Coordinate Systems for Movement Planning

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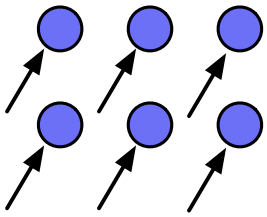
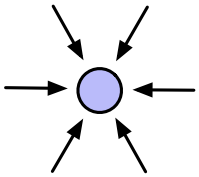
Reach Coding

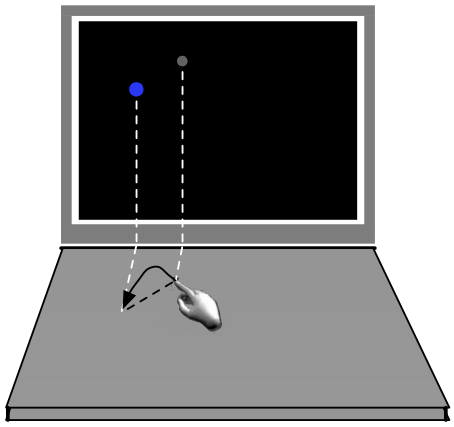


Ghez et al., 1997, 2007
Ghilardi et al., 1995
Rossetti et al., 1995
Scheidt & Ghez, 2007
Vindras et al., 2005



Shadmehr et al., 1993
Thaler & Todd, 2009
van den Dobbelsteen et al., 2001

Reach Coding



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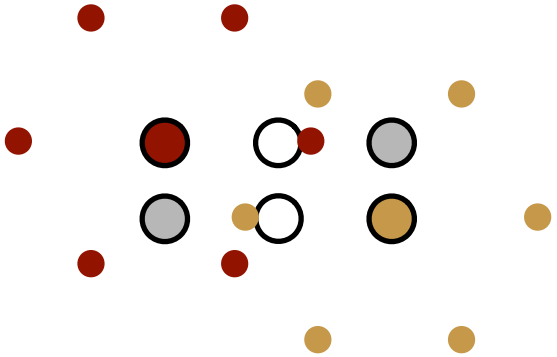

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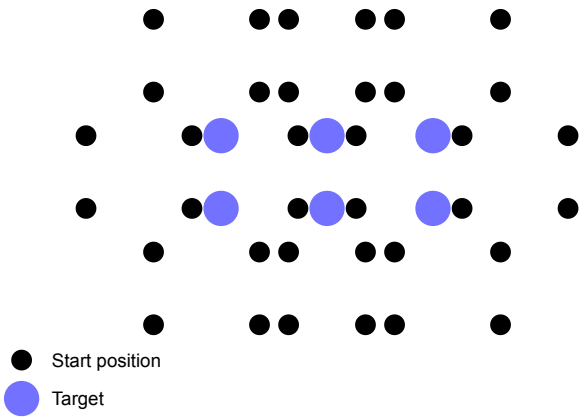
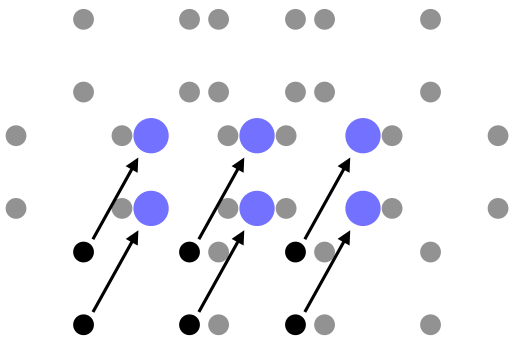
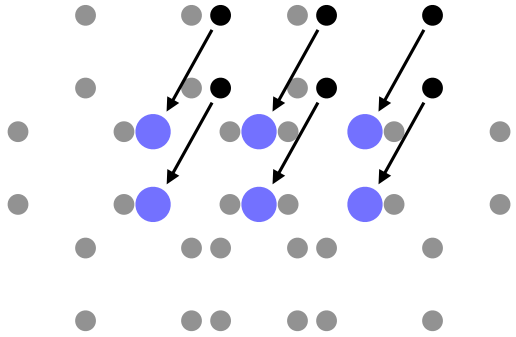


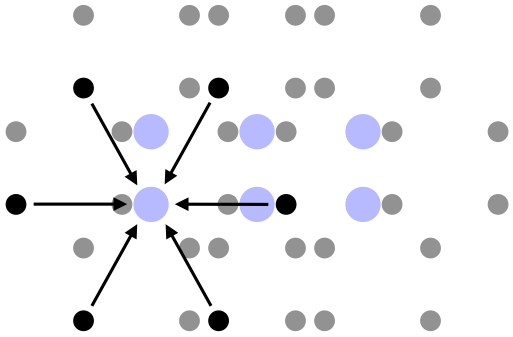
Reach Coding – Vector Grouped



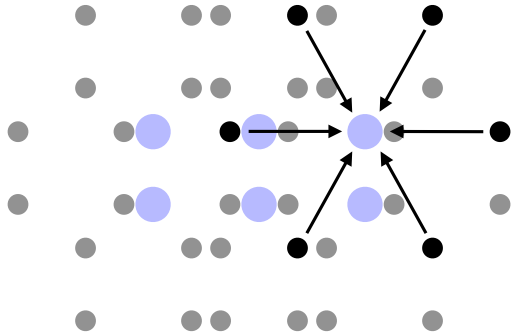
Reach Coding – Vector Grouped



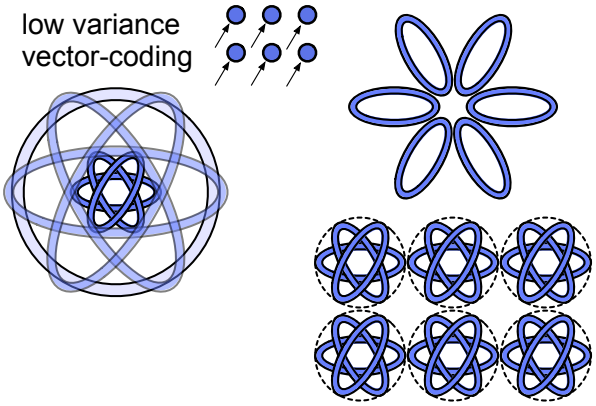
Reach Coding – Target Grouped



Reach Coding – Target Grouped



Reach Coding – Predictions



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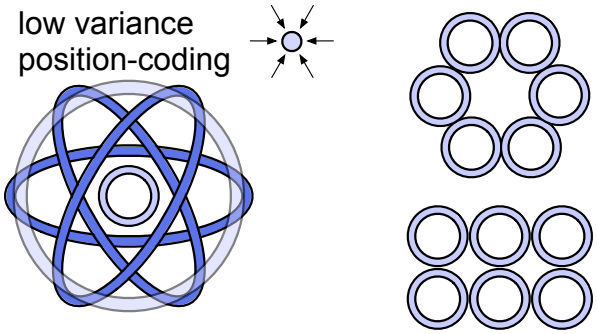
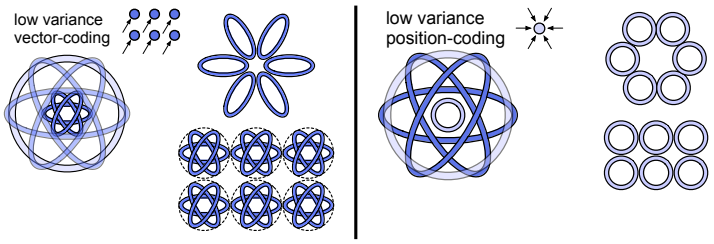
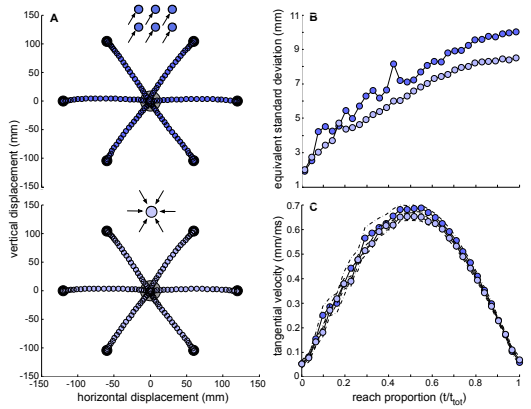


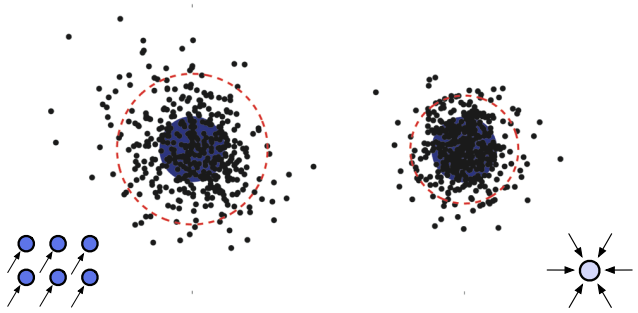
Reach Coding – Predictions



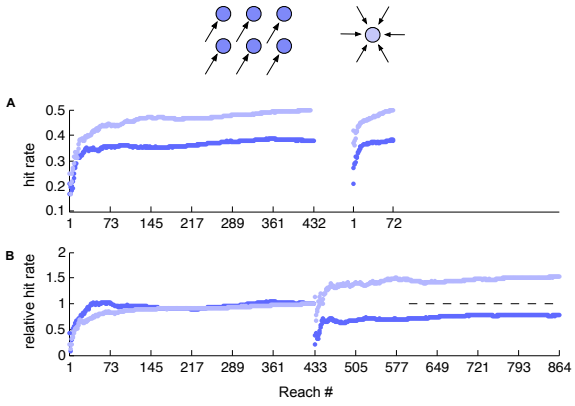
Reach Coding – No Effect of Grouping on Mean Trajectory



Reach Coding – Variability is Larger for Vector-Grouped Reaches

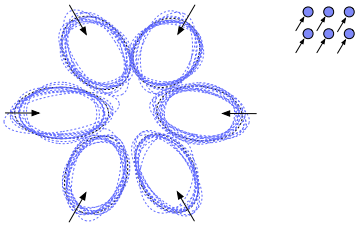


Effect of Grouping on Hit Rate

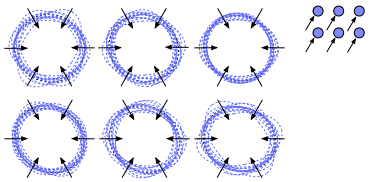


Variability: Vector-Grouped Reaches

Pooled by vector:



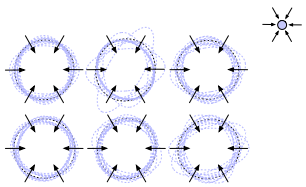
Pooled by target:



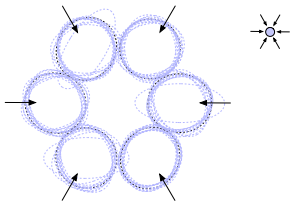
Ellipse areas normalized

Variability: Target-Grouped Reaches

Pooled by target:

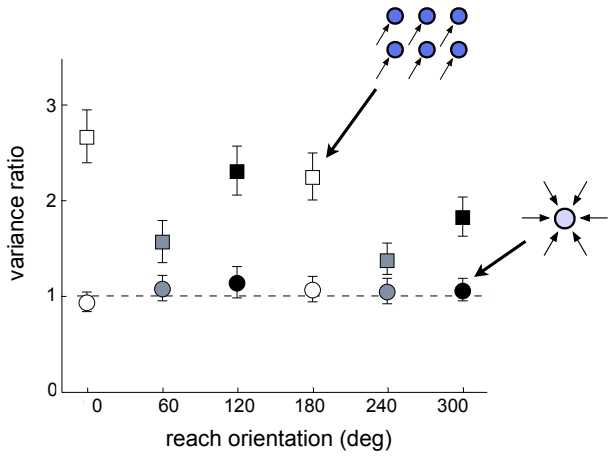


Pooled by vector:



Ellipse areas normalized

Variance Ratio: Along/Across Reach



Summary

We have provided evidence for two movement-planning systems: vector- and target-based.

Each system improves when practice is grouped in the manner appropriate for that system (i.e., by vector or by target).

The vector-based system produces anisotropic variability, larger along the reach direction; the target-based system produces isotropic and, at asymptote, lower variability (and hence higher hit rate).

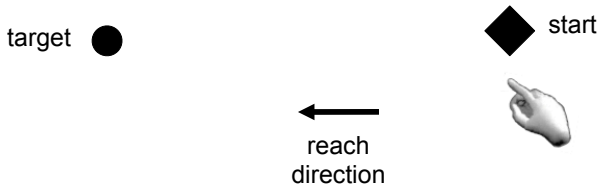
Hudson & Landy, *J Neurophysiol*, 2012

Hypothesis

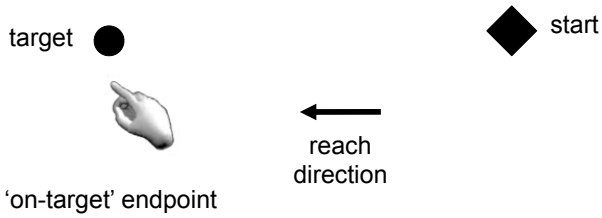
There is a large amount of evidence that multiple sensory cues are combined optimally in sensory estimation.

Perhaps multiple movement plans (i.e., vector- and target-based) are also combined optimally, taking into account their current respective variances, to form the movement command.

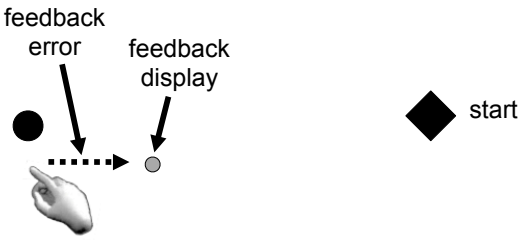
Reach Adaptation



Reach Adaptation

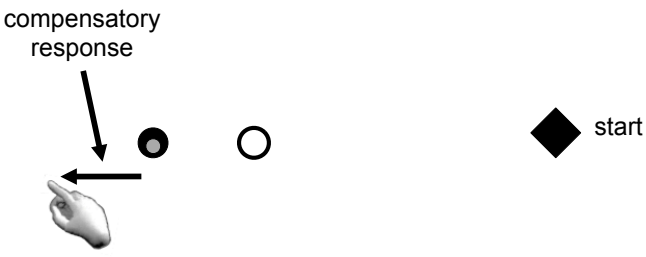


Reach Adaptation



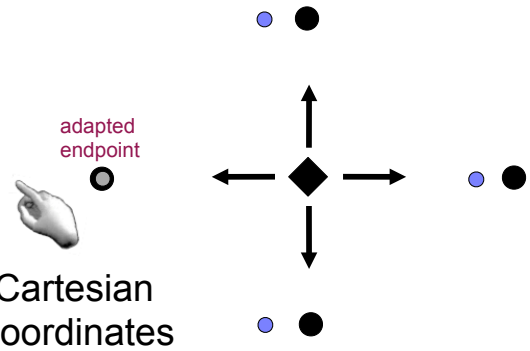
Shift reach feedback, leading in this case to evidence for too-low reach gain.

Reach Adaptation



Compensatory response: reach further so that feedback is on-target.

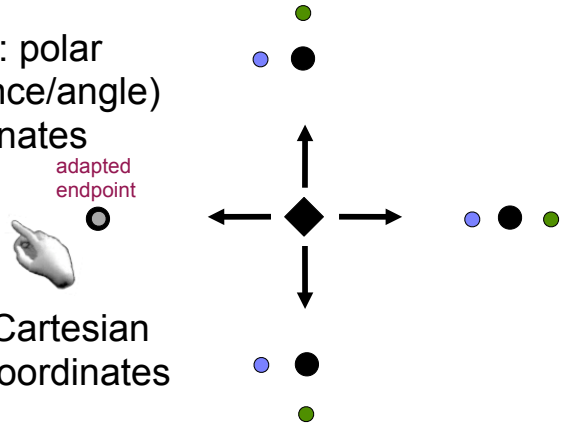
Reach Adaptation - Coordinate Frame



Blue: Cartesian (x/y) coordinates

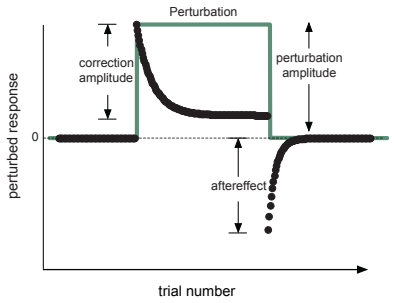
Reach Adaptation - Coordinate Frame

Green: polar (distance/angle) coordinates



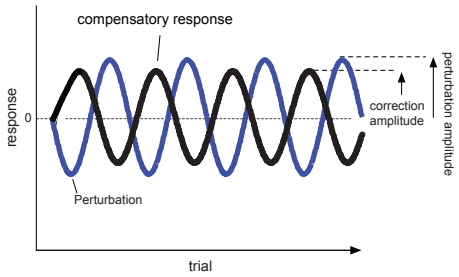
Blue: Cartesian (x/y) coordinates

Measuring Adaptation: Step-function Adapter



Problems
- perturbation needs to be large (and noticeable)
- dynamics fast and thus hard to measure

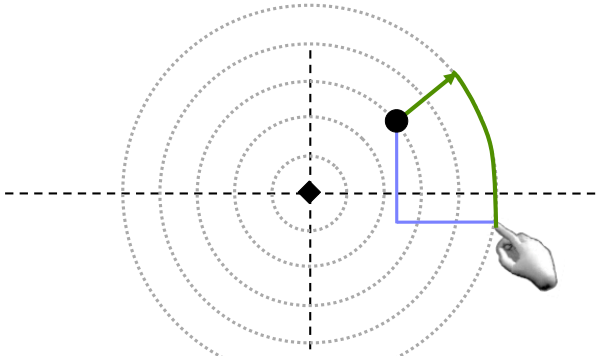
Measuring Adaptation: Sinewave Adapter



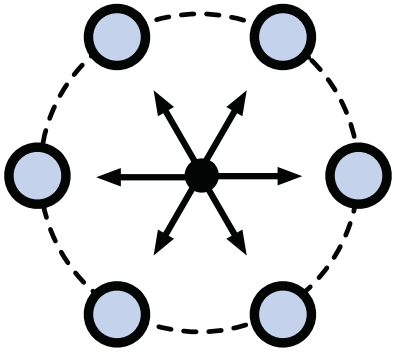
- substantially more sensitive than step-function adaptation
- perturbations can be so small as to remain undetected
- every trial contributes to estimates of gain and phase lag

Hudson & Landy, *J Neurosci Meths, 2012*

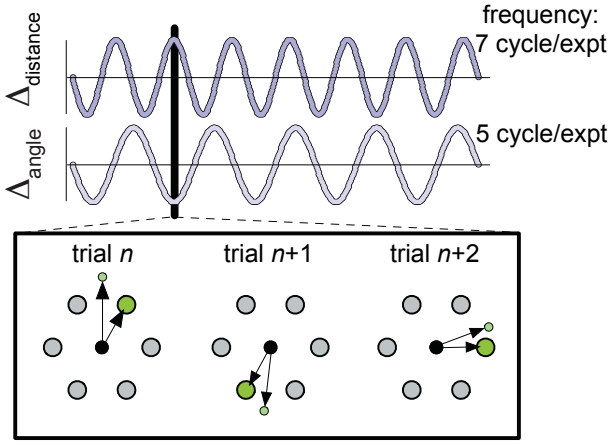
We would like to know whether reaches and reach errors are encoded/represented using polar or Cartesian coordinates.



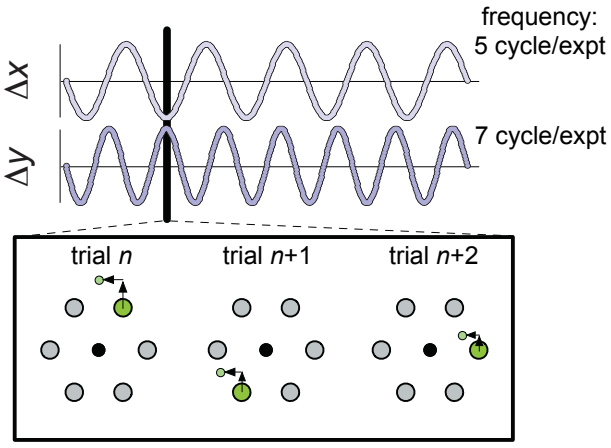
Expt. 1: Six center-out reaches



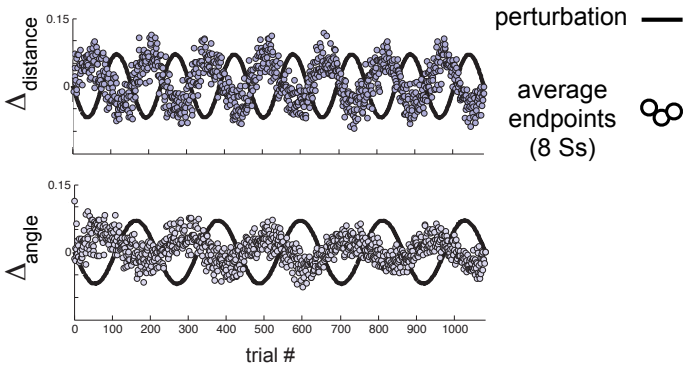
Adaptation: Polar Perturbation



Adaptation: Cartesian Perturbation

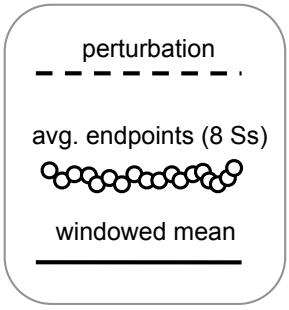


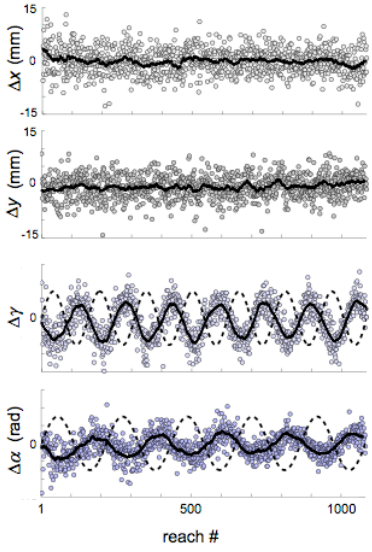
Expt. 1: "Raw" Results Polar Perturbation



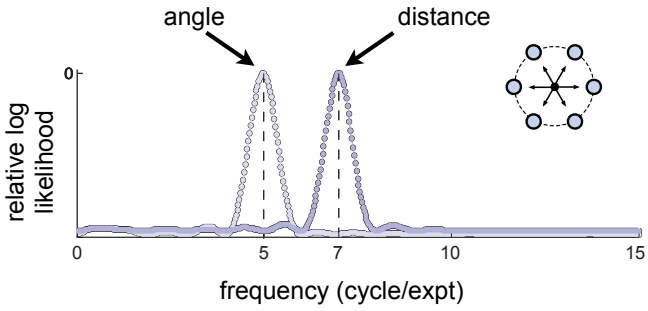
Experimental Results

polar ($\gamma\alpha$)-perturbed endpoints

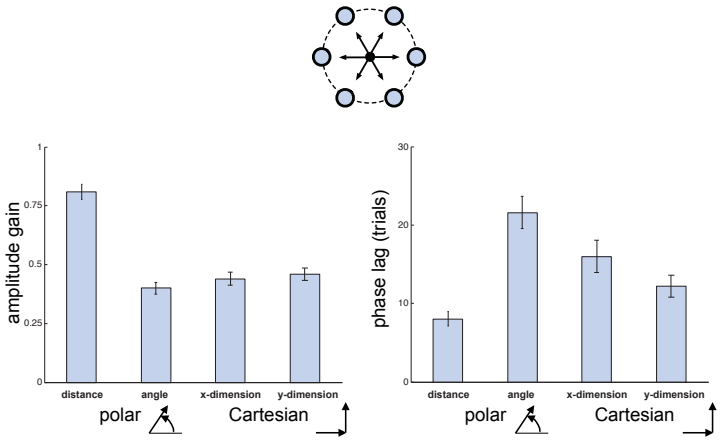




Expt. 1: No Crosstalk



Expt. 1: Gain and Lag



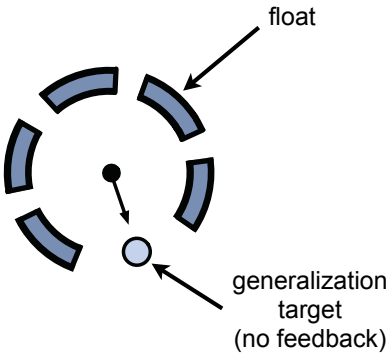
Problem: What if adaptation were target-specific?

This is equivalent to reaching to a single target, in the sense that there is a separate mapping for each target.

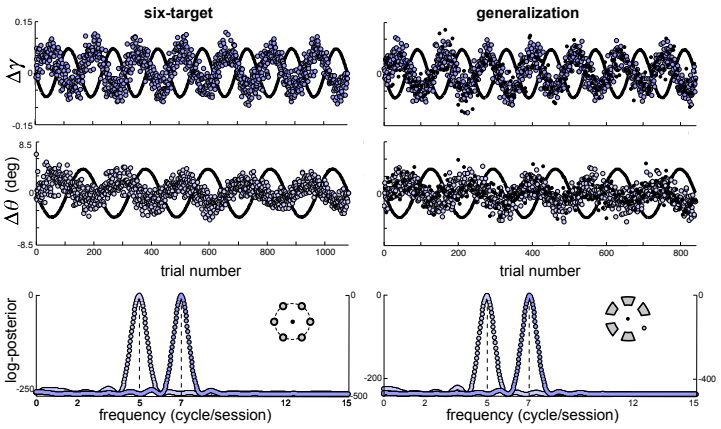
This could show similar results using *either* coordinate system.

Thus, we would not be able to distinguish between polar and Cartesian representations.

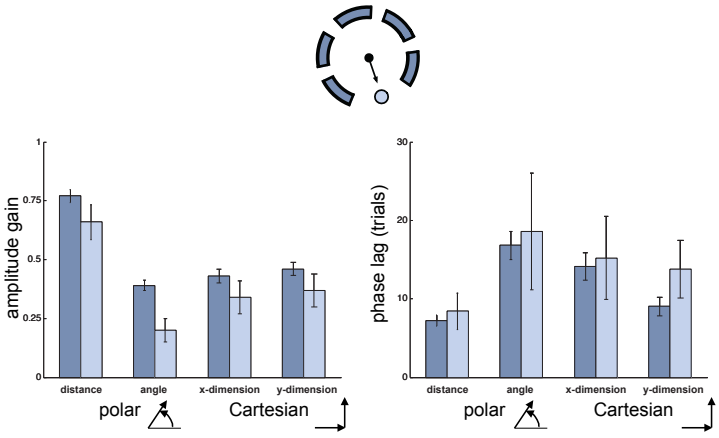
Expt. 2: Generalization Target and "Float"



Expt. 1 and 2: Raw Results



Expt. 2: Gain and Lag

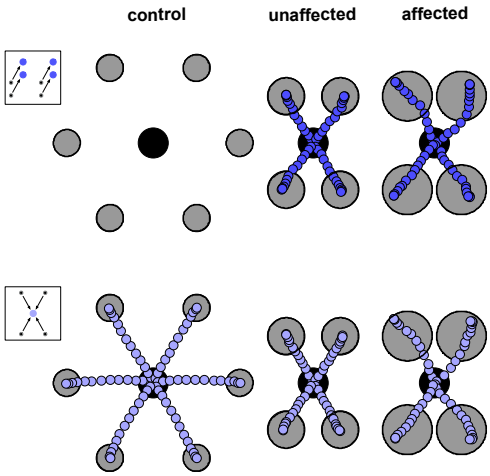


Conclusions

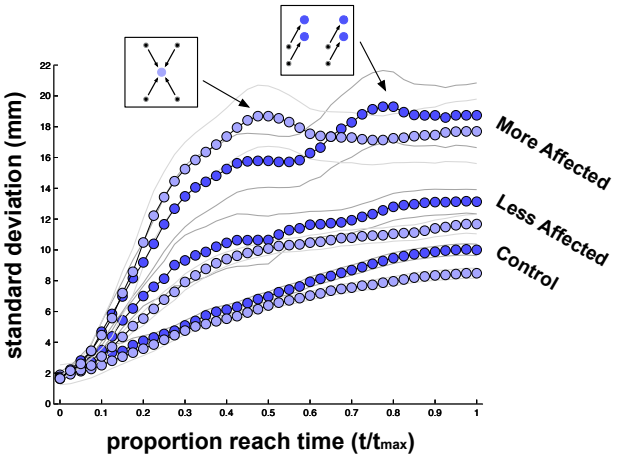
- A new, highly sensitive technique for inducing adaptation and estimating amount and dynamics of the adaptive response
- Along with the vector- and target-coded systems for reach planning, there are polar and Cartesian systems for adaptation (note: so far we only see vector planning for saccades)
- Adaptation is independent in x and y, and in distance and angle
- Visuo-motor adaptation is not strictly local

Hudson & Landy, submitted

Learning Study - Stroke Patients



Learning Study - Stroke Patients



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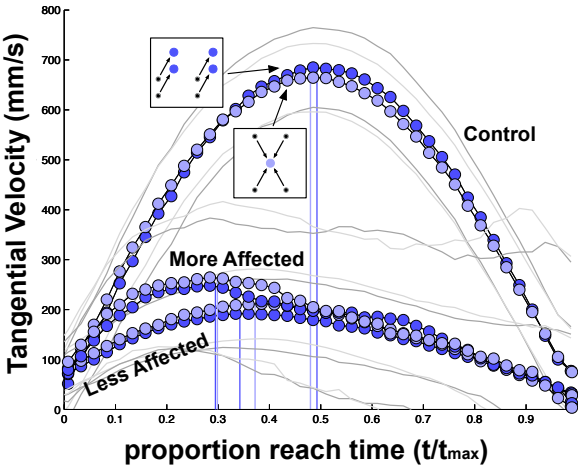

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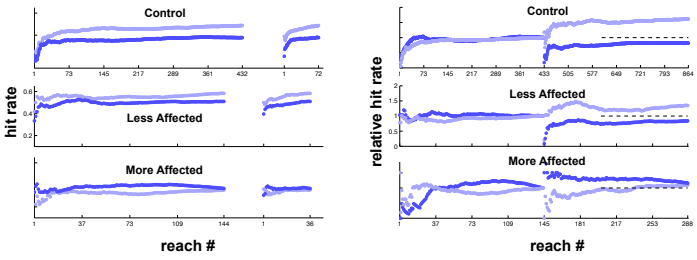
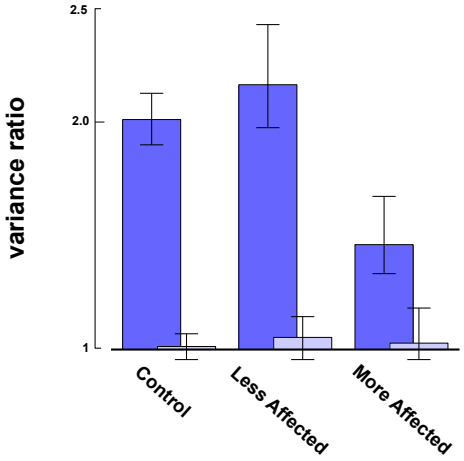


Learning Study - Stroke Patients



Learning Study - Stroke Patients

Summary

Along with the vector- and target-coded systems for reach planning, there appear to be adaptation systems, separate for each, both put into play in determining motor output.

While we recognize the need to determine the regions (global, local, how local?) over which errors are pooled (viz. Krakauer and colleagues), it seems clear that adaptation is not strictly local.