Small errors in movement paths can induce dramatic changes in musculotendon velocities

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Deciding how to move the hand along a given path to produce activities for daily living (ADLs) involves multiple factors such as limb kinetics, choice of muscle activation patterns, online error corrections, robustness to perturbations, accounting for length/velocity muscle mechanics and time-sensitive reflex modulation. In Hagen & Valero-Cuevas (2017) we show how the joint rotations associated with different paths induce different musculotendon (MT) velocities. While different paths will naturally produce different MT velocities, we found that similar paths can exhibit different MT velocity profiles. This matters at the level of individual muscles because differences in MT velocities will require unique muscle activation strategies to compensate for force-length/force-velocity properties and modulation of their spinal reflex mechanisms. Importantly, these differences in MT velocities within and across paths establish the neuromechanical landscape that determines the robustness of muscle coordination patterns and reflex modulation strategies during ADLs.

Here we study how initial variability in the direction of a hand path affects the subsequent time histories of MT velocities. As in our prior work, we used an 18 muscle, 2 joint planar arm model to produce 100 random reaching paths for 6 different pairs of points on a tabletop (3 pairs shared the starting position, 3 pairs shared the ending location). Each valid, smooth reaching path was generated (and its MT velocities found) using a pseudo-random clamped cubic spline, parameterized to follow a bell-shaped tangential velocity curve, simulating reaching movements of 35 cm in length with initial errors compatible with those seen in reaching studies in humans.

We find that uniform initial error (i.e., variability) across paths induces non-uniform distributions of MT velocities. That is, although the induced MT velocities follow a similar profile for each reaching movement, their distributions/deviations change across them. This implies that some reaching paths may be more or less forgiving to initial errors in muscle coordination or reflex modulation. This has important consequences to the study of healthy movement, as well as the rehabilitation of movement for ADLs in neurological conditions and stroke.