

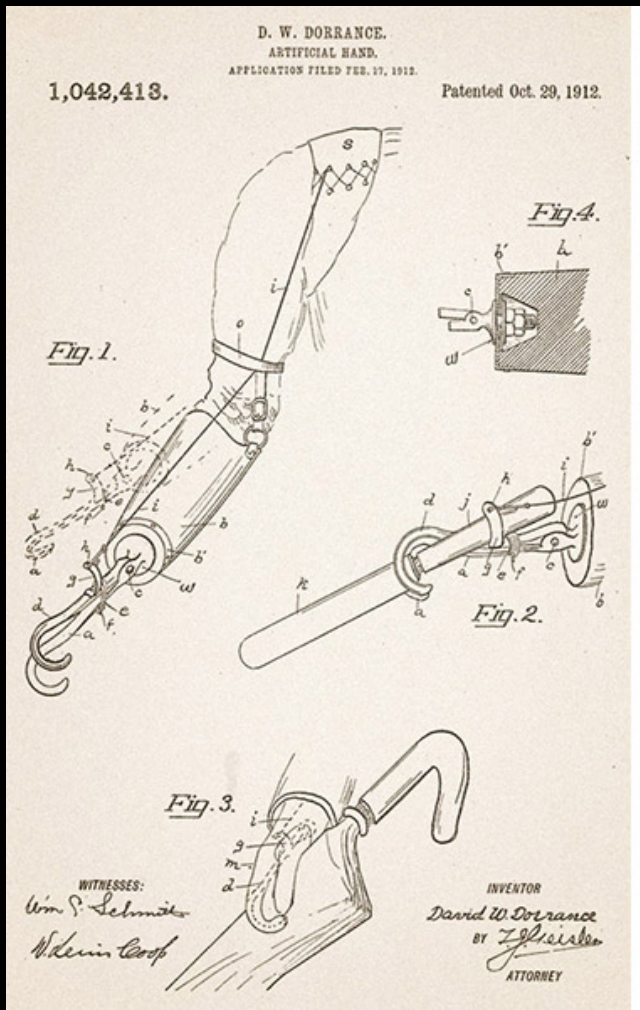
Presentation @ ITA Workshop, San Diego, CA, February 2014

Neural Shaping with Joint Optimization of Controller and Plant under Restricted Dynamics

Bryan D. He and Lakshminarayan Srinivasan

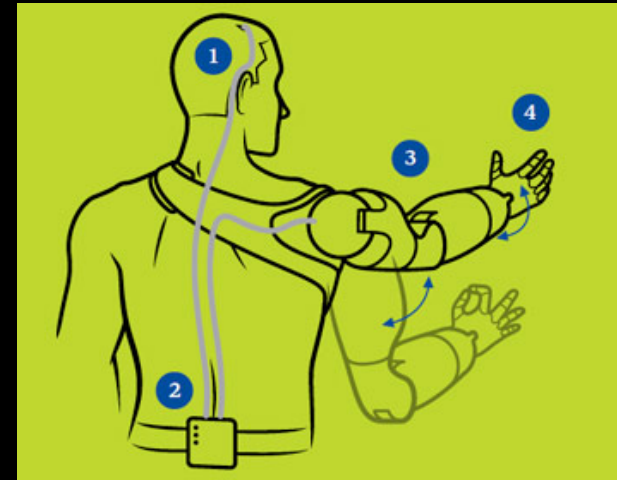
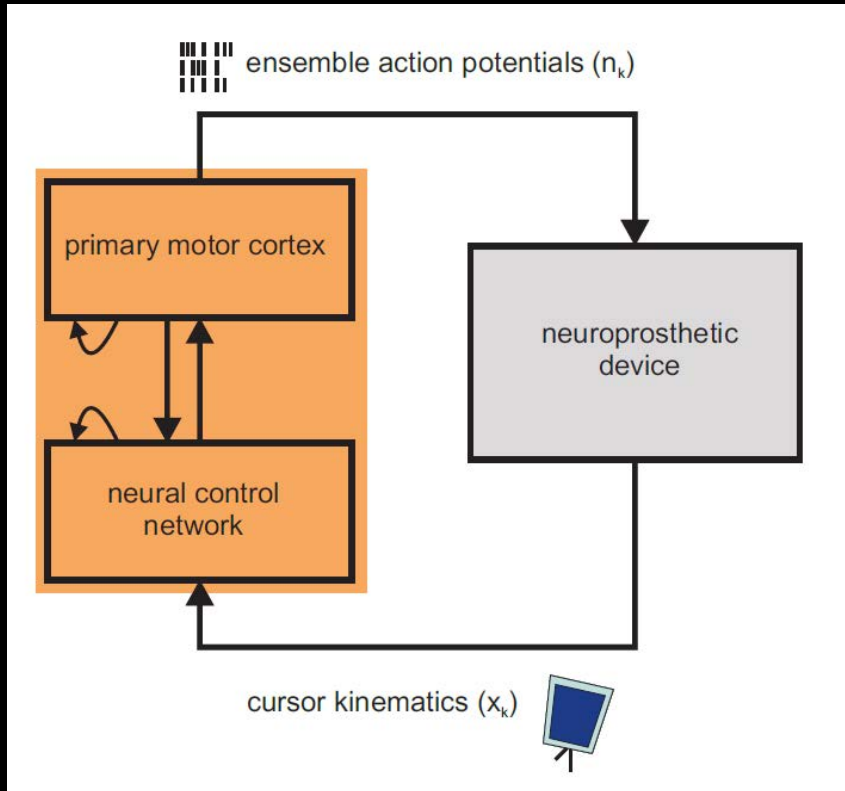
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He, B.D., and Srinivasan, L. (2014) "Neural Shaping with Joint Optimization of Controller and Plant under Restricted Dynamics," Information Theory & Applications Workshop (ITA), <http://ita.ucsd.edu/workshop/>



War and Prosthetics: How Veterans Fought for the Perfect Artificial Limb
<http://www.collectorsweekly.com/articles/war-and-prosthetics/>

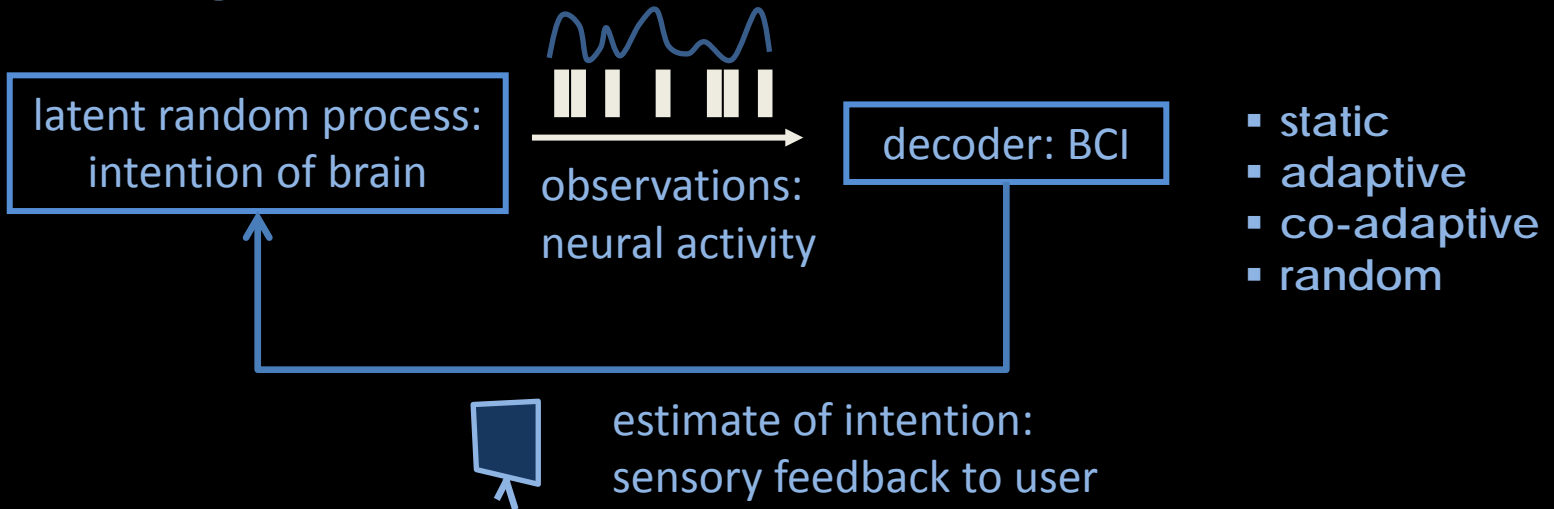
Brain-Computer Interface (BCI)



Lagang & Srinivasan, Stochastic optimal control as a theory of brain-machine interface operation. Neural Computation, 2013

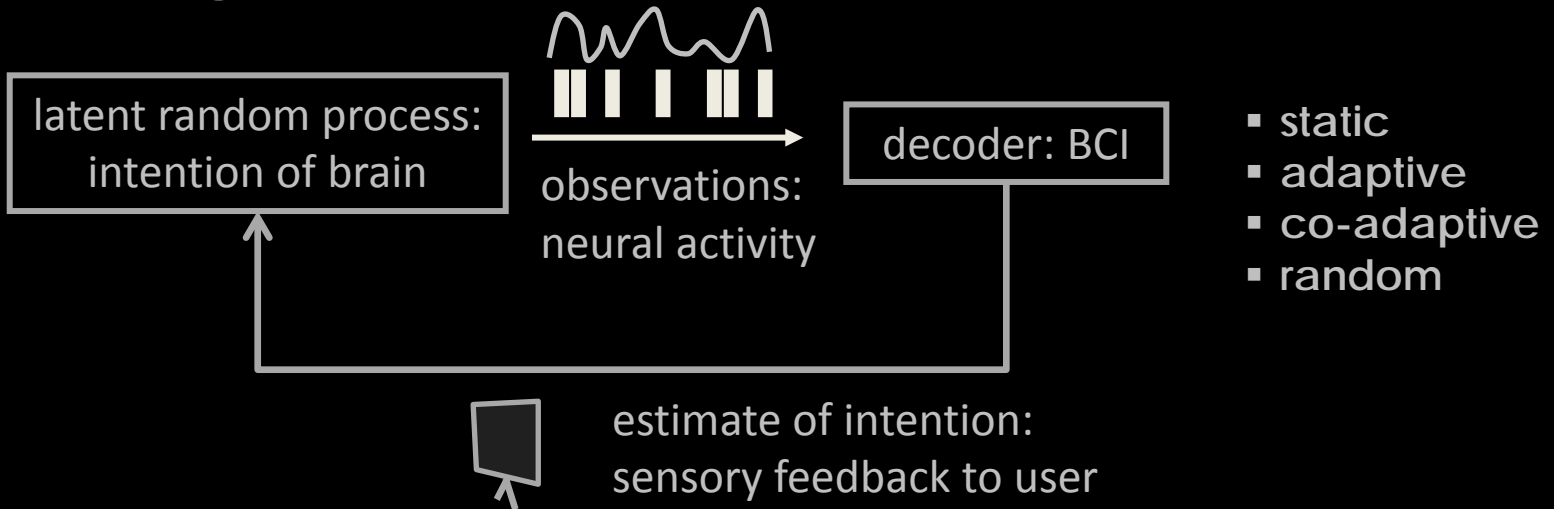
Design Options

BCI as design of a Neural Decoder

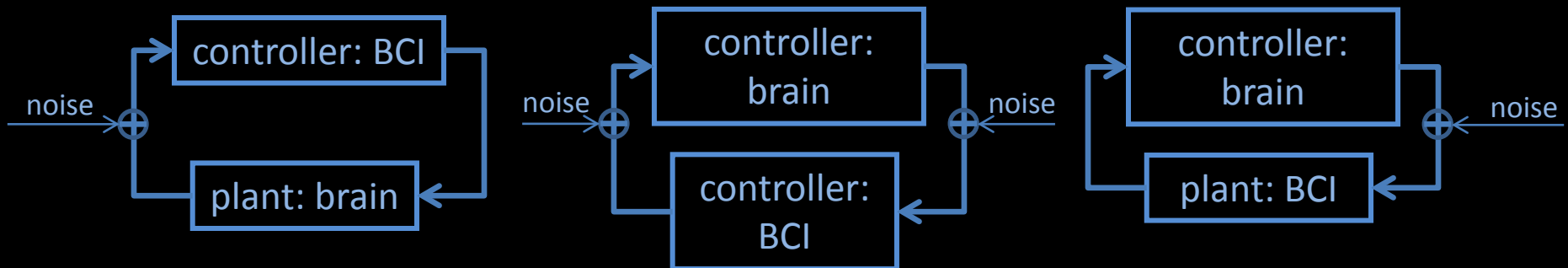


Design Options

BCI as design of a Neural Decoder



BCI as design of a Controlled System (Neural Shaping)



BCI as design of a controlled system

✓ indicates use of joint plant-controller optimization

Controller: BCI, Plant: Brain

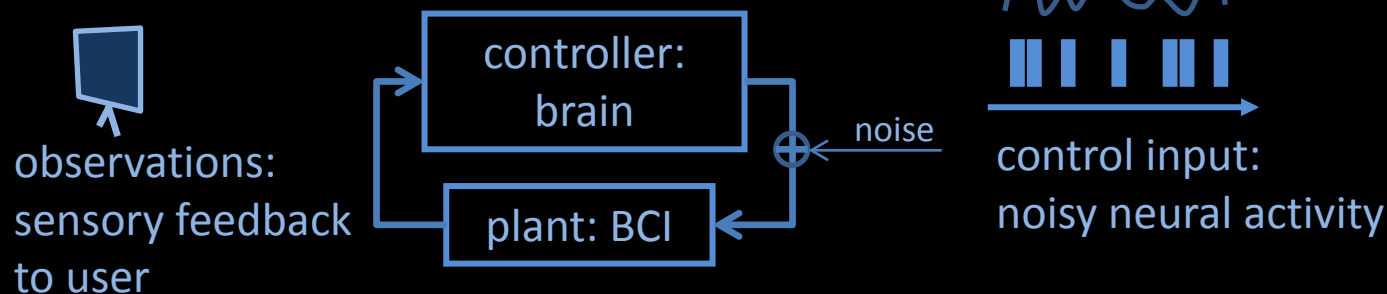
Jarzebowski, J., Srinivasan, L. and Coleman, T. (2008) "Using Stochastic Control with Data Compression Perspectives to Enhance P300 Neural Communication Prostheses," IEEE Information Theory Workshop (ITW)

Park, J., Kim, K. and Jo, S. (2010) "A POMDP Approach to P300-Based Brain-Computer Interfaces," Proceedings of the 15th international conference on intelligent user interfaces

Controller 1: BCI, Controller 2: Brain

✓ Kim, S., and Coleman, T. (2011) "Team decision theory and brain-machine interfaces," IEEE/EMBS Neural Engineering Conference

Controller: Brain, Plant: BCI

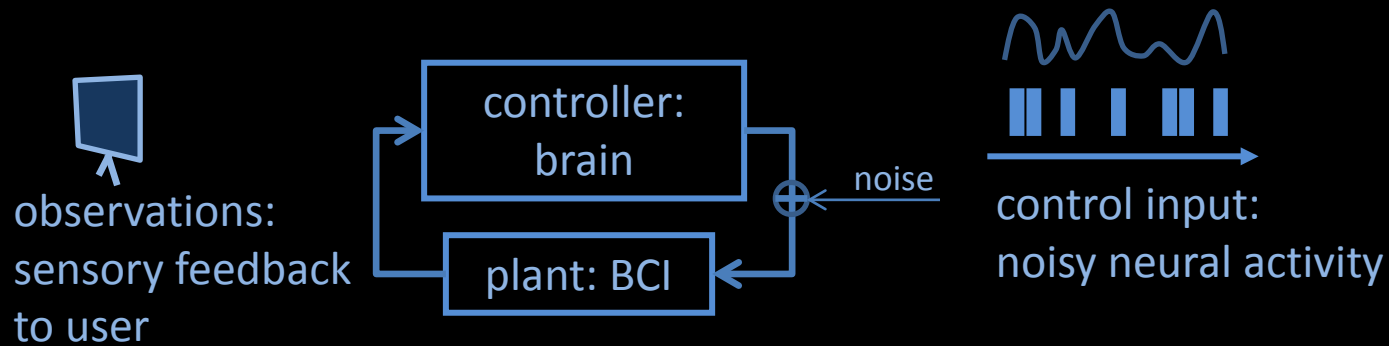


✓ Zollo, L., et. al. (2007) "Biomechatronic design and control of an anthropomorphic artificial hand for prosthetic and robotic applications," IEEE/ASME Transactions on Mechatronics

Gowda, S., Osborn, A.L., and Carmena, J.M. (2012) "Parameter estimation for maximizing controllability of linear brain-machine interfaces," Proc. IEEE EMBC

✓ He, B.D., and Srinivasan, L. (2014) "Neural Shaping with Joint Optimization of Controller and Plant under Restricted Dynamics," Information Theory & Applications Workshop (ITA)

Joint controller-plant optimization in this work



joint formulation

$$(controller^*, plant^*) = \underset{controller, plant}{\operatorname{argmin}} Cost(controller, plant)$$

nested formulation

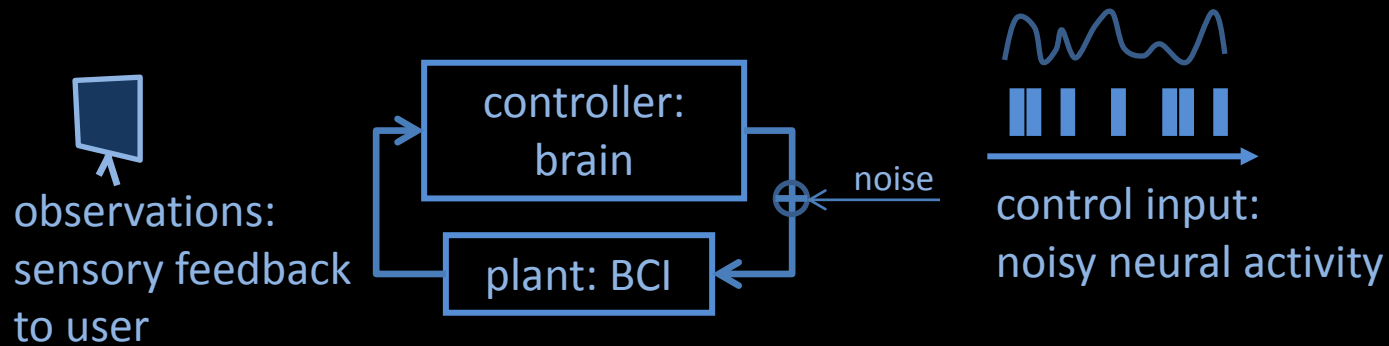
$$controller^*(plant) = \underset{controller}{\operatorname{argmin}} Cost(controller, plant)$$

$$plant^* = \underset{plant}{\operatorname{argmin}} Cost(controller = controller^*(plant), plant)$$

Fathy, et. al (2001) "On the coupling between the plant and controller optimization problems," Proc. American Control Conference

He, B.D., and Srinivasan, L. (2014) "Neural Shaping with Joint Optimization of Controller and Plant under Restricted Dynamics," Information Theory & Applications Workshop (ITA)

Asymmetric costs: objective is unknown to plant



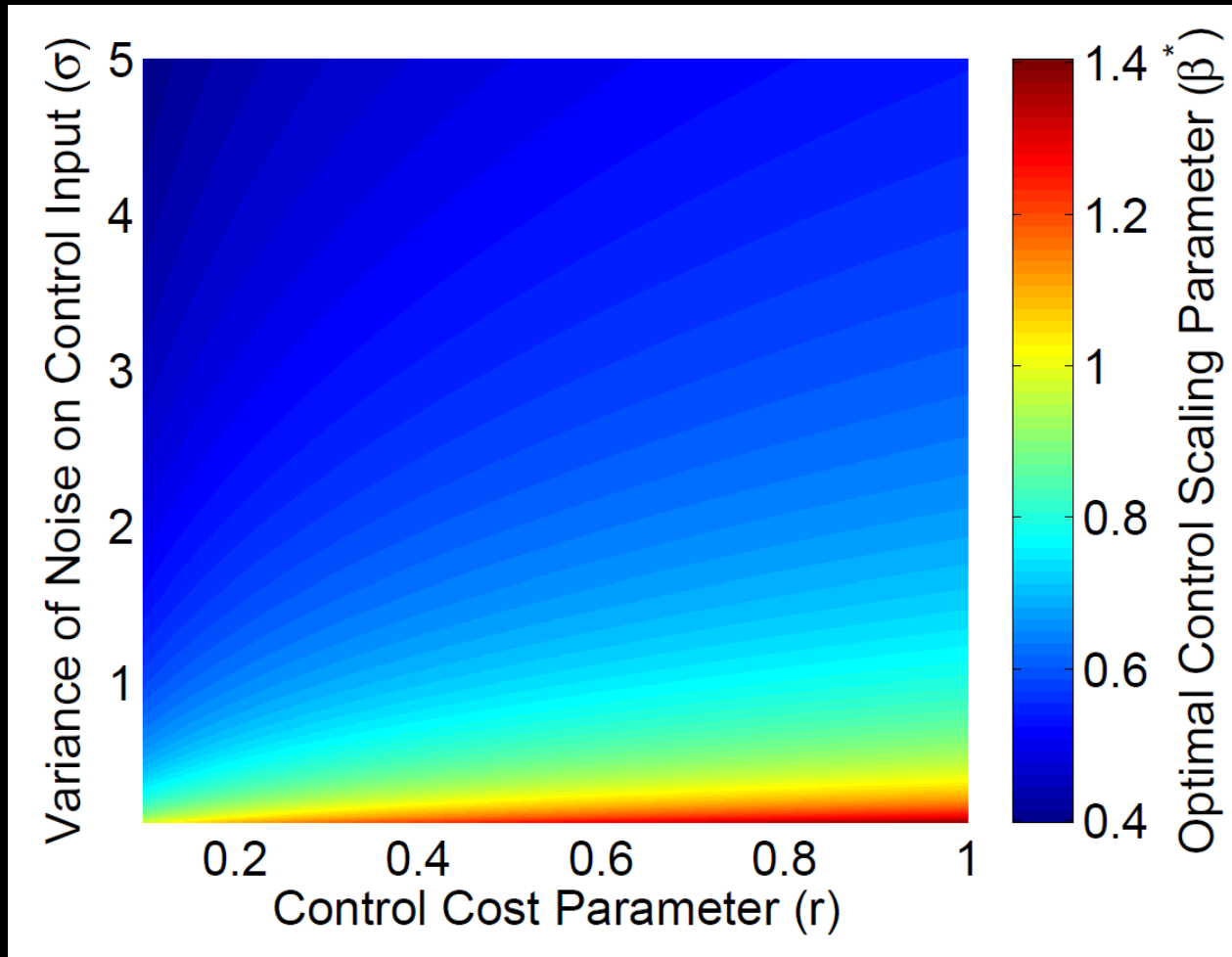
controller perspective

$$Cost_{controller\ perspective}(controller, plant) = E_{x_0, control\ noise} [\dots]$$

plant perspective

$$Cost_{plant\ perspective}(controller, plant) = E_{x_0, control\ noise, objective} [\dots]$$

Special Case: Example Result (2-dim, LQR)



Take-Home Intuition: What's the perfect golf club for beginners?

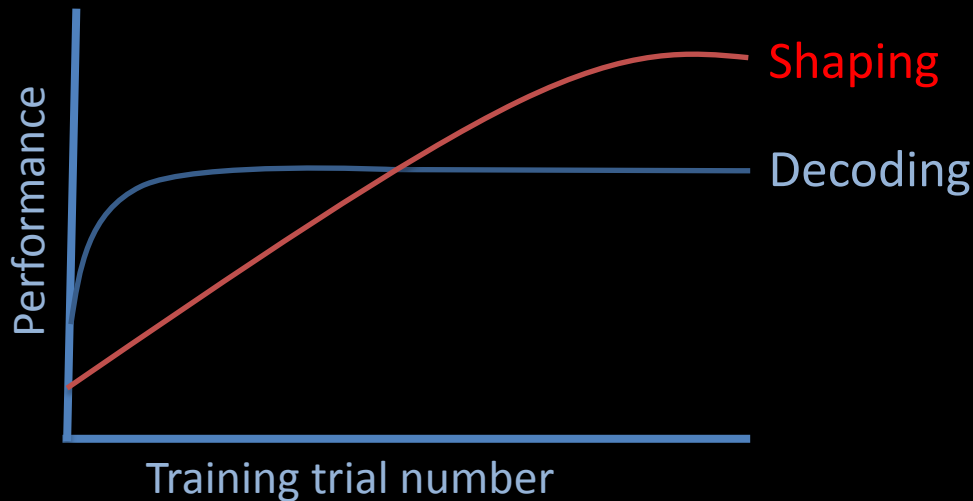


Neural Decoding

Create a club that's matched for the existing capability of the user.

Neural Shaping

Create a club that's matched for where the user will be with some practice.



Expected Benefits of Neural Shaping

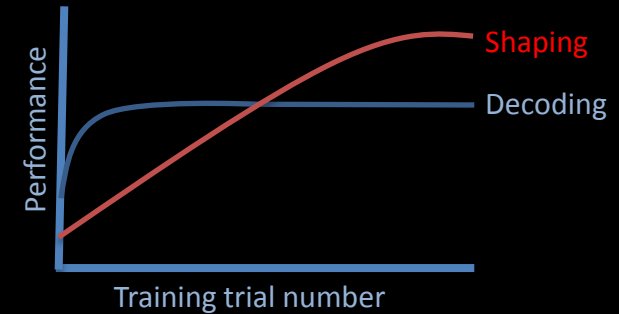
- Better max performance than decoding through strategically directed operant conditioning
- Enhances computer interfaces with any neural or muscular input signal

Neural Shaping - beyond neural decoding



He Ebrahimi Srinivasan

Theory: Bryan D. He
Demo: Mosalam Ebrahimi, PhD
PI: Lakshminarayan Srinivasan, MD, PhD



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