Motor dynamics support a competition model of number processing

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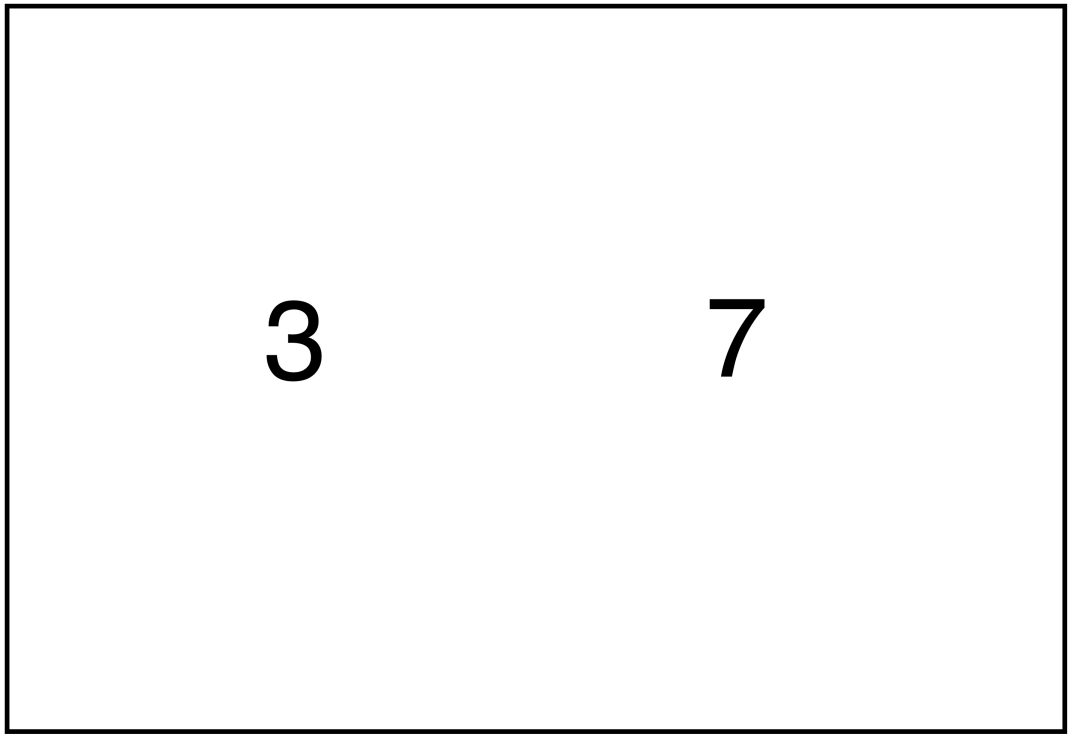
Number Comparison Task

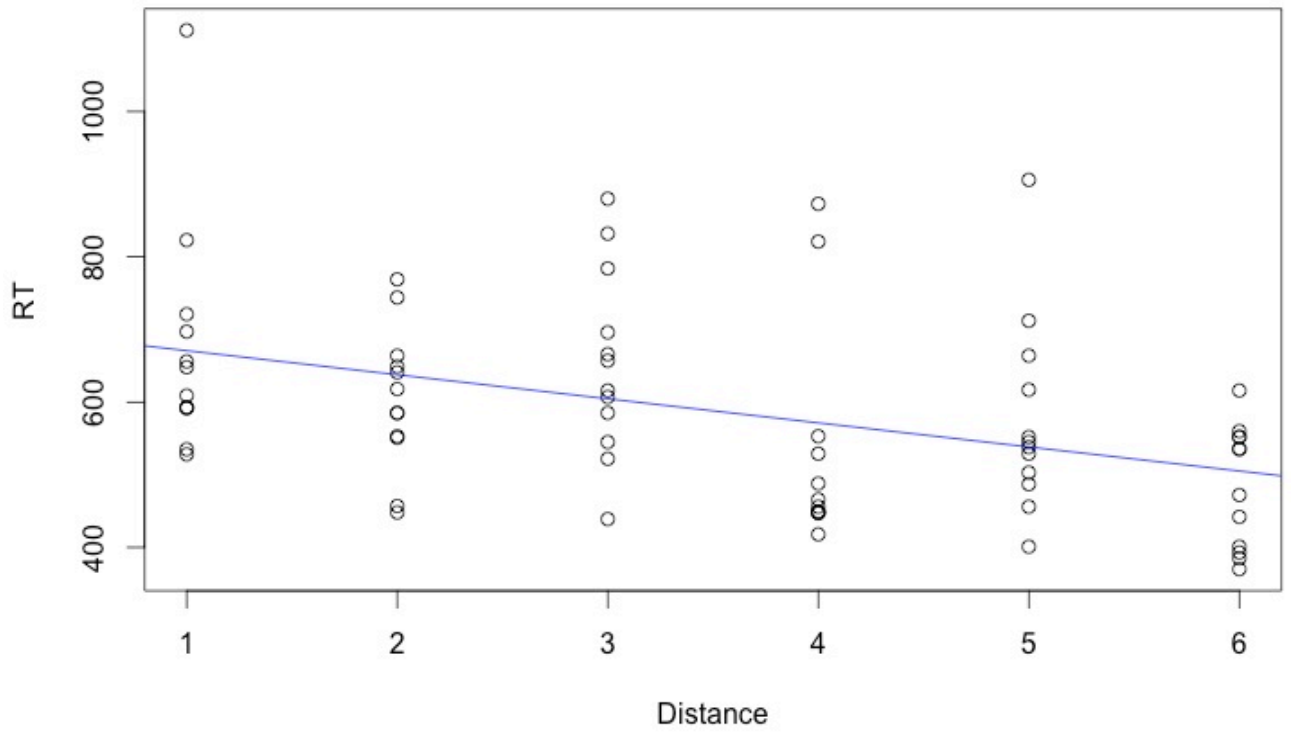
Task: Two numbers presented on screen, choose largest as quickly as you can.



Number Comparison Task

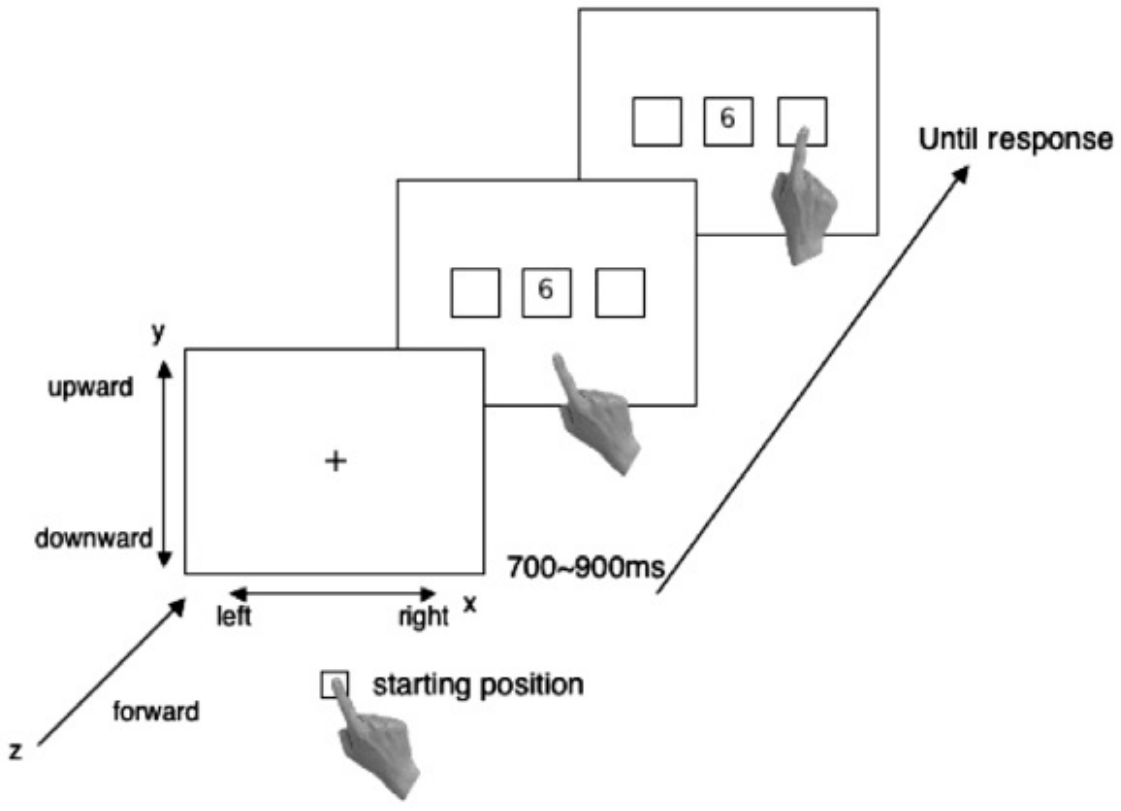
Typical result: RT decreases as distance between numbers increases

- Numerical Distance Effect (NDE; Moyer & Landauer, 1967)



Hand tracking

Song and Nakayama (2008) – measured hand movements in a numerical comparison task (compare to 5)

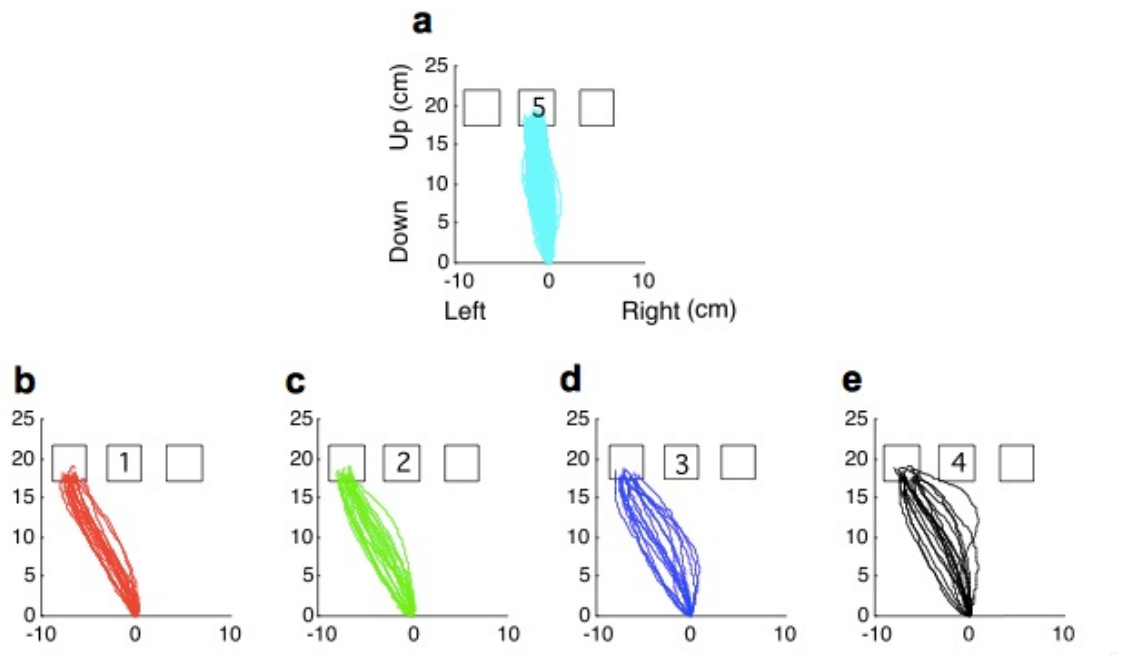


Song, J., & Nakayama, K. (2008). Numeric comparison in a visually-guided manual reaching task. *Cognition, 106*, 994-1003.

Hand tracking

Song and Nakayama (2008) – trajectories curved more as number got closer to 5.

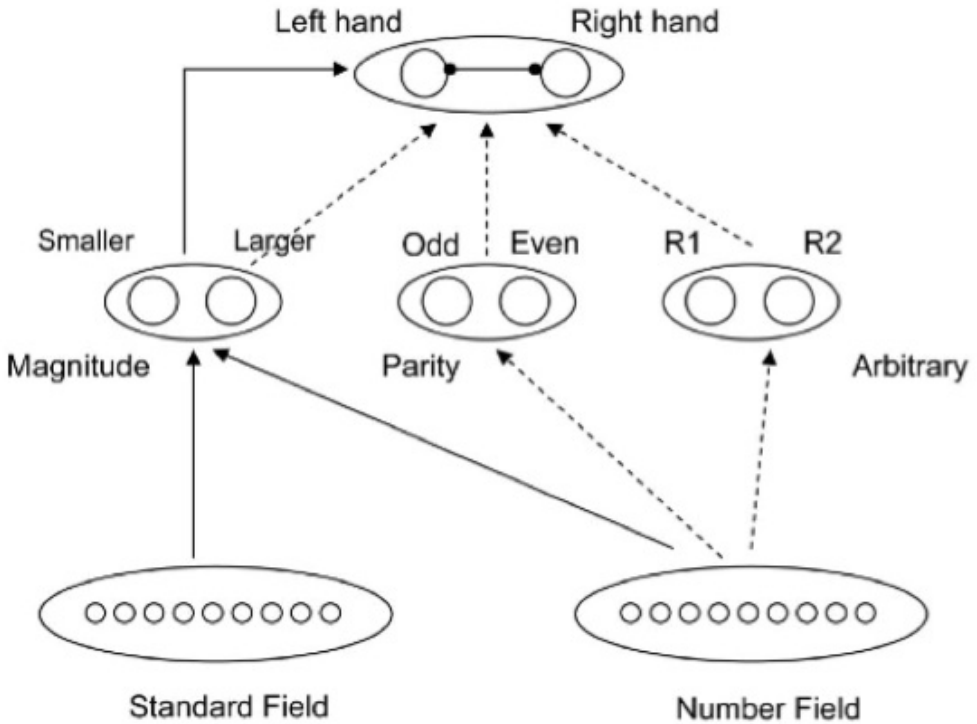
- interpreted as evidence for spatial coding of numbers
- “Direct Mapping Account”



Song, J., & Nakayama, K. (2008). Numeric comparison in a visually-guided manual reaching task. *Cognition, 106*, 994-1003.

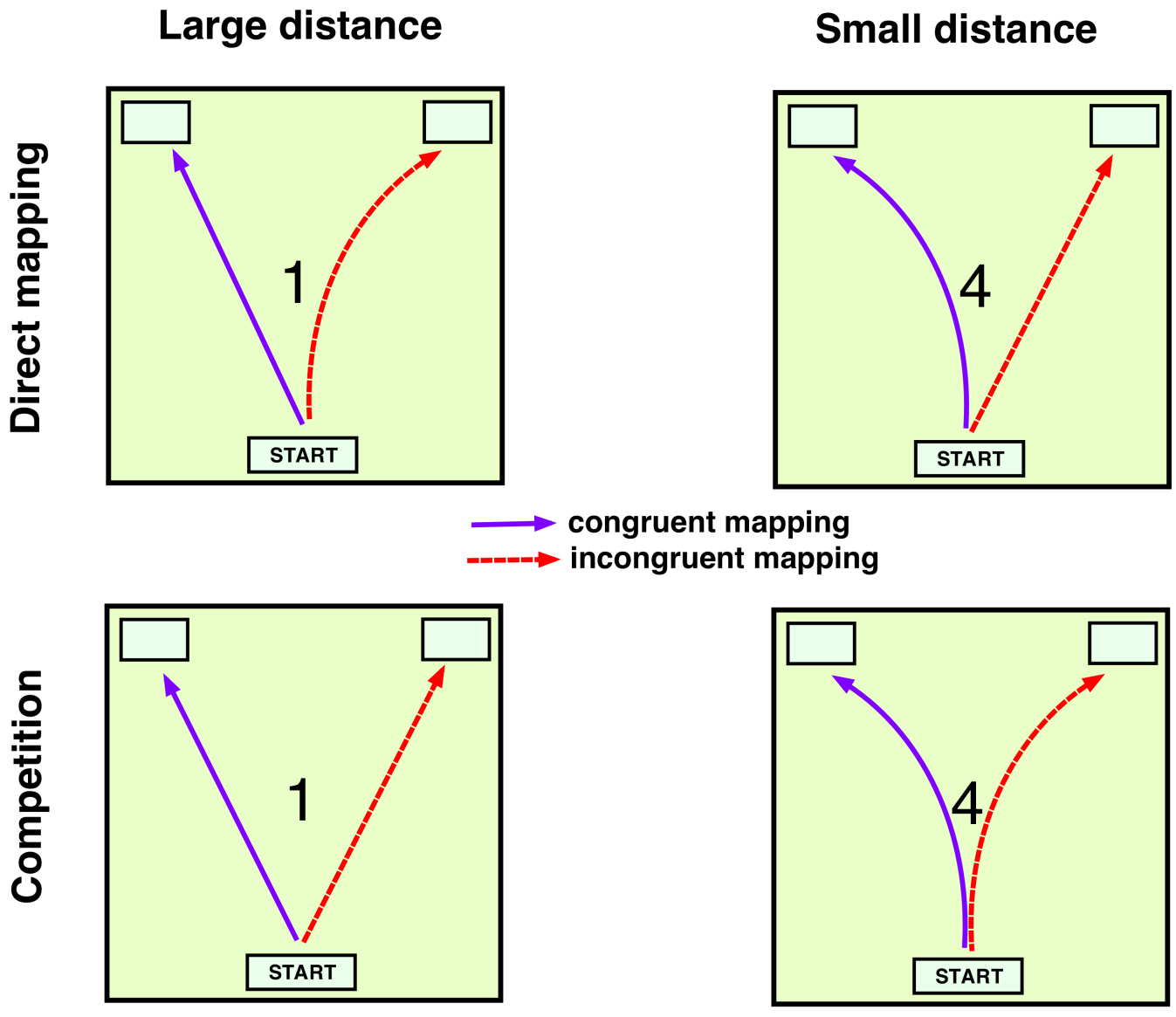
Alternative model

Gevers et al. (2006) – trajectory curvatures may result from competition between partially active representations



Gevers, W., Verguts, T., Reynvoet, B, Caessens, B., & Fias, W. (2006). Numbers and space: A computational model of the SNARC effect. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 32-44.

Predictions from competing models



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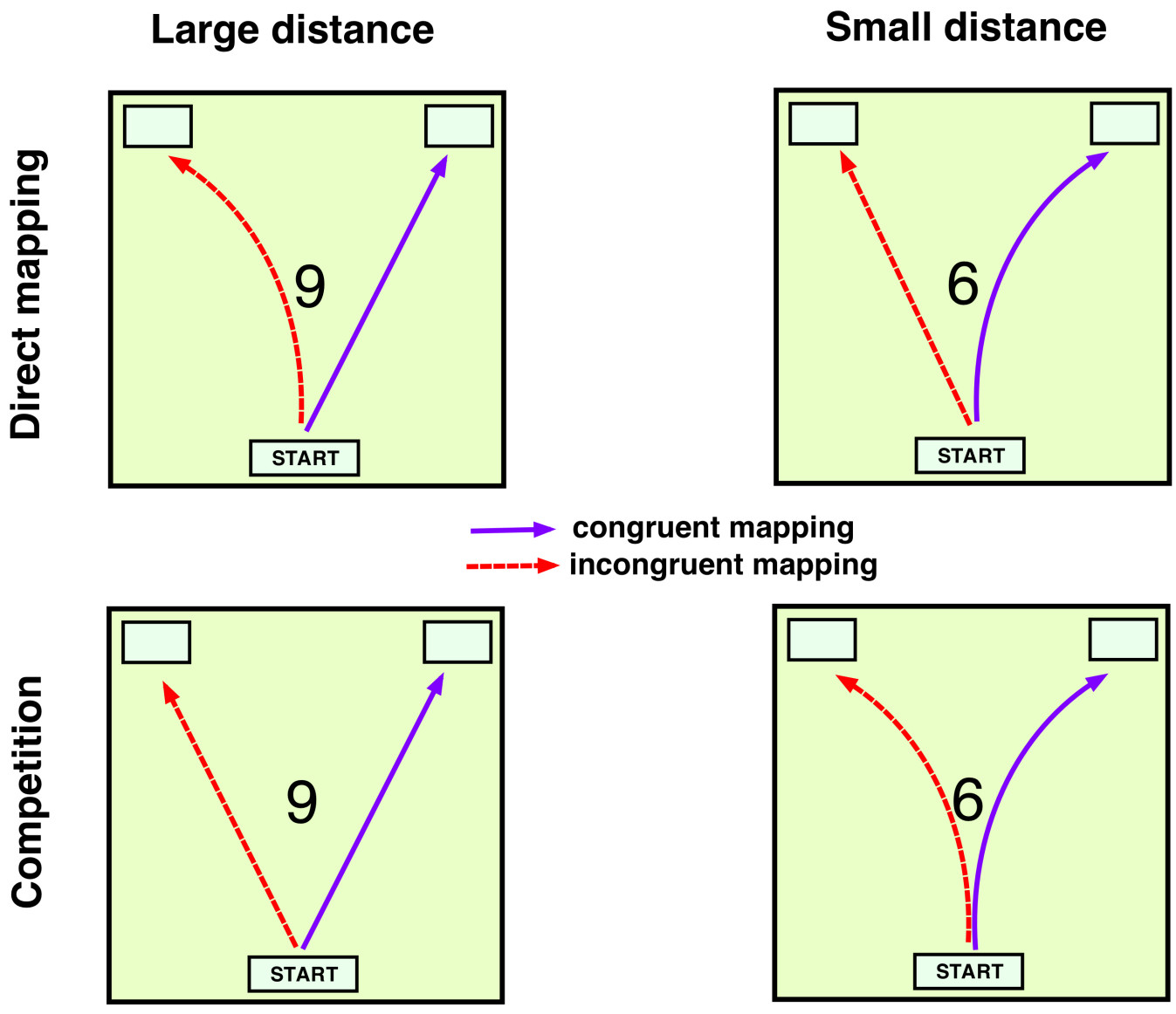
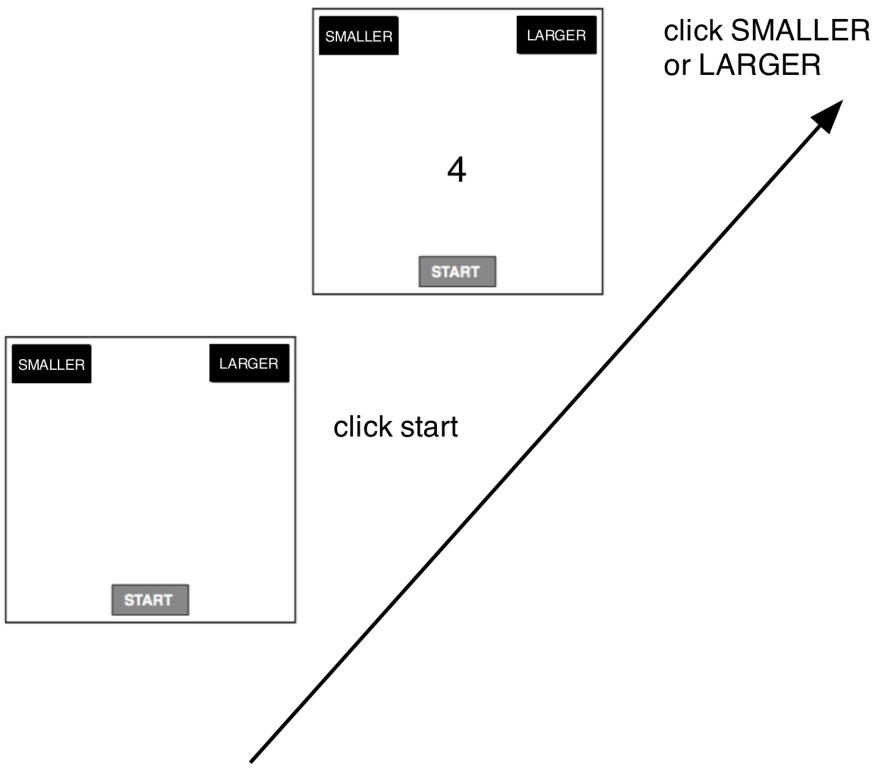


Predictions from competing models

1. For congruent trials, both models predict that curvature decreases as distance from 5 increases.
2. For incongruent trials,
   - competition account $\rightarrow$ curvature decreases as distance from 5 increases
   - direct mapping account $\rightarrow$ curvature increases as distance from 5 increases
3. Across all trials,
   - competition account $\rightarrow$ congruent/incongruent trajectories are symmetric about the movement axis
   - direct mapping account $\rightarrow$ congruent/incongruent trajectories are asymmetric

Experiment 1

- 64 participants
- MouseTracker (Freeman & Ambady, 2010)
- 320 trials
  - congruent
    SMALLER - LARGER
  - incongruent
    LARGER - SMALLER
- Measures:
  - RT
  - streaming (x, y) coordinates of mouse
  - AUC (area under curve) of each trajectory



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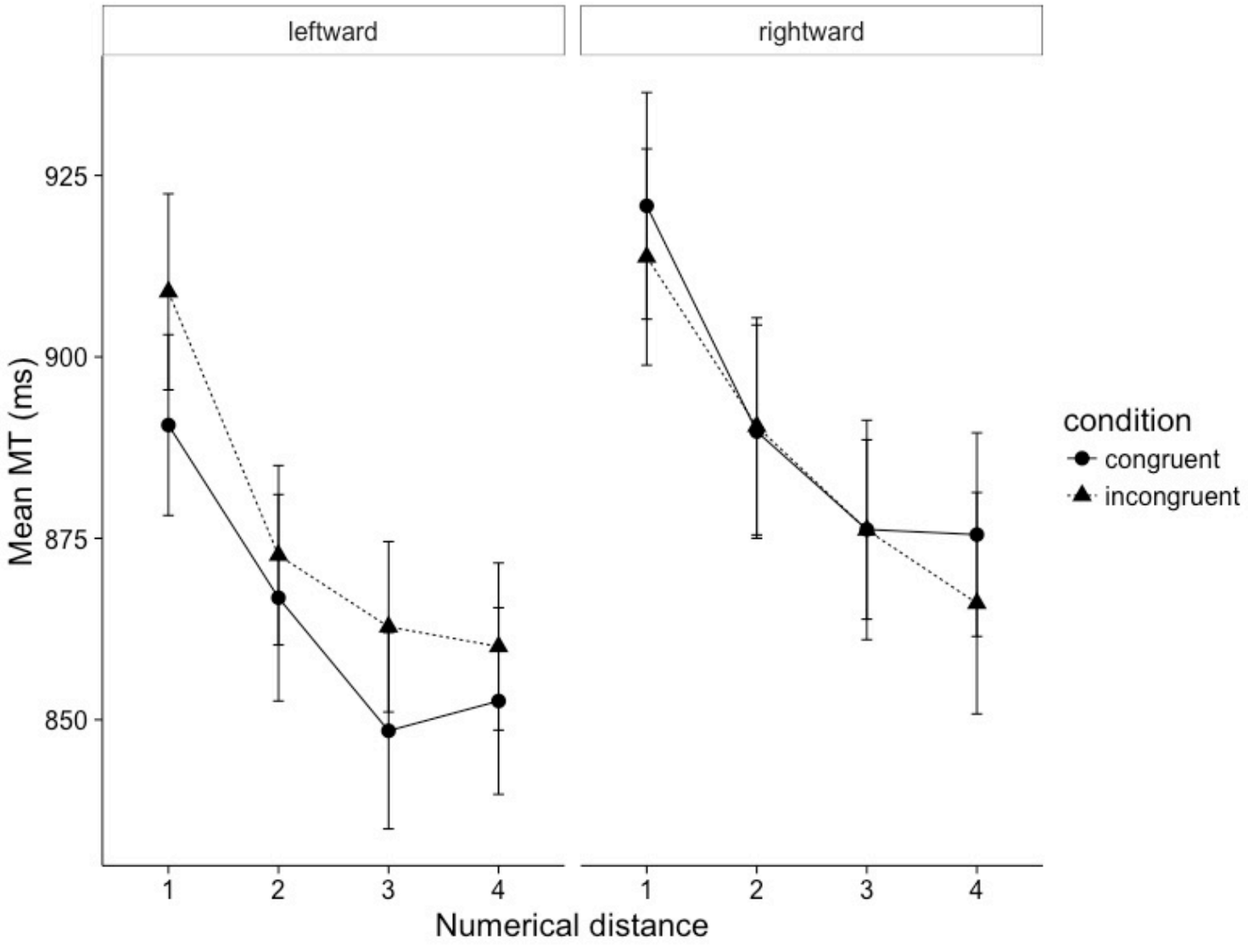

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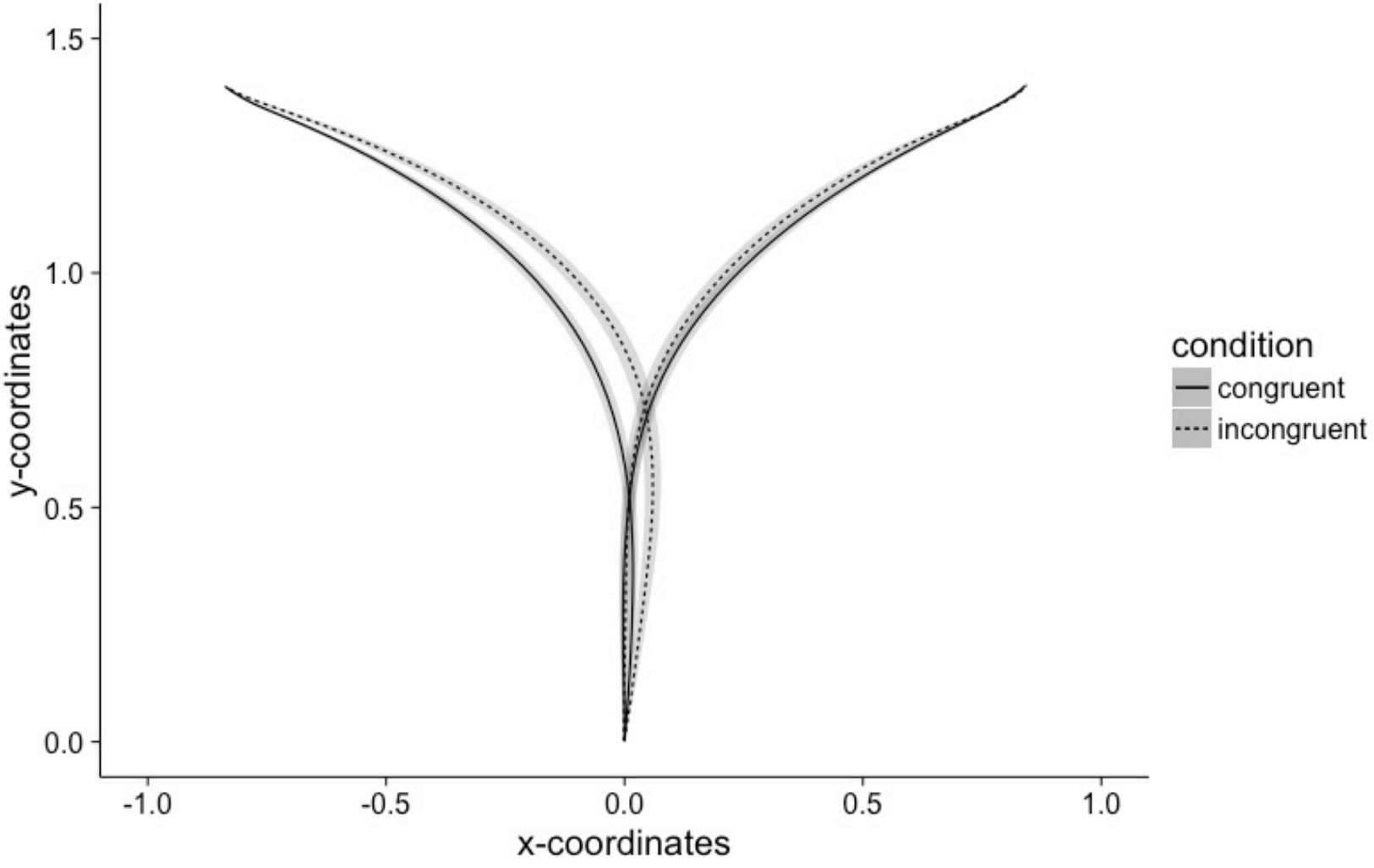

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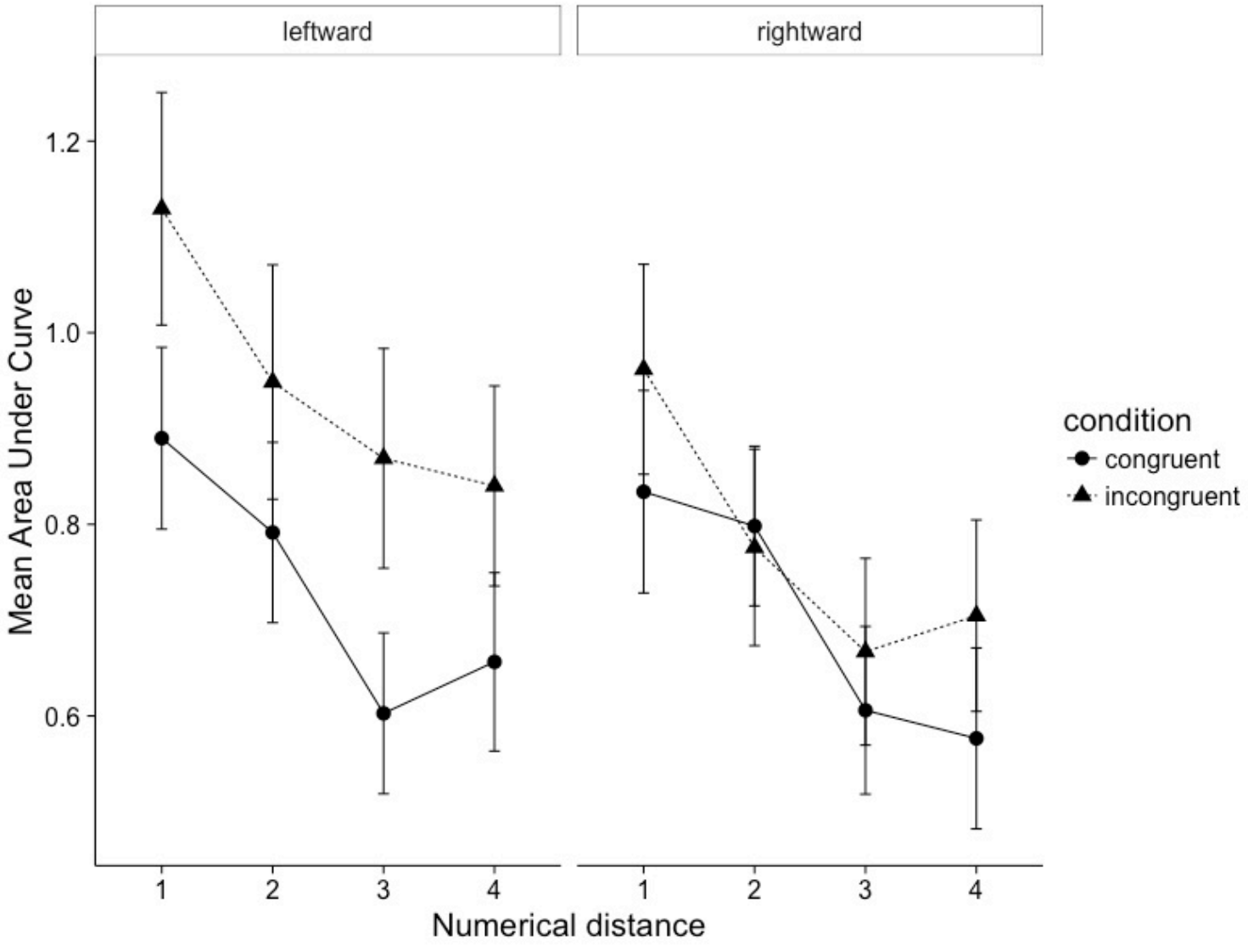

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3. Across all trials,
   - competition account → congruent/incongruent trajectories are symmetric about the movement axis
   - direct mapping account → congruent/incongruent trajectories are asymmetric

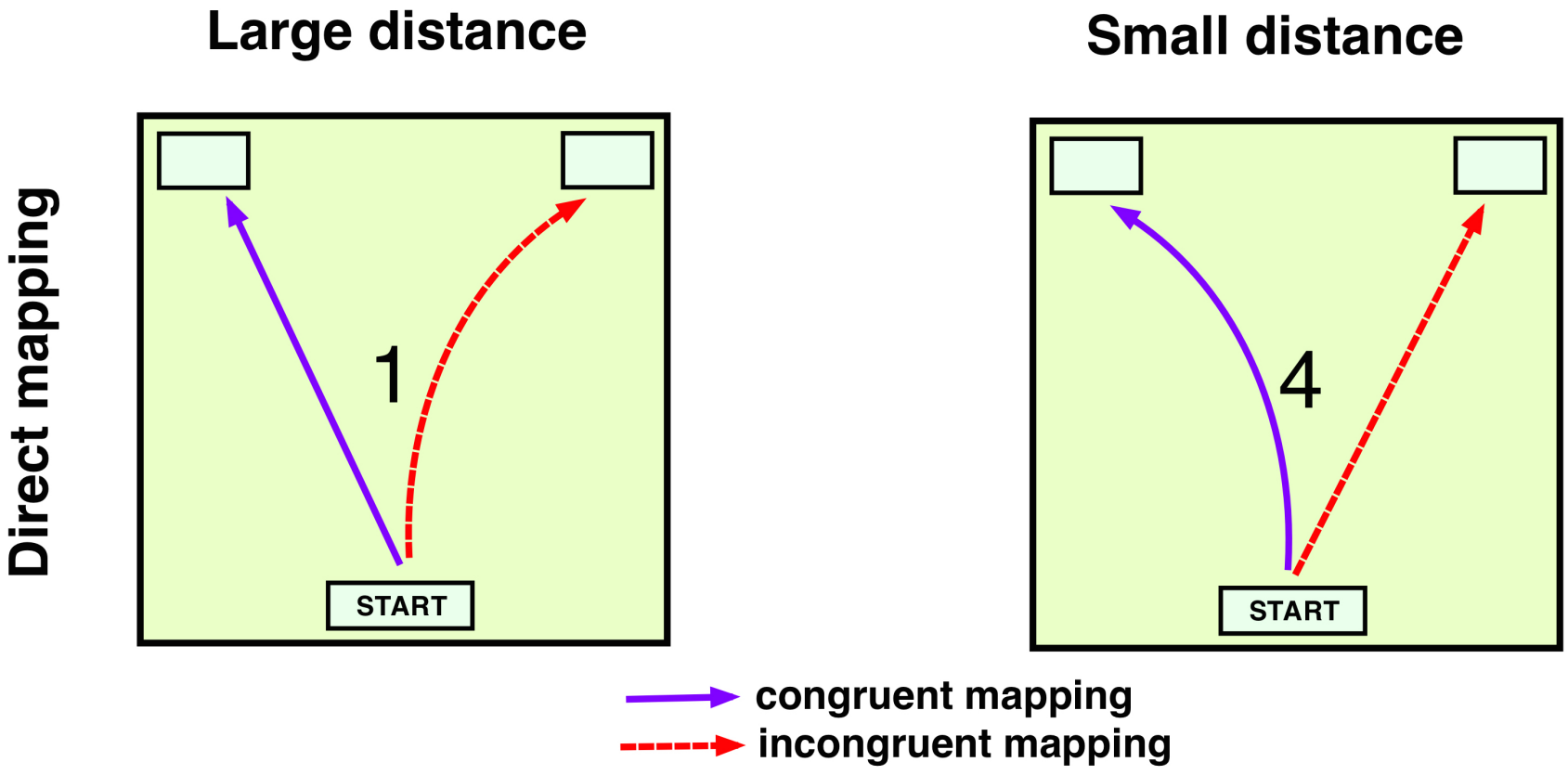
Experiment 1

Definition – asymmetry score

$$\mathcal{A} = \frac{1}{101}\left[\sum_{i=1}^{101} x_C(i) + x_I(i)\right]$$

- $x_C(i)$ = mean x-coordinate at timestep i for congruent trajectories
- $x_I(i)$ = mean x-coordinate at timestep i for incongruent trajectories
- Note:
  - $\mathcal{A} > 0 \rightarrow$ rightward bias
  - $\mathcal{A} < 0 \rightarrow$ leftward bias

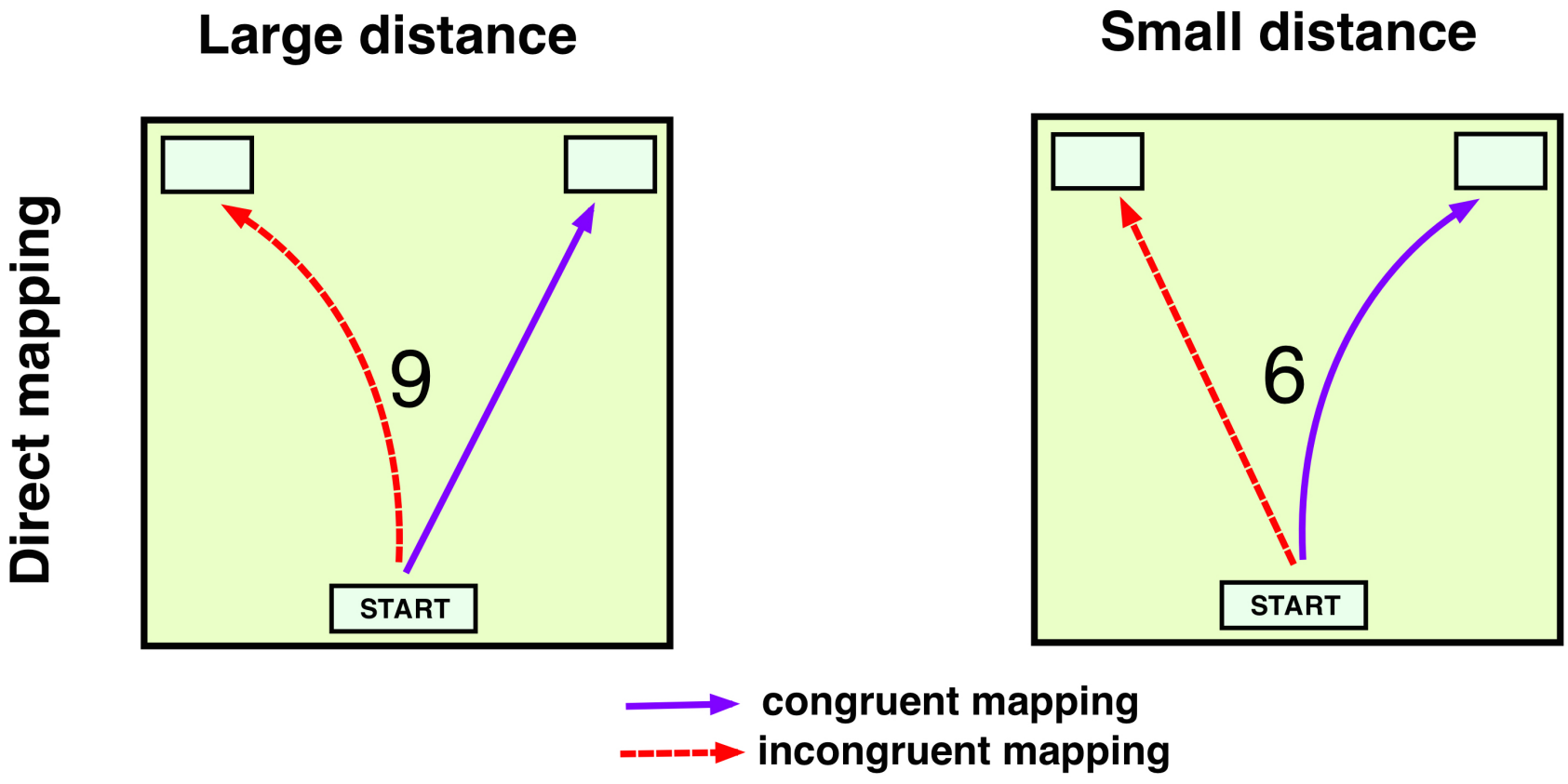
Experiment 1



Direct mapping account: small targets

- as distance from 5 increases, $\mathcal{A}$ decreases from positive to negative

Experiment 1



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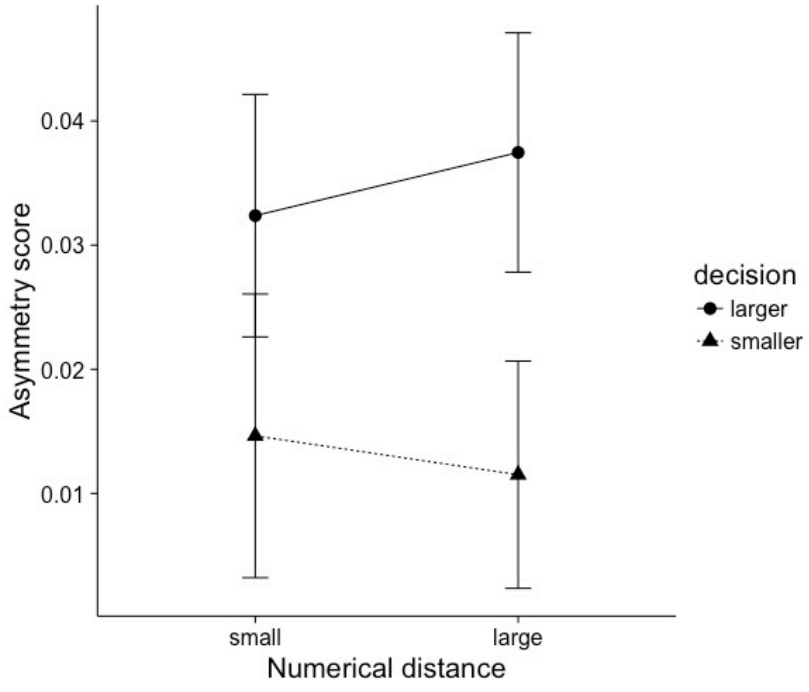
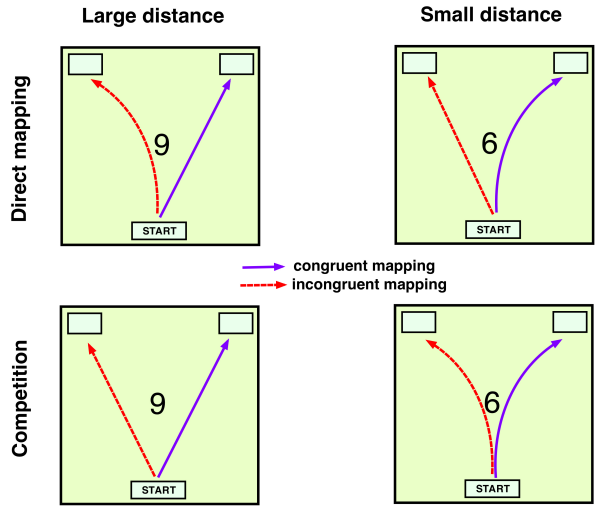
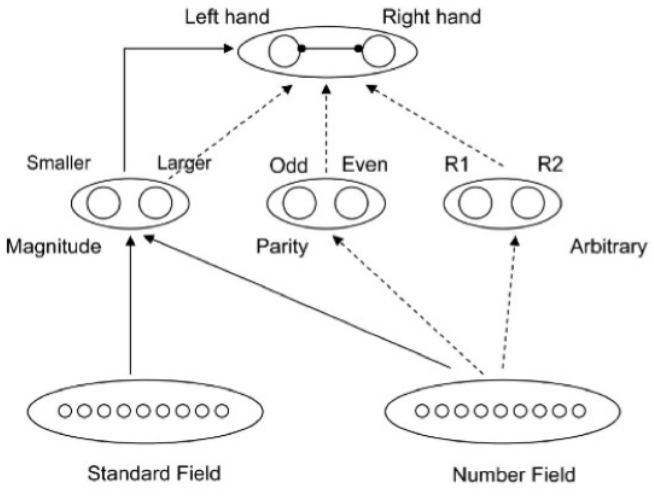


So far...





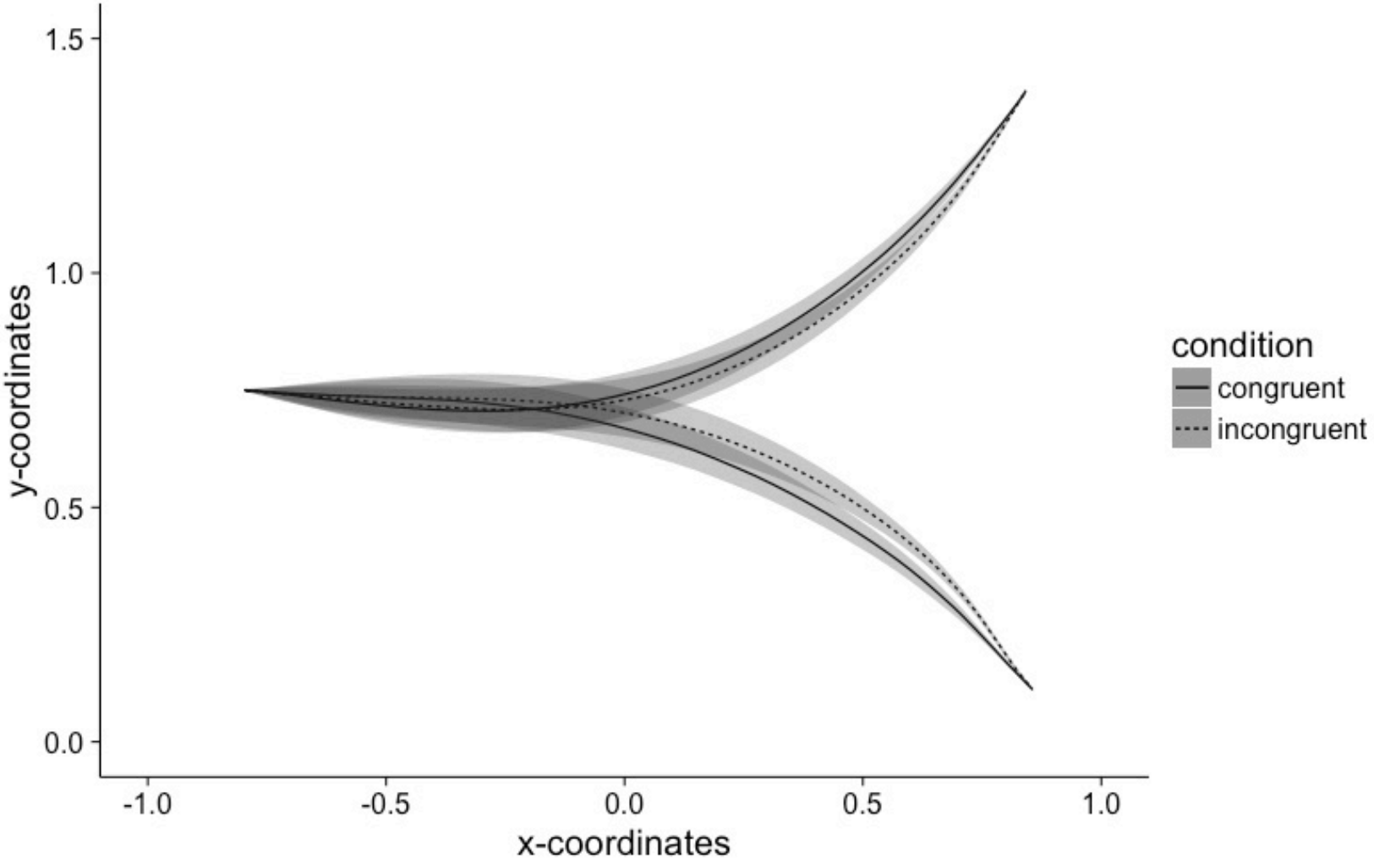
- Trajectory curvature decreases as numerical distance increases
- Decreasing curvature in spatially incongruent trials supports competition model
- Asymmetry of trajectories reveals pervasive direct mapping signature

Experiment 2

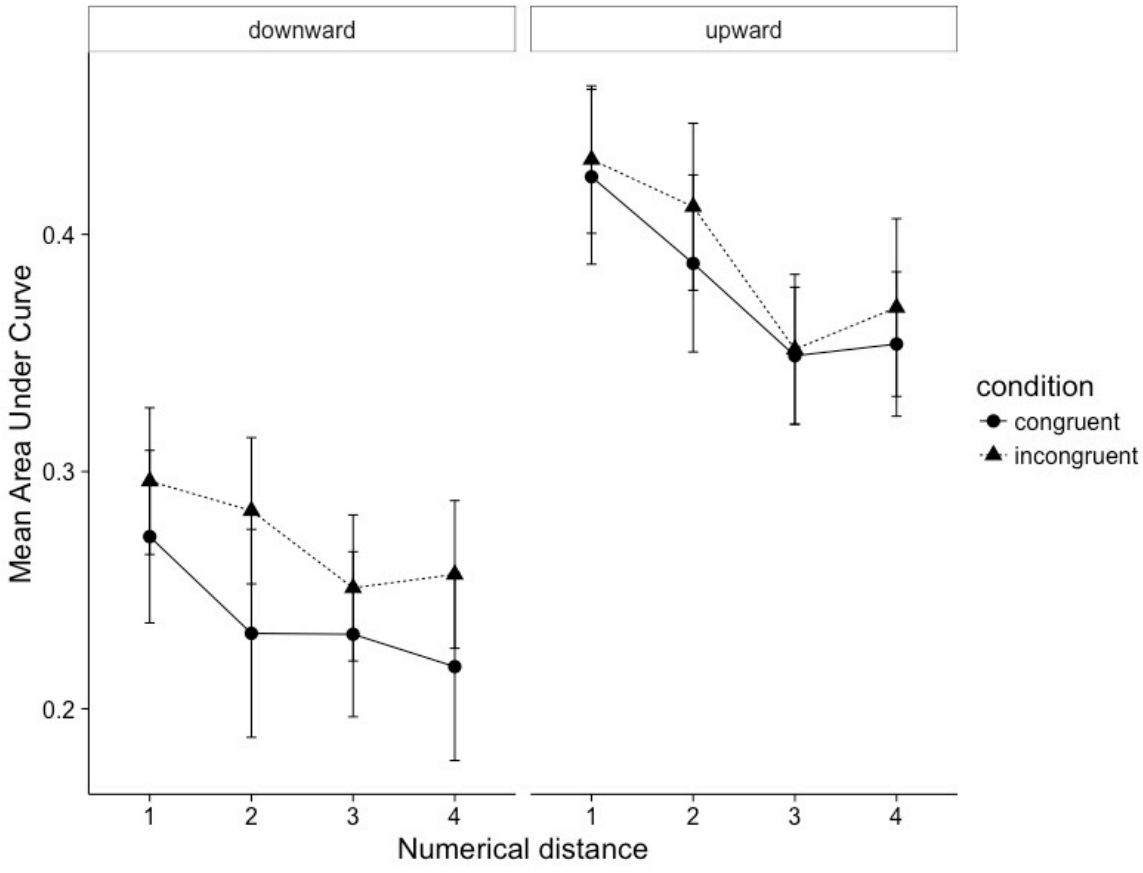
Experiment 2 - is asymmetry due to direct mapping or biomechanical constraints

- 32 participants
- same stimuli and design as Exp 1
- mouse movement rightward across computer screen

Experiment 2



Experiment 2



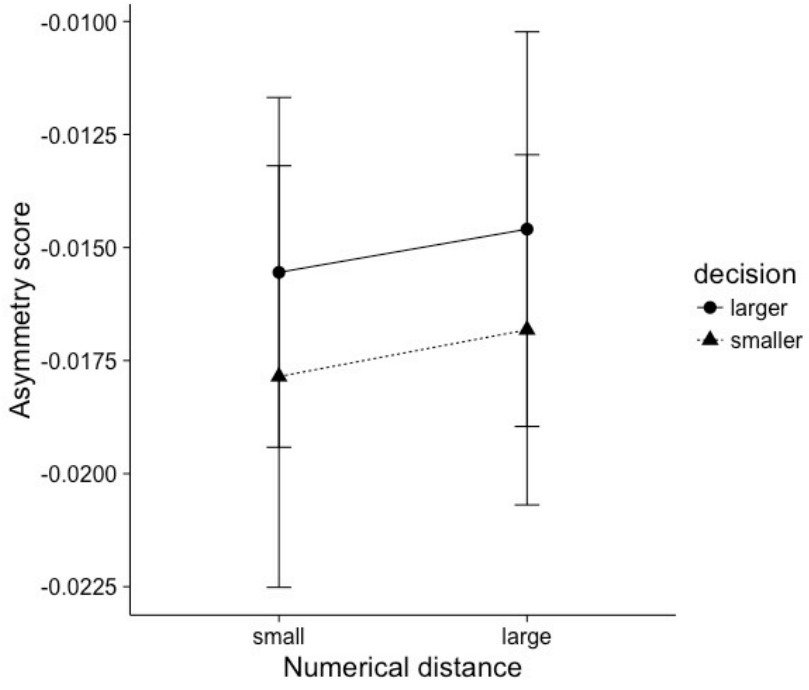
Curvatures decrease as distance increases (again supports competition model

Experiment 2

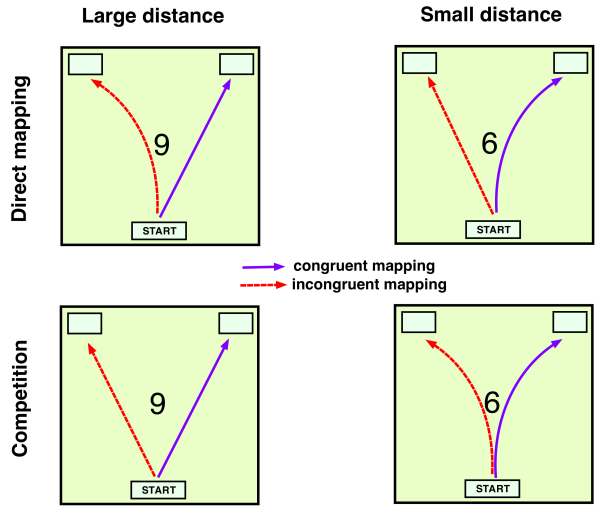
Asymmetry:

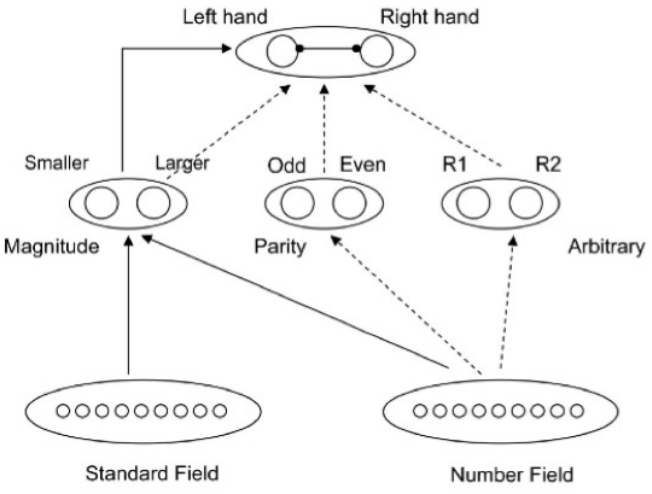
$$\mathcal{A} = \frac{1}{101}\left[\sum_{i=1}^{101} \frac{y_C(i) + y_I(i)}{2}\right] - 0.75$$

- $y_C(i)$ = mean y-coordinate at timestep i for congruent trajectories
- $y_I(i)$ = mean y-coordinate at timestep i for incongruent trajectories
- Note:
  - $\mathcal{A} > 0 \rightarrow$ upward bias
  - $\mathcal{A} < 0 \rightarrow$ downward bias



Take home





- In both experiments, trajectory curvature decreases as numerical distance increases
- Decreasing curvature in spatially incongruent trials supports competition model
- Trajectory asymmetry may not reflect underlying direct mapping representation

Contact

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