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The Influence of Perception on a Developmental Transition in Spatial Working Memory

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Department of Psychology

Title:
The Influence of Perception on a Developmental Transition in Spatial Working Memory

Abstract:
Perception and cognition are inextricably intertwined. This interaction is evident in the development of spatial memory. Early in development there is a transition in memory biases. Young children's spatial working memory (SWM) responses are biased toward the center of a homogenous space, whereas older children and adults subdivide the space along the midline symmetry axis, and their memory responses are biased away from the center of the space. According to Dynamic Field Theory (DFT), a dynamic systems model of spatial cognition, developmental changes in geometric biases in SWM are caused by changes in neural interaction in SWM and the development of children's perceptual abilities. Specifically, over development of children's ability to perceive the location of axes of symmetry improves quantitatively. Ortmann and Schutte (2010) examined whether there were changes in children's ability to perceive the location of symmetry axes by having 3- to 6-year-olds and adults determine on which half of a large monitor a smiley face was located. Three- to 6-year-olds were above chance at classifying all but the location closest to midline, and over development there was improvement in the ability to localize the axis. Despite this apparent ability to perceive the symmetry axes, 3-year-olds do not reliably subdivide space in SWM tasks (Huttenlocher et al., 1994; Schutte et al., 2009). Perhaps their perception of midline is too "fuzzy" for them to use it as a reference axis in memory. Two studies support this proposal. First, when given perceptual support (i.e., cues on midline), 3-year-olds subdivide the space. Second, 3-year-olds' perception of the midline symmetry axis is related to their memory biases. Specifically, children who are better able to determine on which side of midline a target is located are more likely to be biased away from midline in the spatial memory task for all targets except the two closest to midline. These results support Dynamic Field Theory and demonstrate interactions between perception and cognition over development.

The Influence of Perception on a Developmental Transition in Spatial Working Memory

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Why study the development of spatial cognition?

- Related to STEM
- Related to later mathematical ability
- Developmental disorders
  - ADHD
  - Williams syndrome

Why study spatial memory development?

- Function in our world

Spatial Memory

Outline

- Development of spatial working memory (SWM) in Early Childhood
- Dynamic Field Theory
- Integration of cognition and perception

Development of SWM in Early Childhood

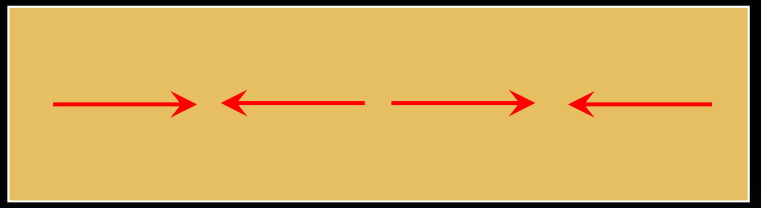
- Memory in homogeneous space

- Continuous measure
- Same measure over development

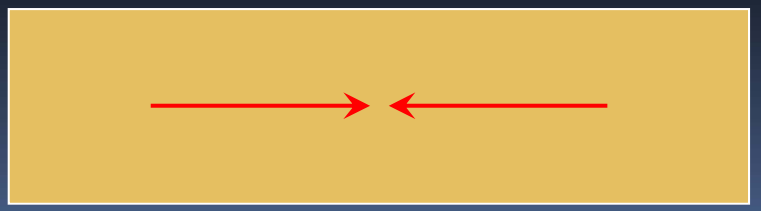
Development of SWM in Early Childhood

- A developmental shift in "geometric" biases (Huttenlocher et al., 1994)

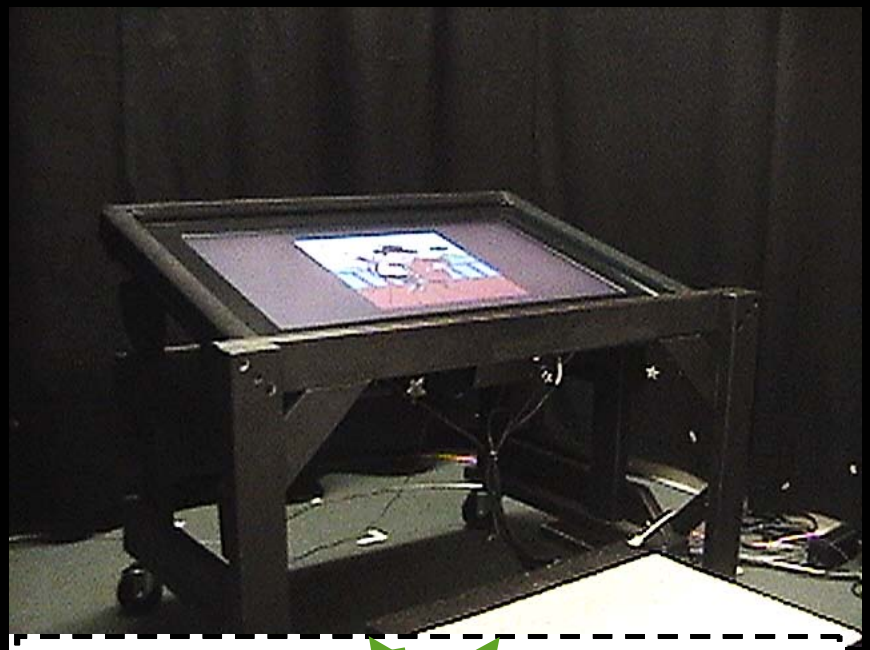
LATE (e.g., 9 yrs)

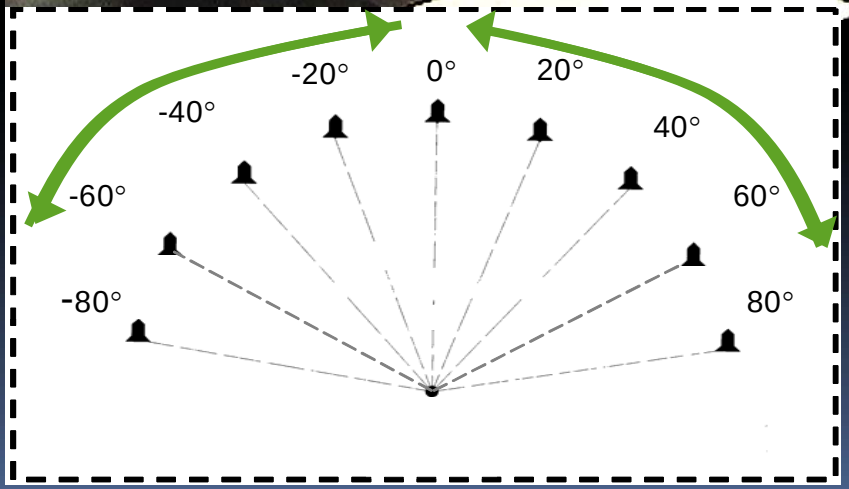


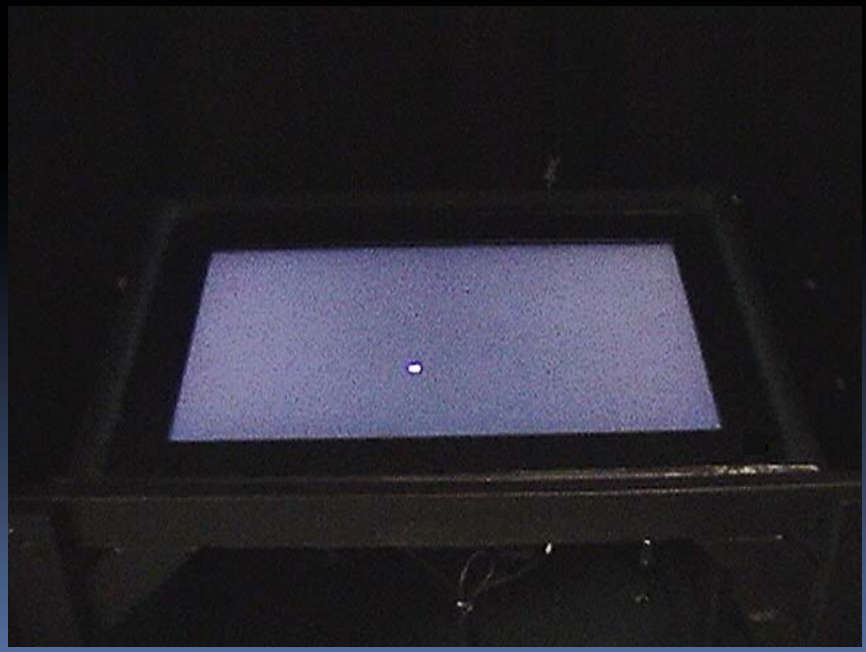
EARLY (e.g., 3 yrs)



Spatial Memory Video Game







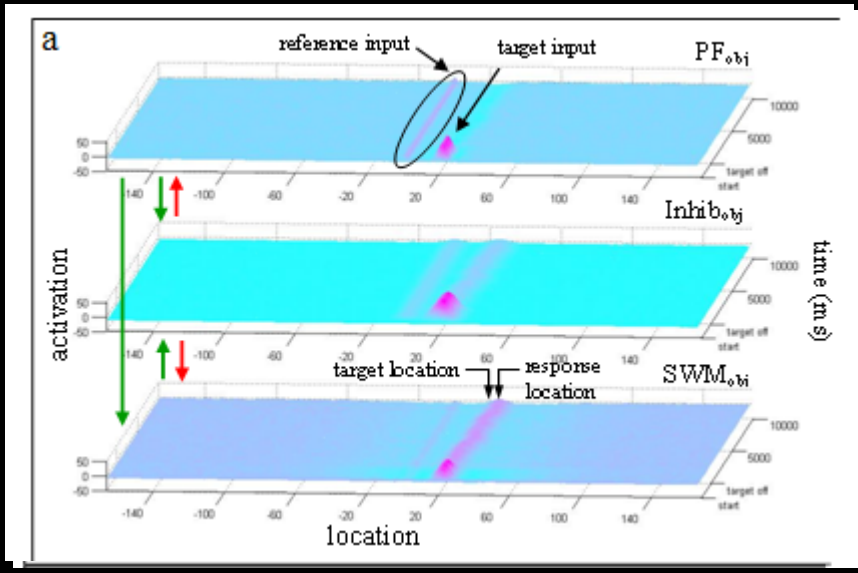
How do we explain this transition?

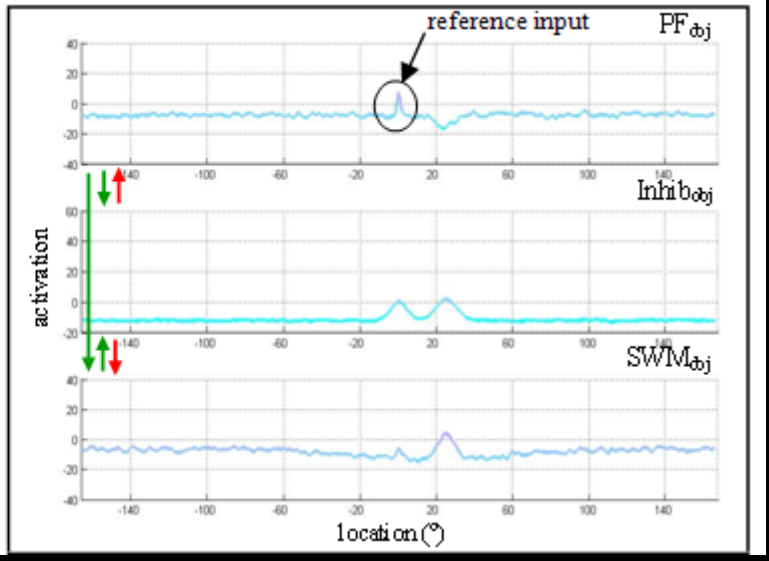
- spatial memory is a dynamic system evolving over time (developmental and real time scales)

Dynamic Field Theory

- Dynamic systems model
- Integrates perception and cognition over real and developmental time
- Uses dynamic neural fields to model spatial cognition

Dynamic Field Theory

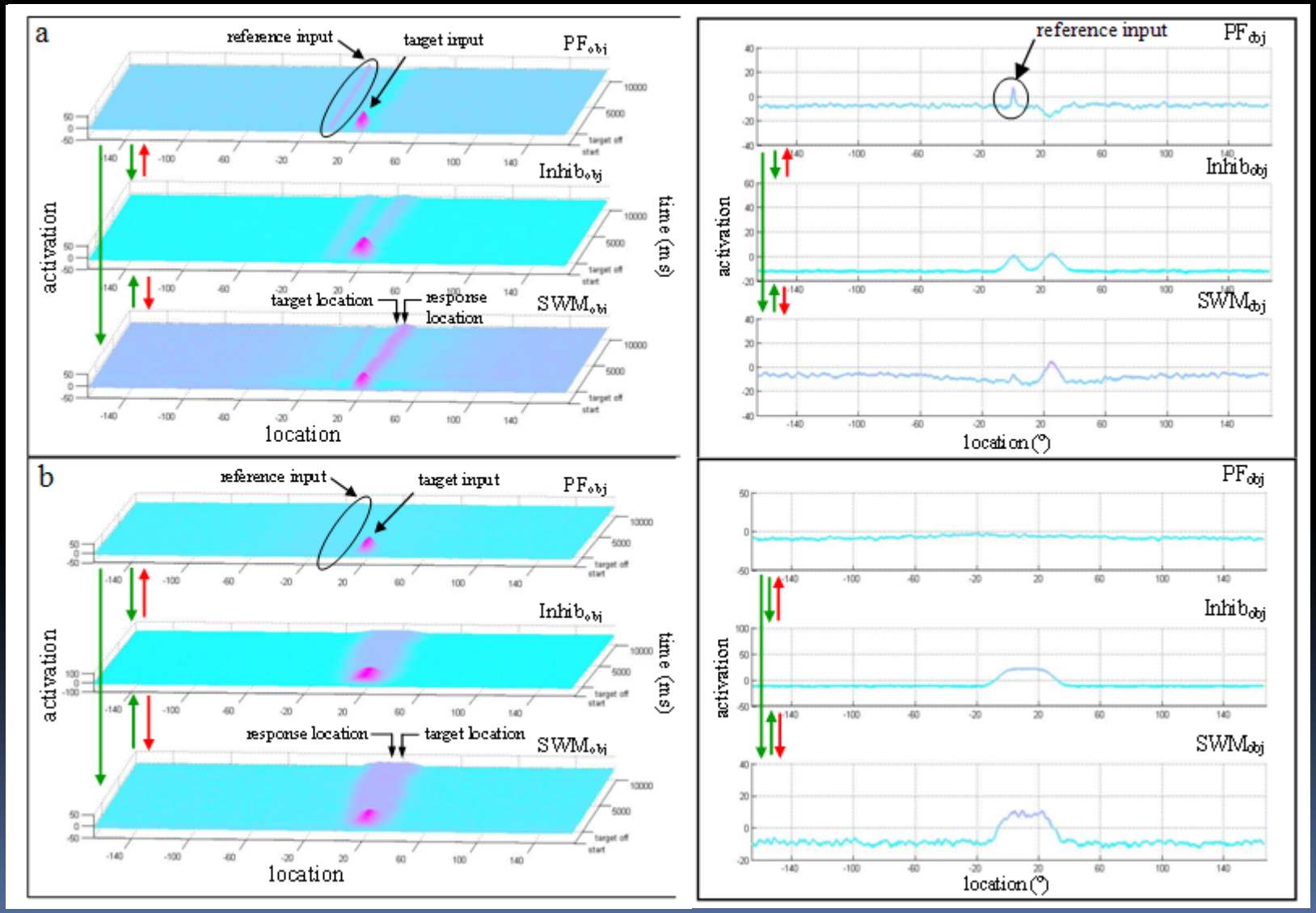




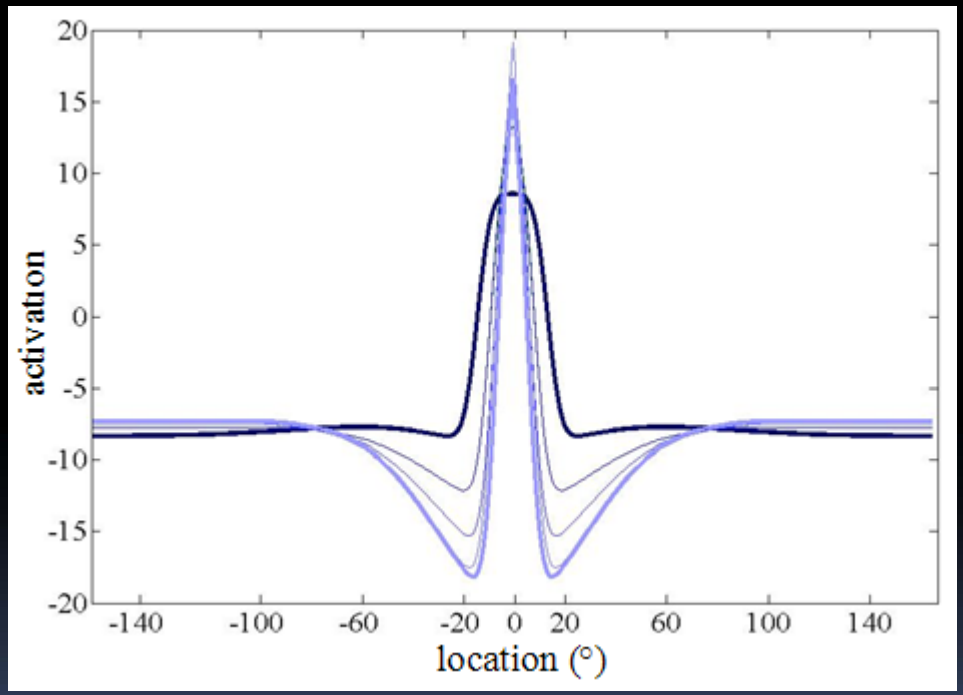
Dynamic Field Theory (DFT): What develops?

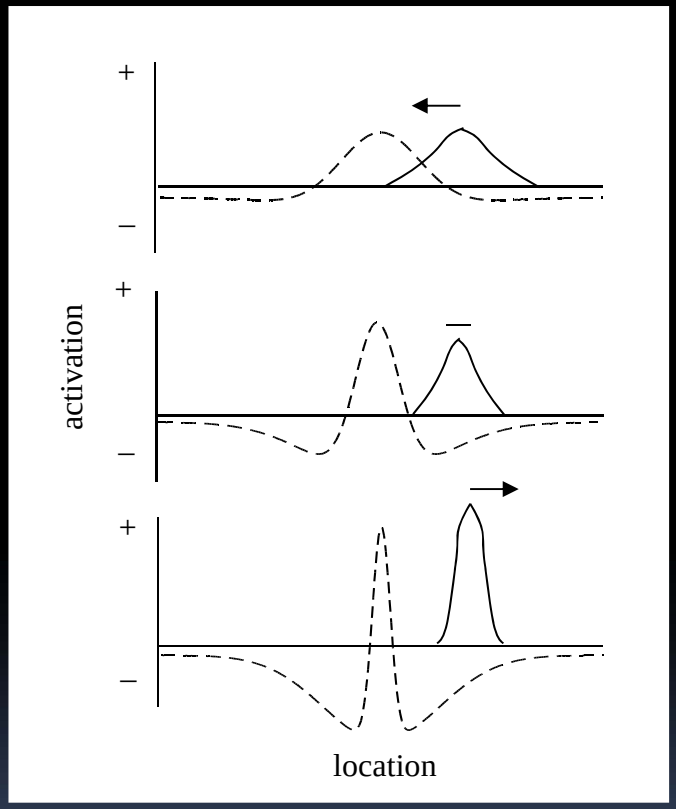
- Two developmental processes:
  - Spatial precision: stronger neural connections
  - Perception of midline symmetry axis

Dynamic Field Theory

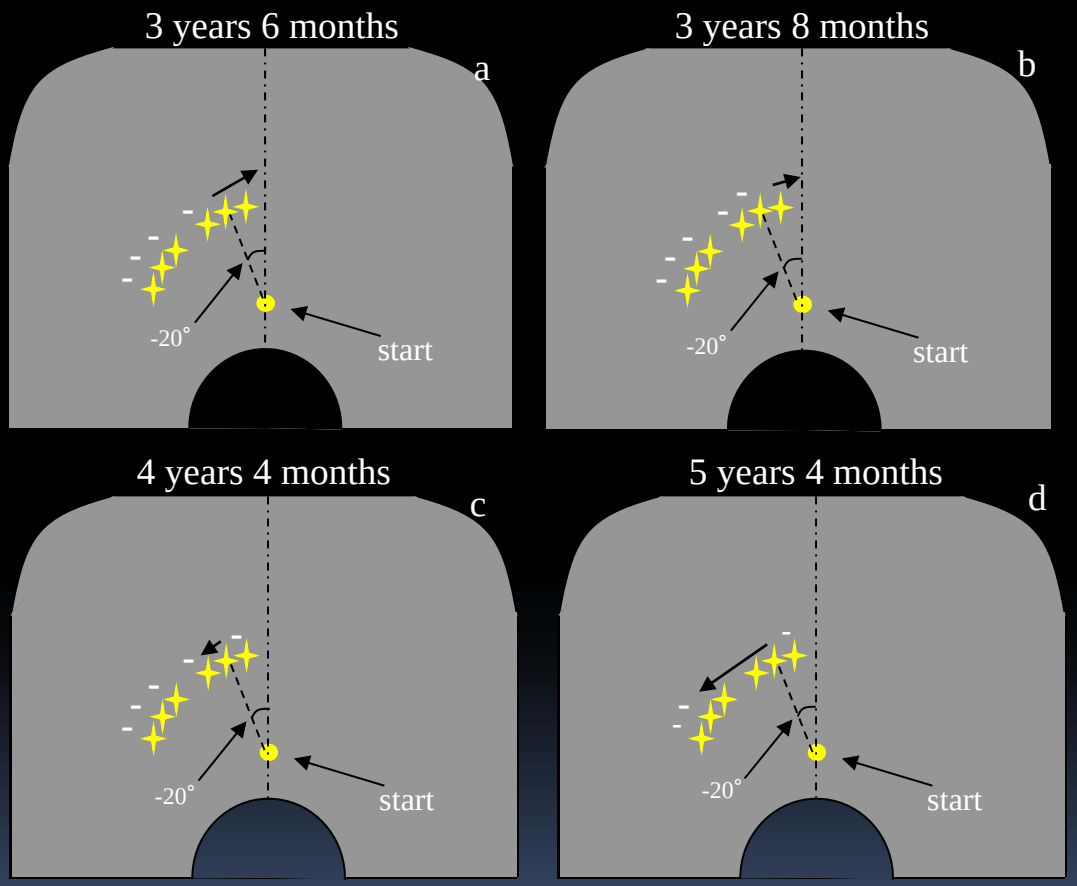


Spatial Precision Hypothesis




+
–
+
–
+
–
activation
location

Geometric biases over development



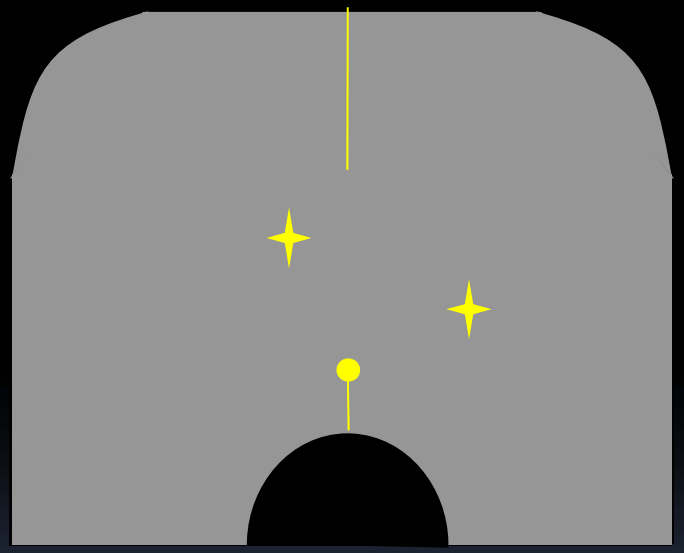
Schutte & Spencer, 2009

Dynamic Field Theory (DFT): What develops?

- Two developmental processes:
  - Spatial precision
  - Perception of midline symmetry axis

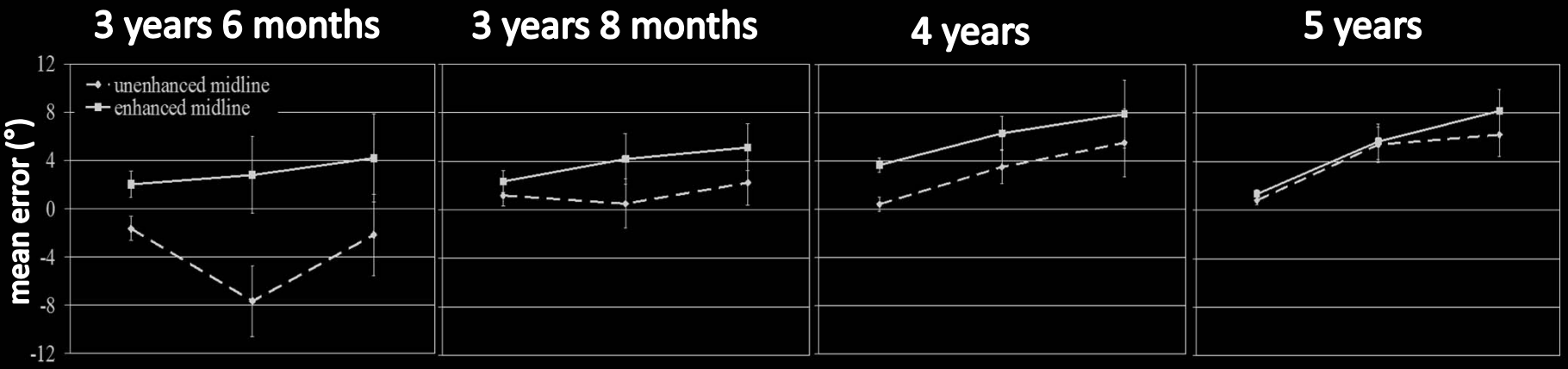
Prediction:

Children younger than the transitional age will show a more advanced developmental pattern when tested with a perceptually salient midline axis.

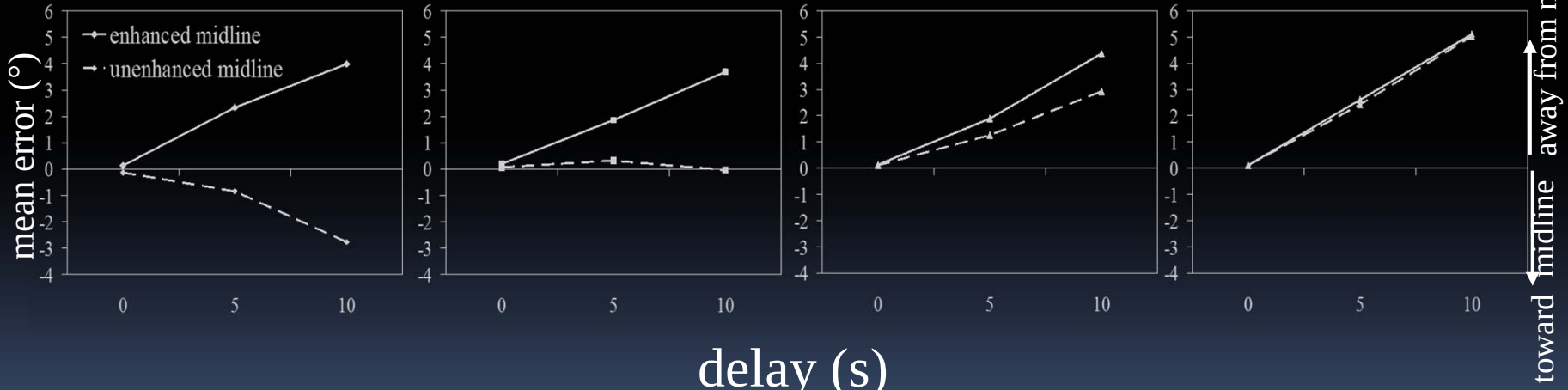


Schutte & Spencer, 2010

Children

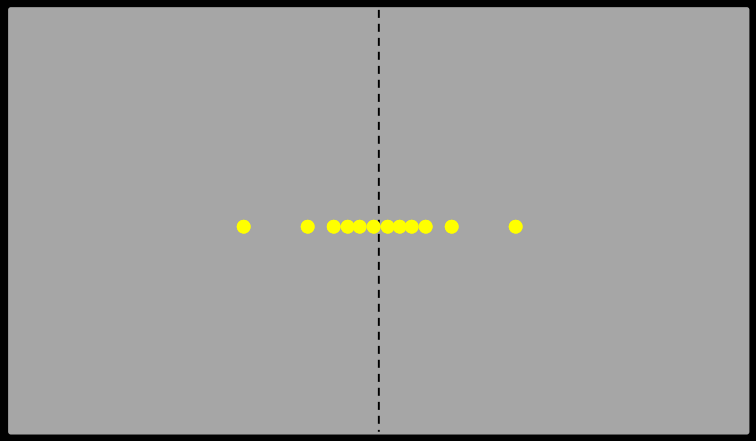


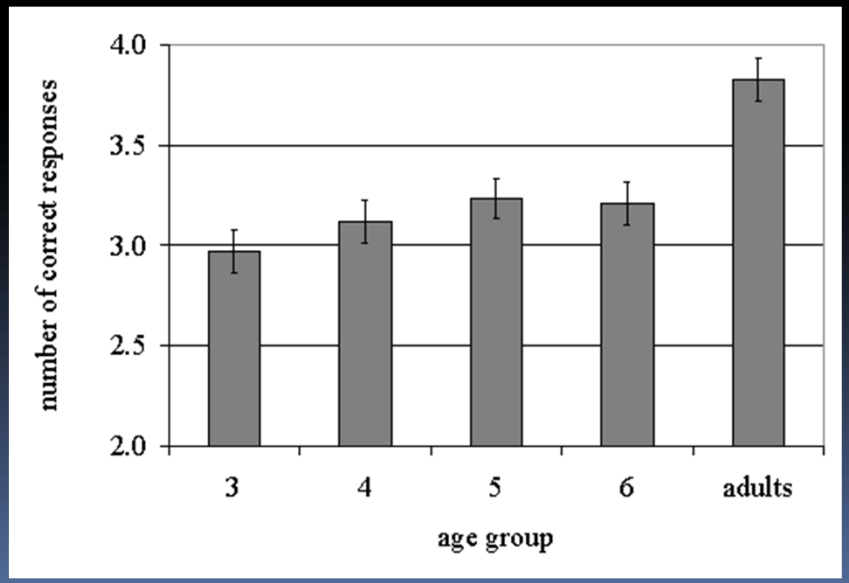
Model



Perception of Midline Symmetry Axis

- significant age effect
- 3- to 6-year-olds above chance for all but location closest to midline





Ortmann & Schutte (2010)

…but are they related?

- Correlation between perception of axis and memory biases?
- DFT prediction: correlation between width of midline input and memory error for intermediate target locations

Simulation correlations:

target location	correlation of error with midline input width	p-value
5°	.04	.591
10°	.25	<.001
20°	.61	<.001
40°	.13	.056
60°	.10	.138

Methods

- 18 3-year-olds (3 years 6 months)
- 4 sessions
  - session 1: spatial memory task
  - session 2-4: midline perception task

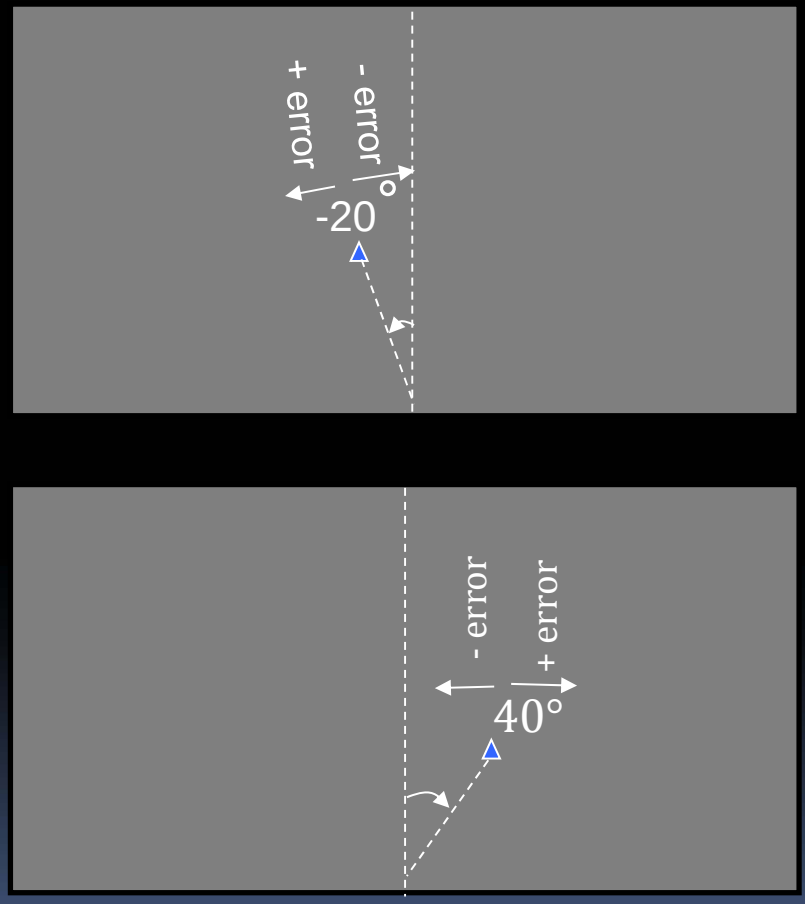
Spatial Memory Task

Task: remember target location on monitor

Delays:

- 100 milliseconds
- 10 seconds

Targets: ± 5º, ±10º, ±20º, ± 40º, ±60º

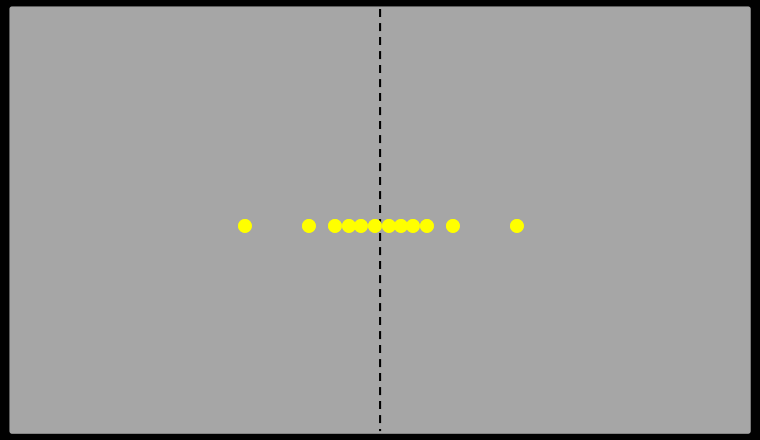


Midline Perception Task

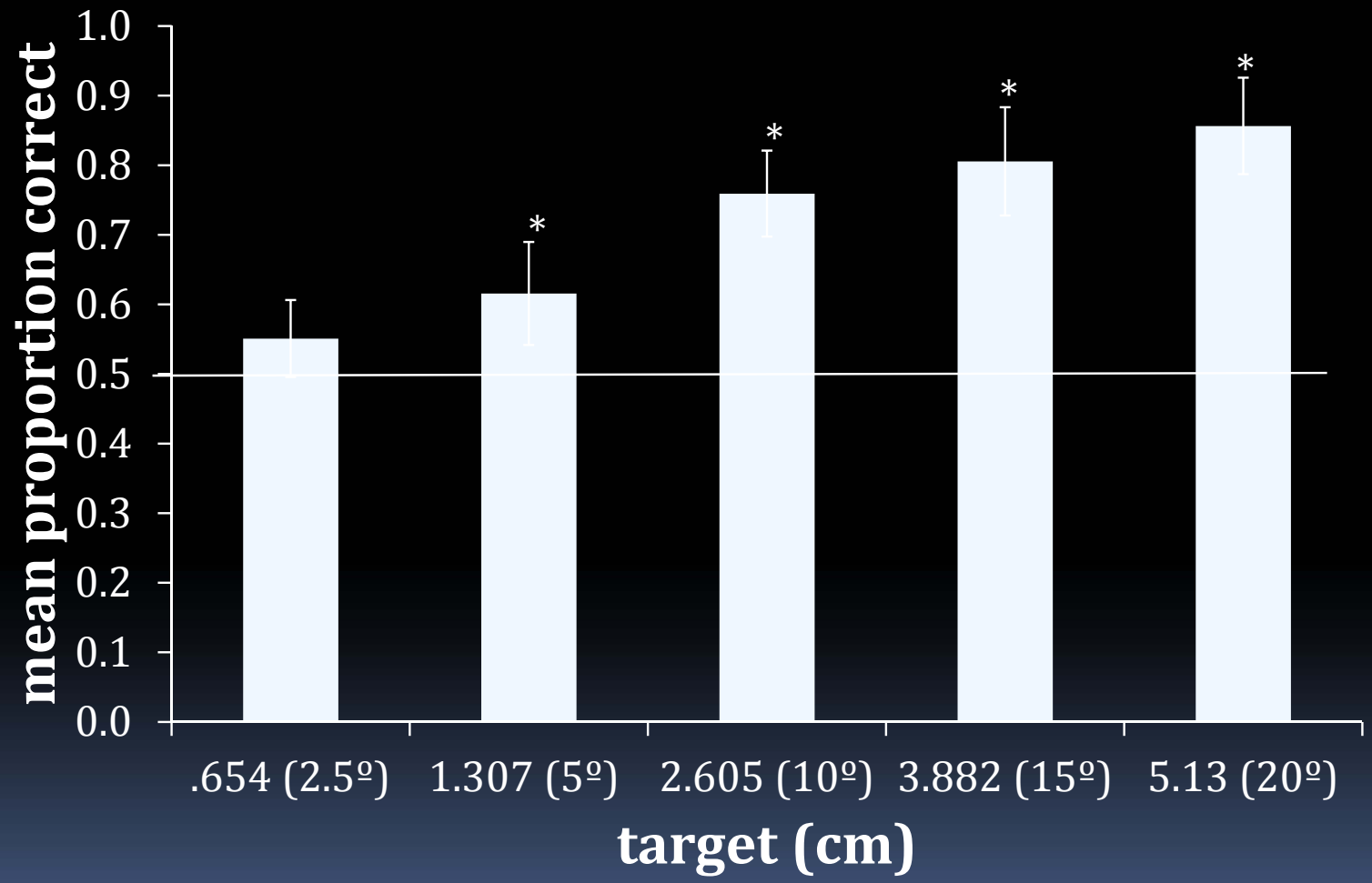
Task: 2 identical twins—one living on each side of midline. Children used a joystick to indicate which "twin" they saw.

Target locations relative to midline:

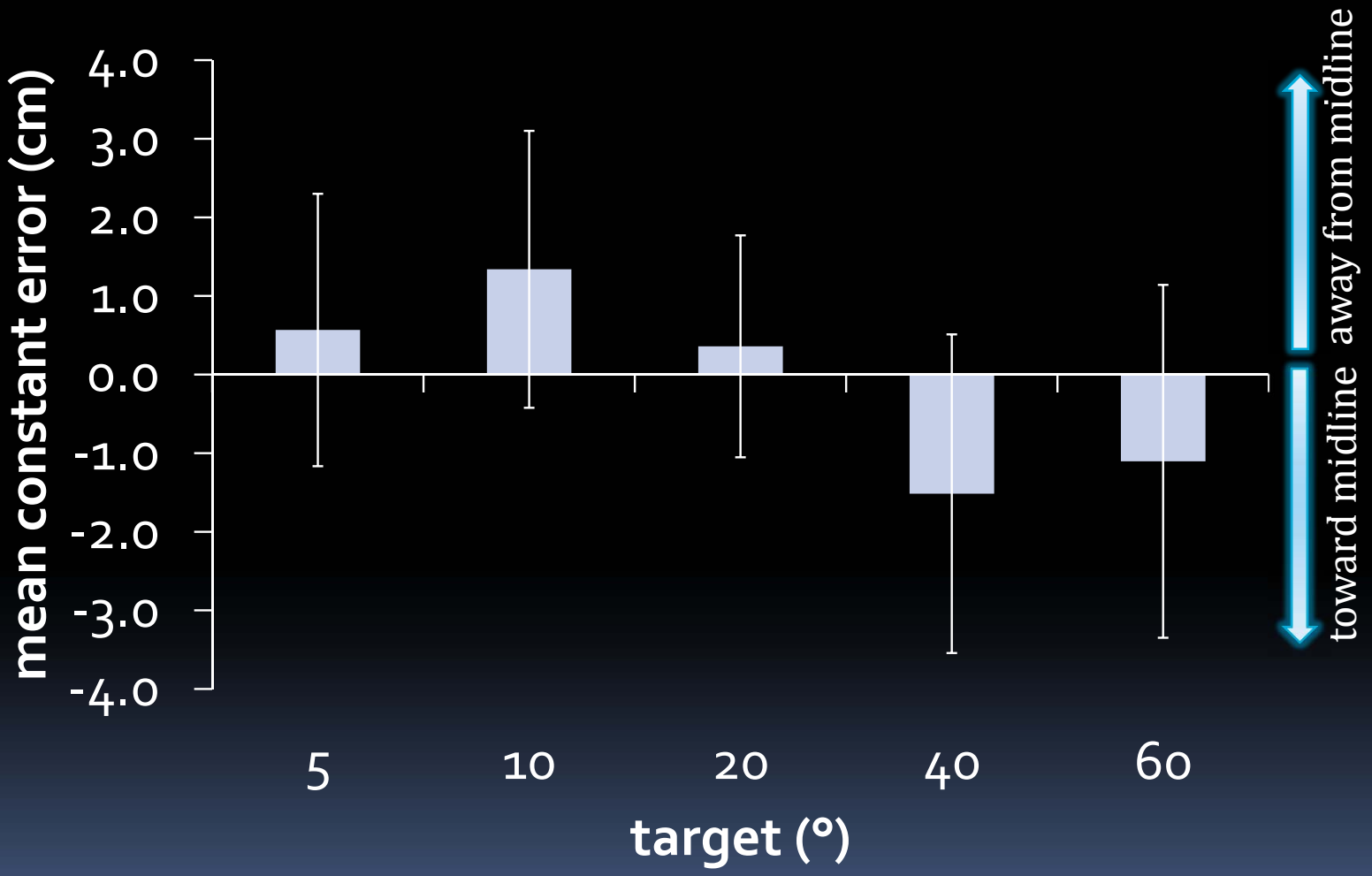
- ±11.491 cm (50°, control location)
- ±5.13 cm (20°)
- ±3.882 cm (15°)
- ±2.605 cm (10°)
- ±1.307 cm (5°)
- ±.654 cm (2.5°)



Results: Midline perception task



Results: Spatial memory task

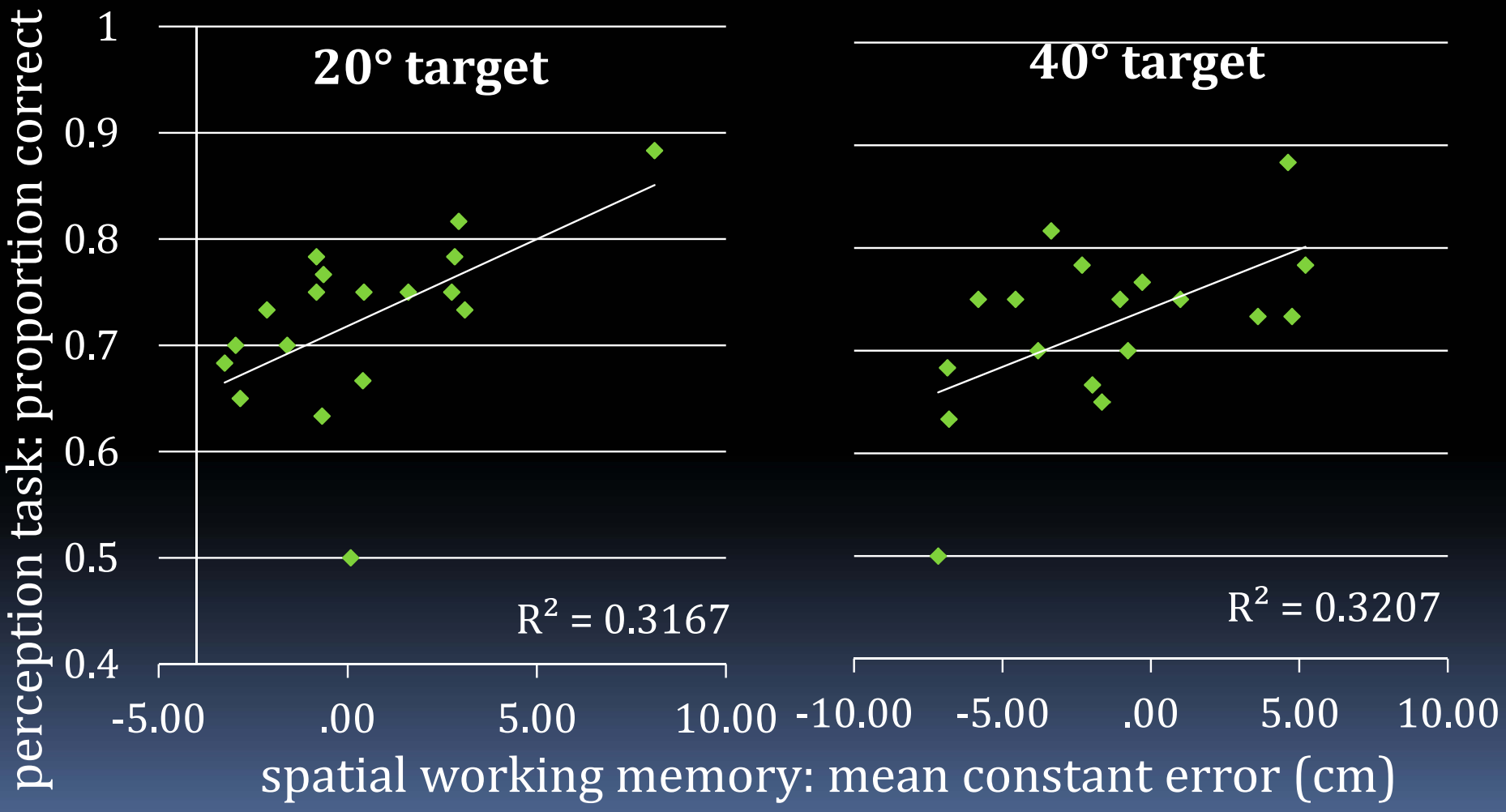


Correlations in 3-year-olds

target location (spatial memory task)	correlation with perception task	p-value (2-tailed)
5°	-.09	.72
10°	.27	.28
20°	.56	.02
40°	.57	.01
60°	.20	.43

target location	correlation with axis width	p-value
5°	.04	.591
10°	.25	<.001
20°	.61	<.001
40°	.13	.056
60°	.10	.138

Results:


20° target
40° target
perception task: proportion correct
1
0.9
0.8
0.7
0.6
0.5
0.4
R² = 0.3167
R² = 0.3207
-5.00
.00
5.00
10.00
-10.00
-5.00
.00
5.00
10.00
spatial working memory: mean constant error (cm)

Discussion

- Spatial memory errors correlated with ability to localize the symmetry axis of the space
  - Pattern of correlations: intermediate targets were significantly correlated
- Perception of symmetry axis influences direction of spatial working memory error

Conclusions

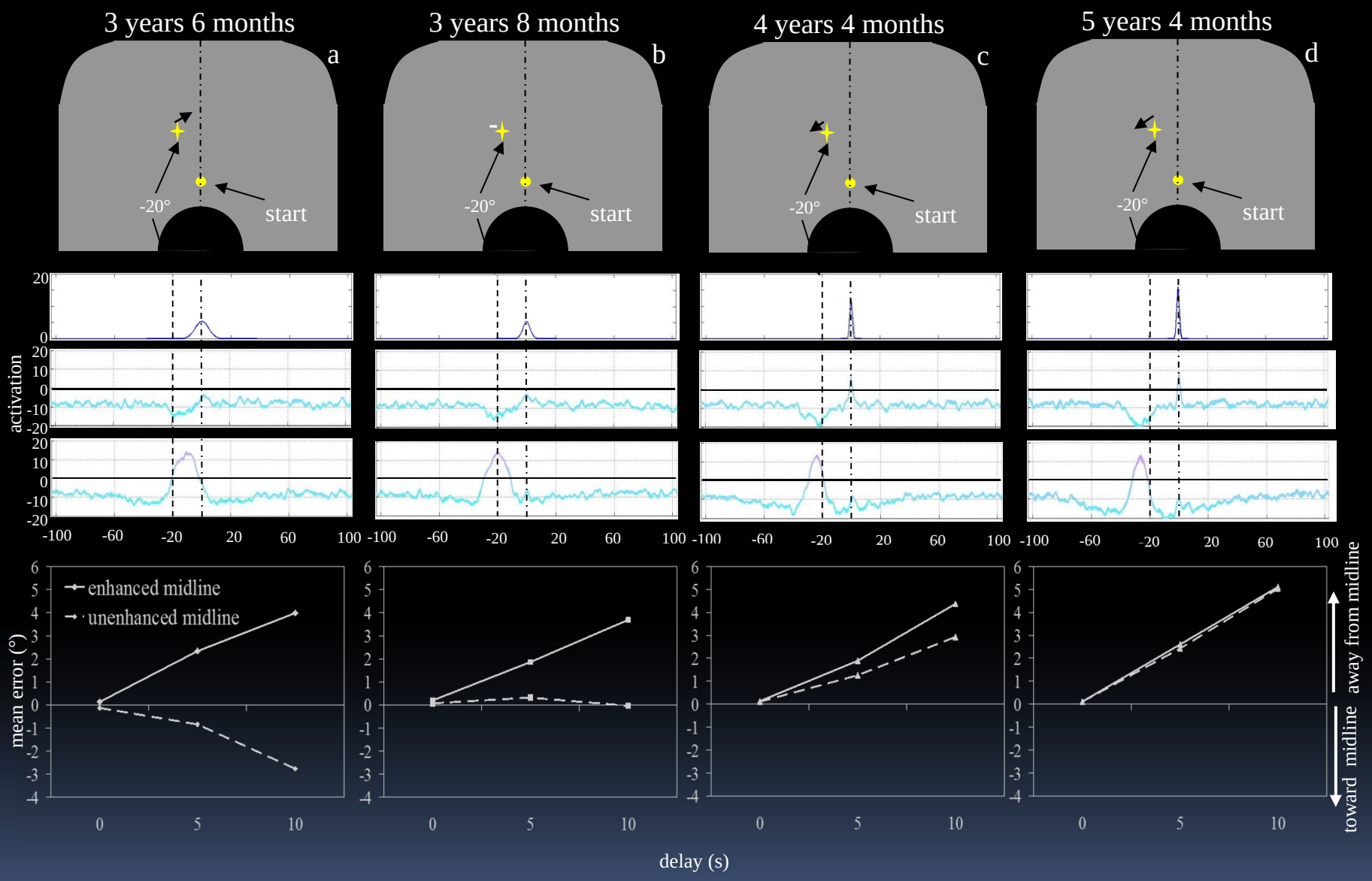
- Dynamic systems theory
  - Perception and cognition are part of a self-organizing system
  - Variability

- Next steps: What influences development :
  - of perception of symmetry axes?
  - of precision of spatial working memory?

Thanks to:

- Margaret Ortmann
- Research Assistants
- Parents and children

- Supported by NICHD R03 HD053359

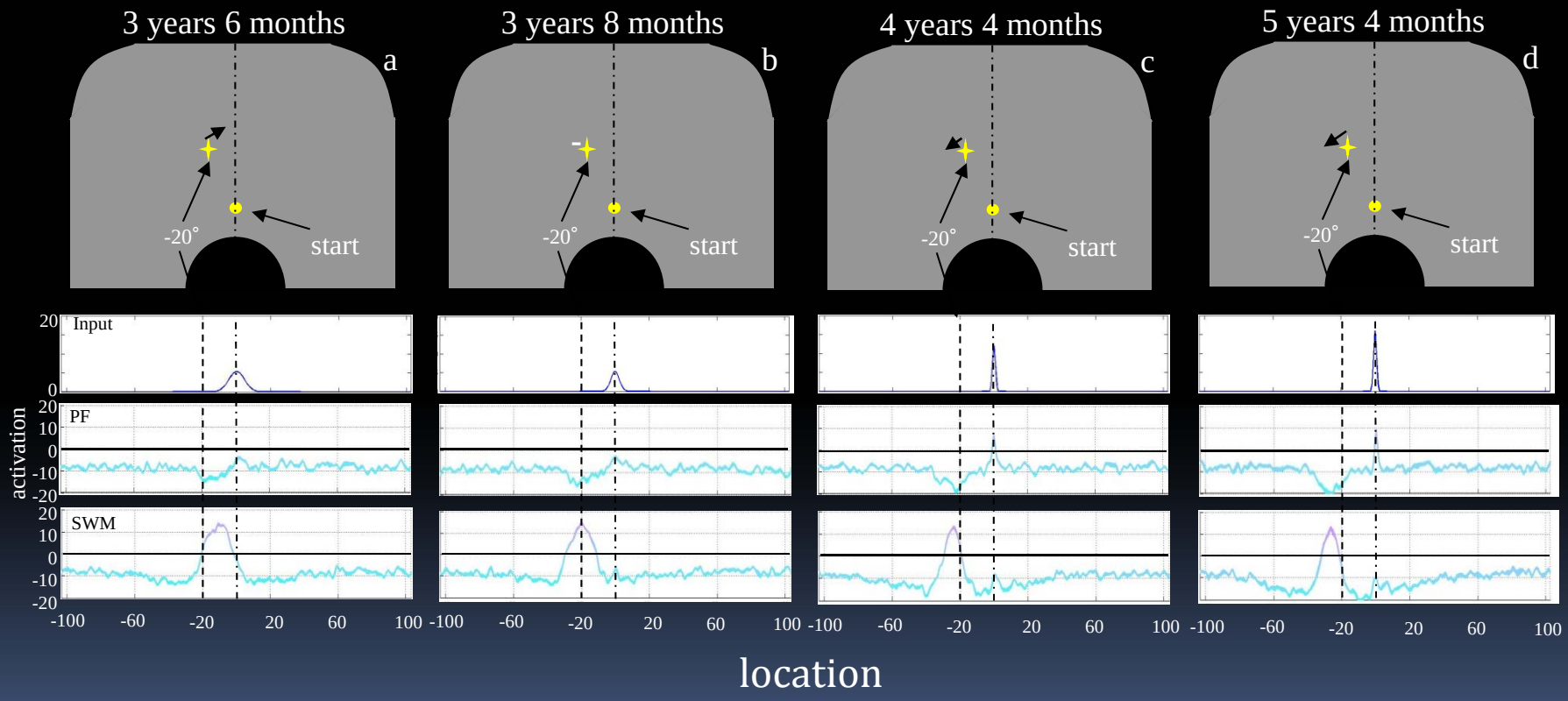


Schutte & Spencer, 2010

Computational Models: Advantages

- Make theory's assumptions explicit
- High level of control for testing a theory
- Provides a unified framework

Example for one target location



Schutte & Spencer, 2010

Reference input (midline)