The Error Clamp is not a Singularity: Challenges for Modeling

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Motivation

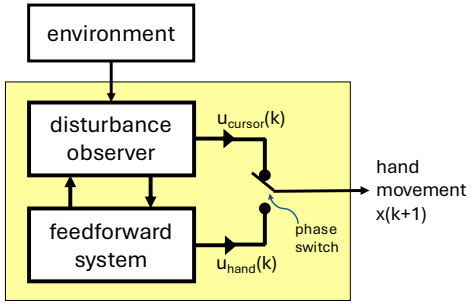
Visuomotor models have lagged behind in explaining a plethora of new phenomena revealed in visuomotor rotation experiments.

Challenges for Modeling

Savings	Instructions	Spontaneous recovery
• Explicit • Implicit	Error clamp	No visual feedback

Visuomotor Model

- A ***disturbance observer*** (DO) detects and eliminates persistent environmental disturbances.
- The ***feedforward system*** learns from the DO to improve open-loop performance and offload the work of the DO.

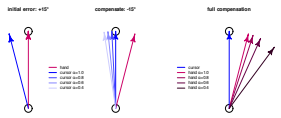


Graded Error Clamp

The cursor is placed at:

$$y(k) = r(k) + \alpha(x(k) - r(k)) + d(k)$$

- $\alpha = 1$: standard learning
- $\alpha = 0$: error clamp



The ***graded error clamp*** sweeps α between 0 and 1.

Phase Switch

Definition. A ***phase switch*** is a switch in computational streams during visuomotor adaptation.

The model predicts a phase switch when:
- Learning trials ←→ no visual feedback trials.
- Move cursor to target ←→ move hand to target.

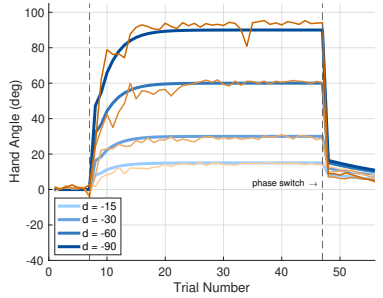
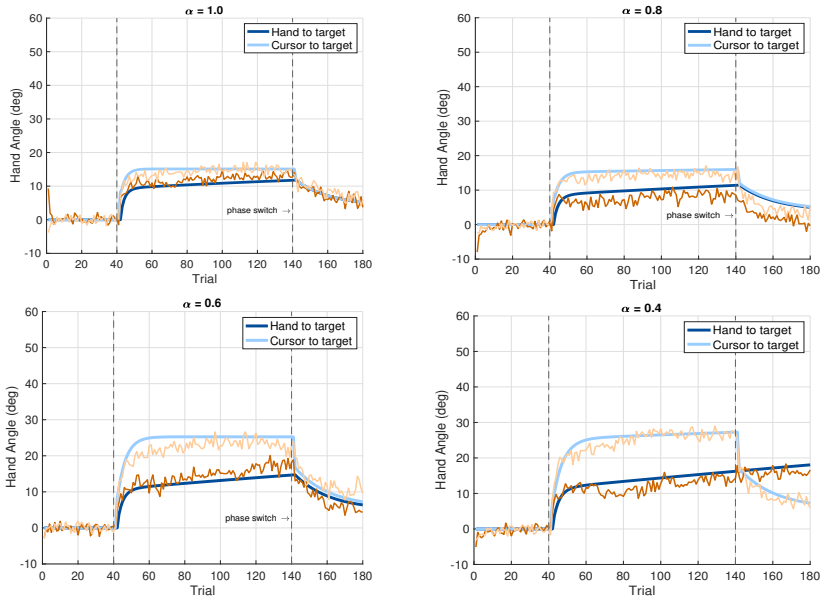


Fig. Experiment 3 from Bond & Taylor, 2015.

Results



Takeaways

The error clamp is ubiquitous in visuomotor adaptation and must be accounted for in any model.

Model behavior emerges from structure and phase switches, not parameter fitting.

A classification of all phase switches is needed

References

[1] B, Francis and W.M. Wonham, "The internal model principle of control theory," *Automatica*, vol. 12, September 1976.

[2] M. E. Broucke, "Adaptive internal model theory of the oculomotor system and the cerebellum," *IEEE Transactions on Automatic Control*, vol. 66, November 2021.

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