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.
- Mental rotation (MR) akin to physical rotation (PR)
- but do individuals universally apply this strategy during MR?
- Our recent work suggests: 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
  - 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
  - Measurements
    - Response time, error rate
    - Continuous angular disparity (PR)

Results: Response Time & Error Rate

- ADEs & S/A trade-off
- Rotational convergence

- Aggregate data show some evidence of convergence, but clearly individuals do not universally apply one strategy

Extracting Strategies with Data Mining

3-Step procedure

1. Filter data
2. Compute distance matrices from PR data
3. 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 (2nd sample – 1st > 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?

A: Dynamic Time Warping (DTW)

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

Step 3: Cluster Analysis

- We used K-medoids cluster analysis
- Set λ = 2 to capture potential motoric and analytic strategies

Motoric & Analytic Strategies

Motric & Analytic Strategies

Results: Optimal Strategy Selection

- Motoric:
- Analytic:

Discussion

Goal 1: Identify

- Using data mining techniques, we identified two divergent MR strategies from PR data
  - 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

- MR is not a singular cognitive process
  - Rather dynamically invokes different strategies
  - Spatial thinking is linked to STEM success
  - 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 (dBCS) and transcranial magnetic stimulation (TMS) to motor cortices selectively enhance/improve the motoric strategy?

References