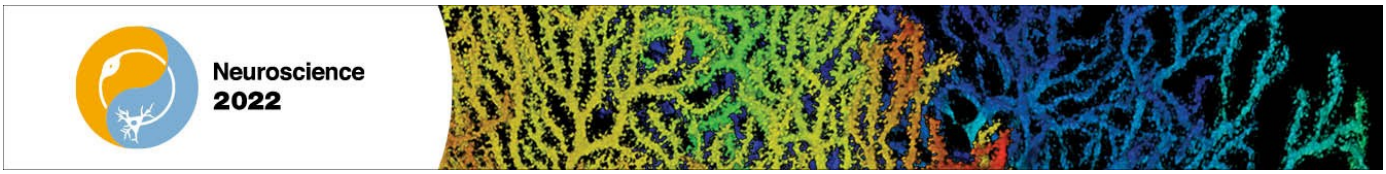

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Control/Tracking Number: 2022-S-6920-SfN
Activity: Scientific Abstract
Current Date/Time: 6/16/2022 11:41:07 PM

Only certain phase relationships of alpha-gamma coordination facilitate voluntary movement

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Abstract:
It is still unknown in detail to what extent and in what way spinally-mediated sensorimotor mechanisms contribute to natural voluntary movement. Specifically, there is a need to disambiguate the functional contribution of descending alpha (α) and gamma ($\gamma_{dynamic}$, γ_{static}) cortico-spinal projections from propriospinal, sensory, and proprioceptive projections. As an extension of our neuromorphic computational approach in Jalaledini et al. (2017), Niu et al. (2017) and Nagamori et al. (2021), we actuated a tendon-driven single-joint robotic finger using motors programmed to act in real-time as an agonist-antagonist pair of Hill-Type muscles. In addition to modeling spiking neurons (Izhikevich, 2003), muscle spindles (Mileusnic et al., 2006) and Golgi tendon organs (Mileusnic and Loeb, 2006), their stretch reflex pathways were also innervated by descending α, $\gamma_{dynamic}$, and γ_{static} drives. The α drive (in pulses per second, pps) was set to produce slow sinusoidal or point-to-point movements on the robotic finger's joint. By sweeping across various values of amplitude and relative phase of the $\gamma_{dynamic}$ and γ_{static} drives to the two muscles, we were able to quantify the effect of these various α-γ interactions on joint kinematics. 'Realism of movement' was quantified using three metrics: 1. *magnitude of voluntary movement*, measured in degrees; 2. deviation from *minimum jerk* to measure smoothness; and 3. *two-thirds power law* to compare movements with varying parameters. We saw that only a particular, typically phase-advanced family of γ drive profiles enables greater sinusoidal joint movements. Also, careful scheduling of γ drives during the ramp and hold phases is crucial to accurately start and stop point-to-point movement. Our results highlight that only certain families of task-specific amplitudes and phases of γ drives are sufficient (yet not necessary) to produce naturalistic motor action. This warrants further study in human neuromorphic models to validate the nuanced role of descending α-γ cortico-spinal commands in enabling spinal circuits to produce natural voluntary movement.

Author Disclosure Information:

S. Chakravarthi Raja: None. **T. Fanelle:** None. **J.E. Lao:** None. **F.J. Valero-Cuevas:** None.
Presentation Preference (Complete): No Preference
Linking Group (Complete): None selected
Theme and Topic (Complete): E.07.d. Afferent and descending control ; D.01.a. Spinal circuits
Nanosymposium Information (Complete):
Keyword (Complete): MOTOR CONTROL ; FUSIMOTOR SYSTEM ; NEUROMORPHIC
Support (Complete):
Support: Yes
Grant/Other Support: : USC Research Enhancement Fellowship
Grant/Other Support: : NIH grant R01-AR050520
Grant/Other Support: : NIH grant R01-AR052345
Grant/Other Support: : NIH grant R21-NS113613
Grant/Other Support: : DoD CDMRP grant MR150091
Grant/Other Support: : DARPA contract W911NF1820264
Grant/Other Support: : NSF CRCNS Japan-US 2113096

Special Requests (Complete):
How do you plan to participate in Neuroscience 2022?: In-Person and Virtually
Religious Conflict?: No Religious Conflict
Additional Conflict?: No
Is the presenting author of this abstract a high school or undergraduate student?: None

Status: Finalized