

Kinematically similar basketball free throws have surprisingly different muscle contraction velocity profiles



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Question

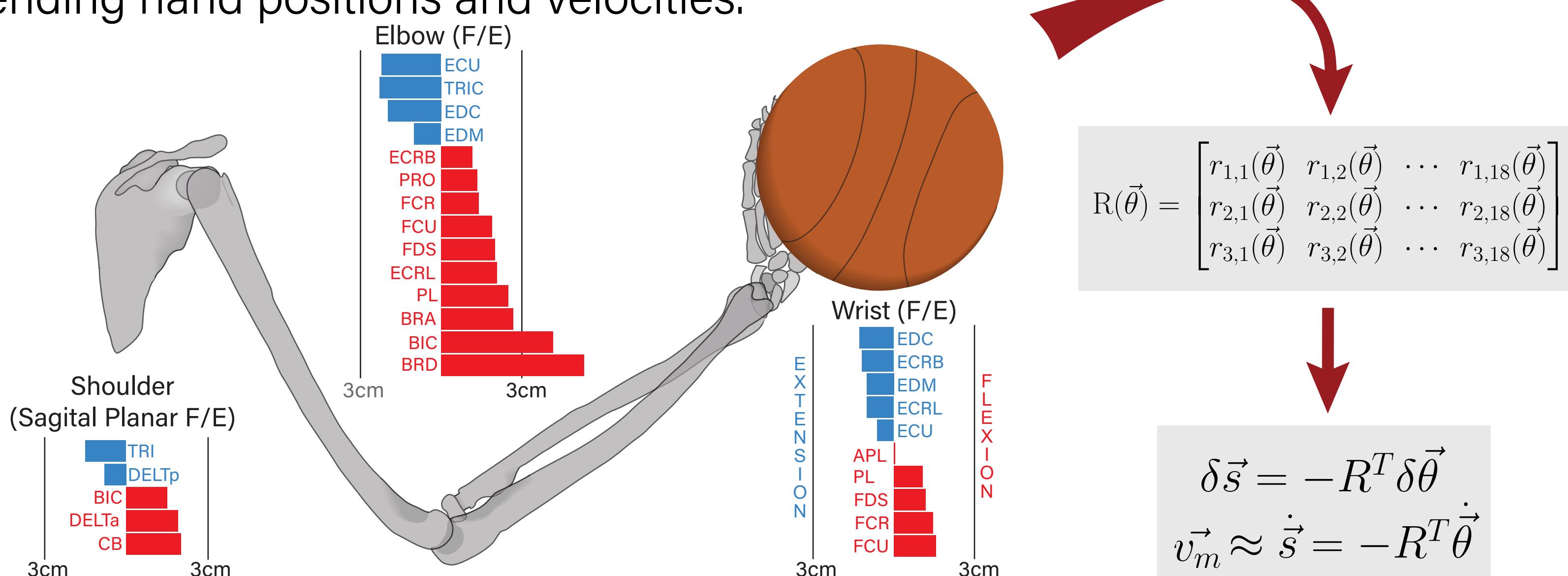
Is there a difference between a **good shot** and a **good looking shot** in basketball?

- Recent work re-emphasizes that neural control of limb movements is in fact **overdetermined**, with the rotation of a **few joints** determining the length changes in **many muscles** [1, 2].
- As per Sherrington, if even one eccentrically contracting muscle fails to silence its stretch reflex appropriately, the movement will be disrupted [3].
- Throws requiring **faster eccentric contractions** will naturally require more precise alpha-gamma coordination, and are likely more prone to variability.
- We investigated whether kinematically similar throws could exhibit large differences in eccentric and concentric muscle fiber contraction velocities.

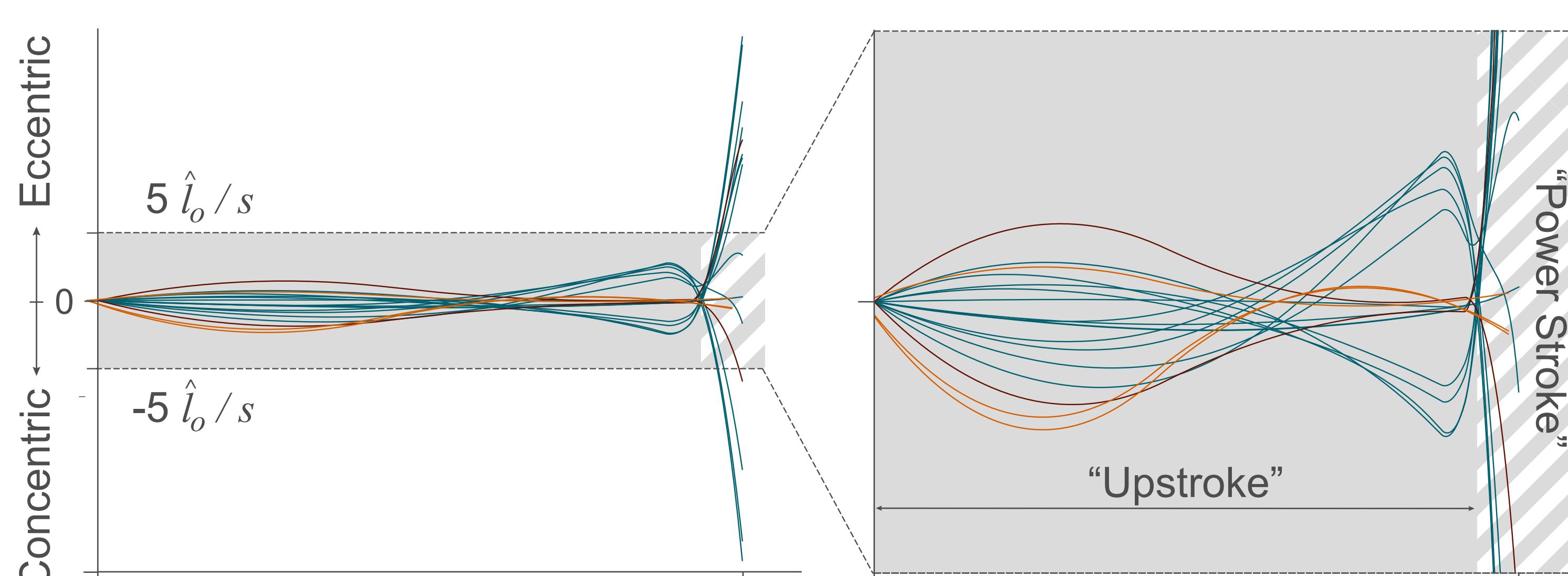
Methods

18-muscle planar arm model to calculate a family of 100,000 random, feasible shoulder, elbow and wrist joint rotations that produced stereotyped basketball shots.

Each shot with a different hand trajectory but all with identical starting and ending hand positions and velocities.



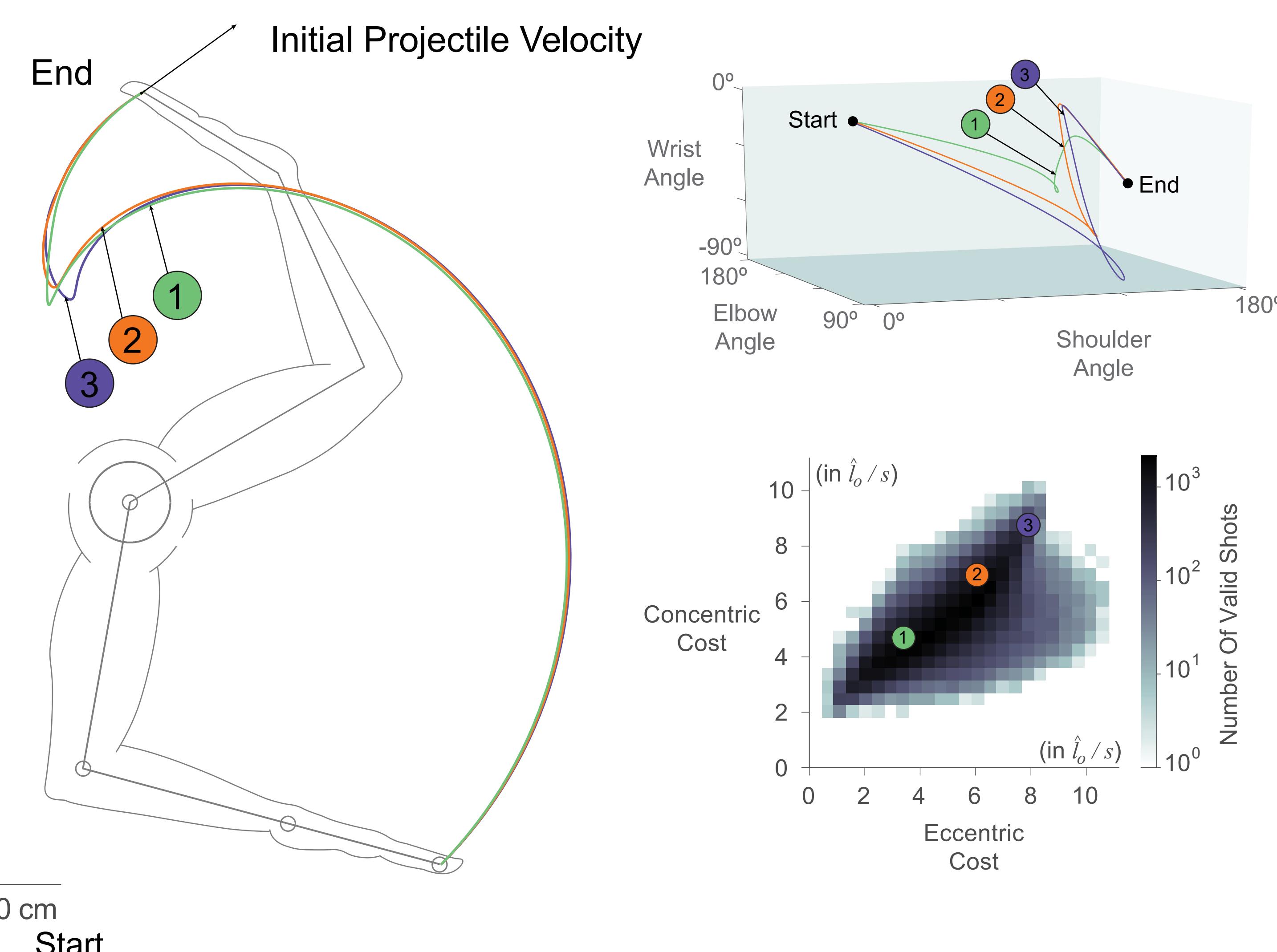
Using a posture-dependent moment arm matrix we estimated **muscle velocities** from **angular velocities** [1, 4, 5, 6].



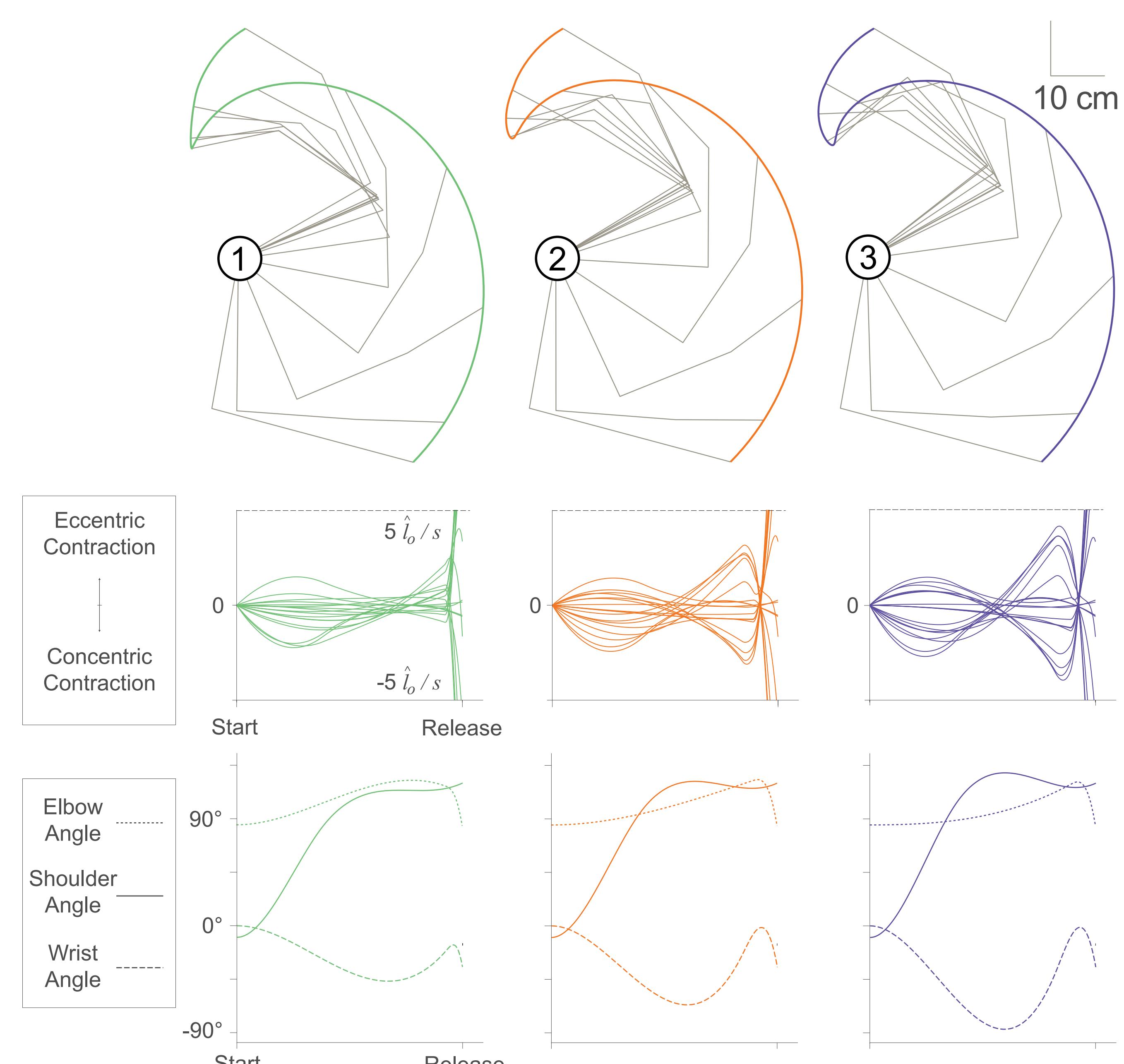
Each shot exhibits a unique **muscle velocity profile**.

We calculated the **Euclidean norms** of the maximal eccentric and concentric velocities during the "upstroke." This metric is indicative of the **eccentric and concentric contraction levels**, respectively.

Results



Illustrated here are **three kinematically similar hand trajectories** that demonstrate **different levels of eccentric and concentric contractions** (top panel, bottom right), different configuration space trajectories (top panel, top right and bottom panel, bottom traces) as well as **different muscle fiber velocity profiles** (bottom panel, middle traces)



Discussion

- Muscle velocity profiles provide a way to distinguish between good shots and good looking shots.
Athletes must search the solution space effectively as it has consequences to
- the needed precision for alpha-gamma coactivation.
The time sensitive coordination of reflexes is overdetermined, challenging the notion of muscle redundancy for the control of movement.
- These results begin to explain why learning to move well is so difficult (Michael Jordan!), and why smooth and accurate movements are so easily disrupted in neurological conditions.

References:

- [1] Valero-Cuevas, FJ. *Fundamentals of Neuromechanics*. Springer-Verlag London, 2016. [2] Valero-Cuevas, F, Cohn, B, Yingvason, H, & Lawrence, E. *J Biomech*, **48**(11), 2887–2896, 2015. [3] Sherrington, C.S. *Exp. Physiol.*, **6**(3) 252–310, 1913. [4] Winter, DA. *Biomechanics and motor control of human movement: Fourth edition*. Elsevier BV, 2013. [5] Ramsay, JW, Hunter, BV, & Gonzalez, RV. *J Biomech*, **42**(4), 463–473, 2009. [6] Holzbaur, KR, Murray, WM, & Delp, SL. *Annals of Biomedical Engineering*, **33**(6), 829–840, 2005.

(Additional references available upon request.)

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