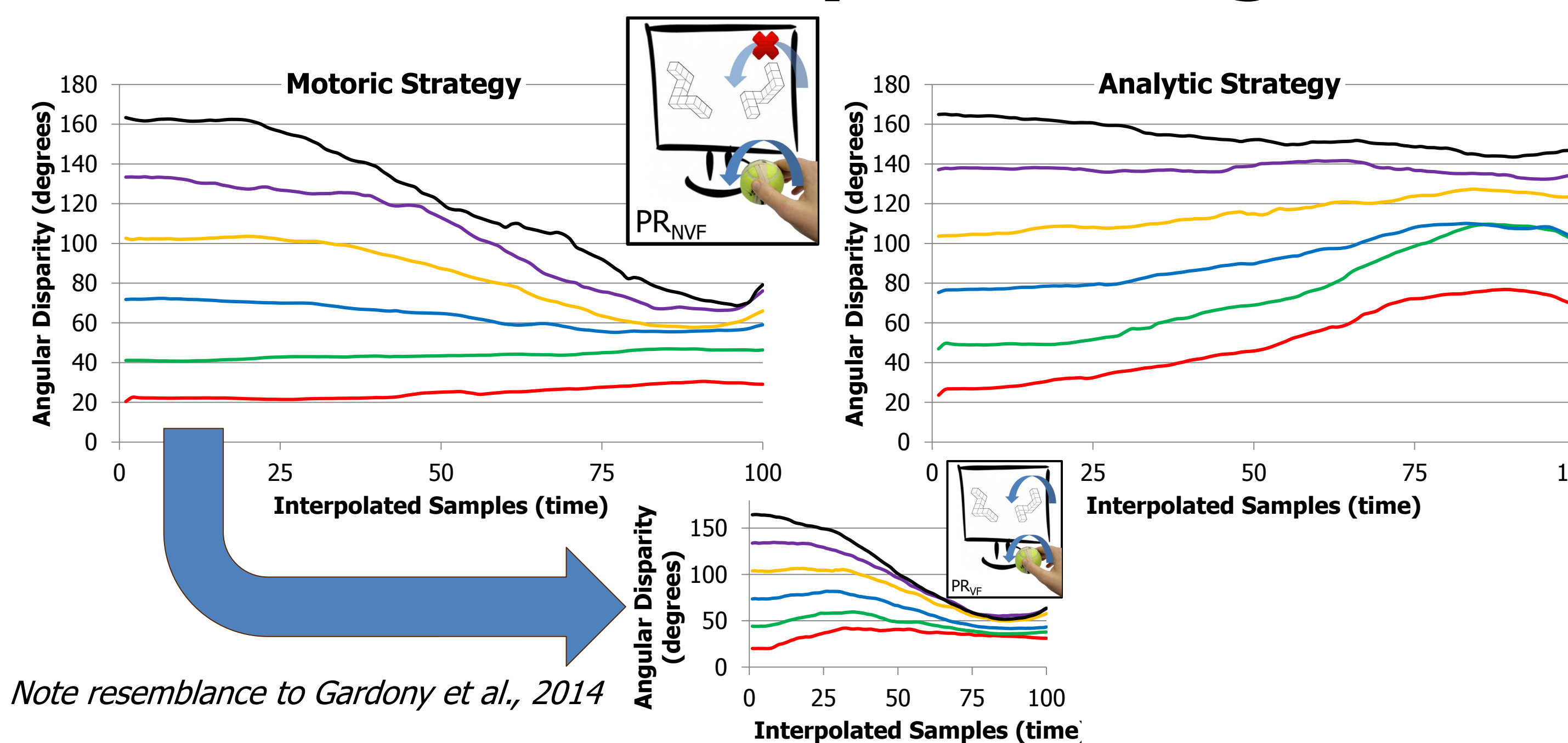


Using DTW, we computed distance matrices for each angular disparity bin (6)

### Step 3: Cluster Analysis

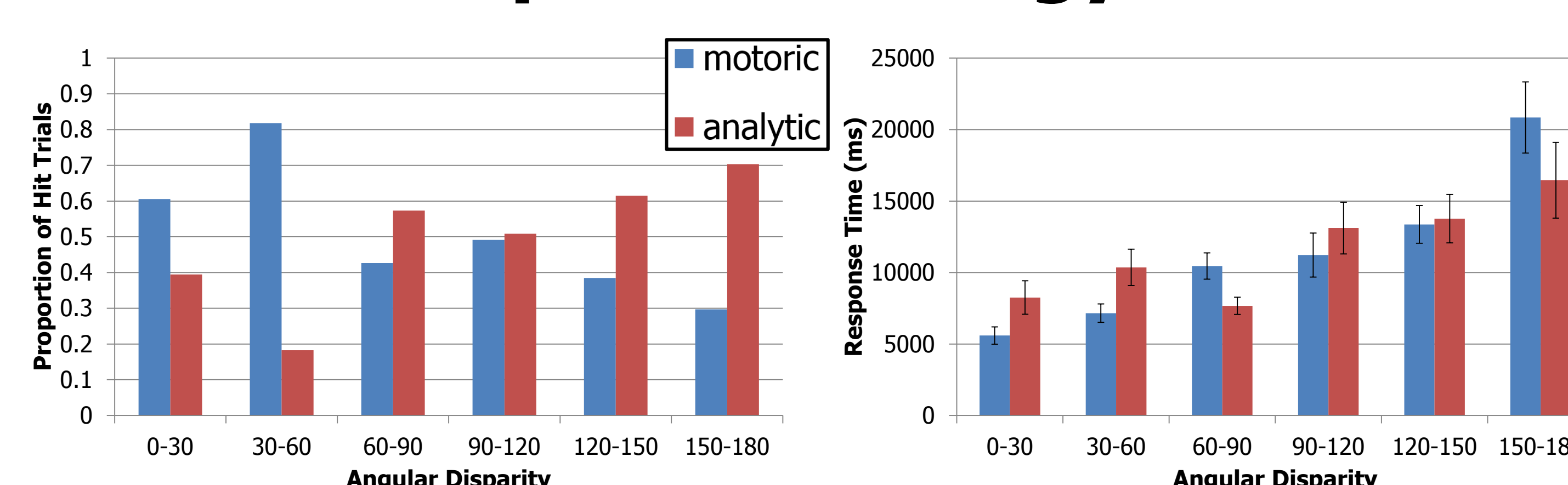
- We used K-medoids cluster analysis<sup>5</sup>
- Set  $k = 2$  to capture potential motoric and analytic strategies

## Motoric & Analytic Strategies



Note resemblance to Gardony et al., 2014

## Results: Optimal Strategy Selection



## Discussion

### Goal 1: Identify

- Using data mining techniques, we identified two divergent MR strategies from PR data
  - a motoric strategy akin to PR
  - a distinct analytic strategy

### Goal 2: Examine

- Motoric strategy biased for low difficulty trials
- Analytic strategy biased for high difficulty trials
- Strategy tradeoff is optimal with respect to RT
- Individual differences (gender, large-scale spatial ability, mental imagery vividness) did not influence strategy selection

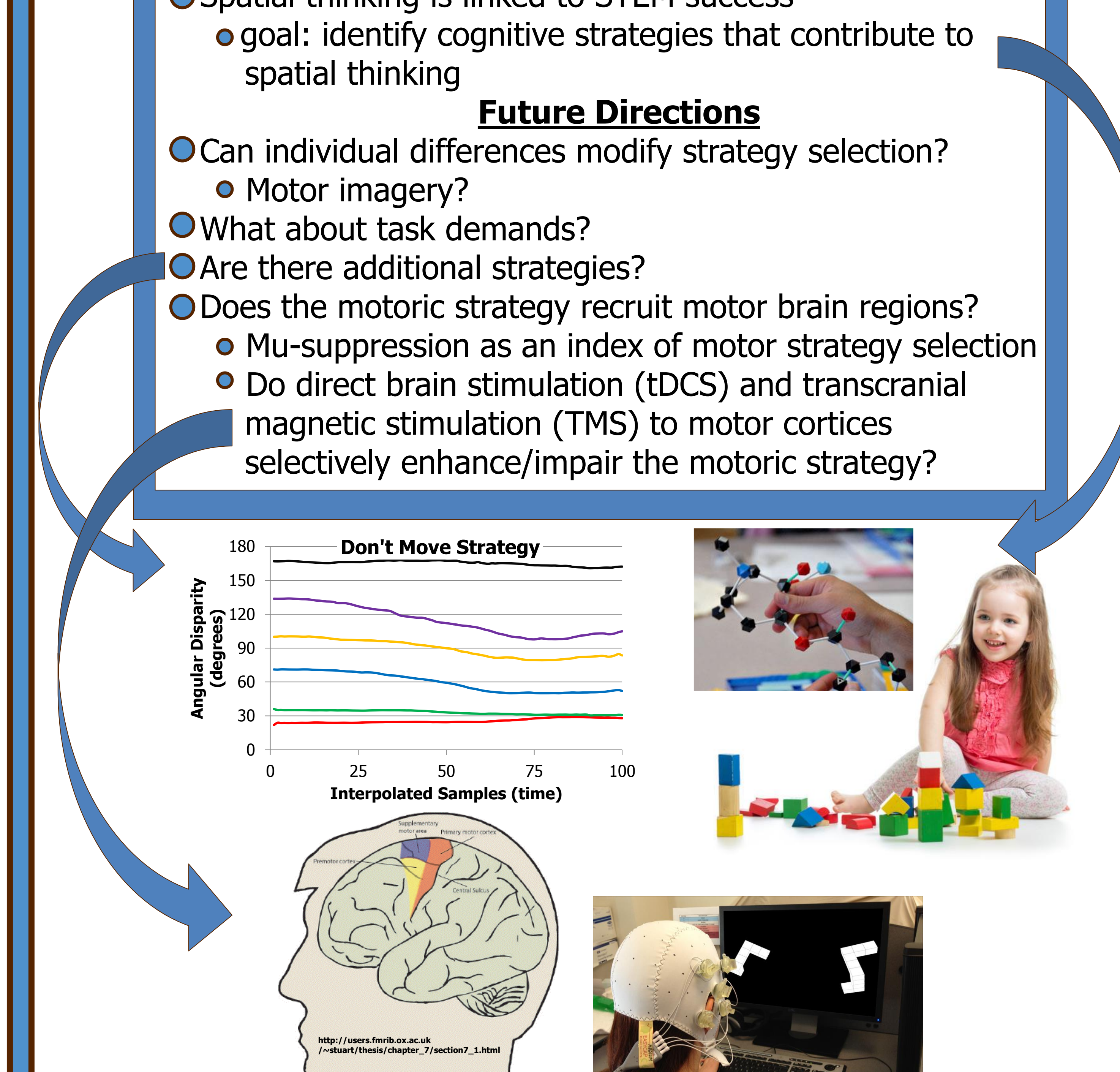
## Implications & Future Directions

### Implications

- MR is not a singular cognitive process
  - rather dynamically invokes different strategies
- Spatial thinking is linked to STEM success<sup>6</sup>
  - goal: identify cognitive strategies that contribute to spatial thinking

### Future Directions

- Can individual differences modify strategy selection?
  - Motor imagery?
- What about task demands?
- Are there additional strategies?
- Does the motoric strategy recruit motor brain regions?
  - Mu-suppression as an index of motor strategy selection
  - Do direct brain stimulation (tDCS) and transcranial magnetic stimulation (TMS) to motor cortices selectively enhance/impair the motoric strategy?



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