Simulating the impact of sensorimotor deficits on reaching performance
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Introduction
Stroke can result in a variety of sensorimotor deficits including muscular weakness, abnormal muscle tone and spasticity, and sensory deficits. Although these deficits are often characterized after a stroke, the complexity of the human neuromusculoskeletal system makes it difficult to understand how they impact motor performance, both individually and in combination. Our lack of understanding makes it difficult to design therapies that efficiently and safely improve sensorimotor performance. Toward a deeper understanding of the factors that lead to disability, we model the human upper extremity and nervous system as an optimal-feedback-controlled robotic arm to which we systematically apply and modulate stroke-like sensorimotor deficits. We can then evaluate the extent to which motor performance is impaired by each sensorimotor deficit.

Methods
We model human neuromusculoskeletal system as an optimal-feedback-controlled1-4 2-dof 6-prism planar arm with physiologically based parameters (e.g., mass, inertia, conduction delays)5. We then simulate point-to-point reaches and systematically apply sensorimotor deficits commonly observed after a stroke.

Results

Discussion
Our results indicate that reaching performance is highly robust to prediction error resulting from increased estimation noise and changes to the plant (decreased muscle strength or changes in tone/spasticity), but is greatly impaired by unmodeled dynamics. This result suggests that humans are naturally adept at stochastic control, but the more difficult control problem appears to be the robust control problem. This framework could be extended to examine relative contributors to disability in people that have suffered other neuromotor injuries or illnesses such as cerebral palsy, spinal-cord injuries, deafferentation, etc. This framework in conjunction with a well-formulated cost function, such as maximizing reachable workspace, could be used to design optimal rehabilitation strategies or assistive devices.

References

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