Illusory differences in movement variability and learning rates as a function of movement amplitude

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Background
A primary question in human motor control research is how the central nervous system detects and learns from reaching errors. This process is complicated by noise in execution that is not always constant or uniform relative to the hand in extrinsic space. Here we examine the distribution of variance in “shooting” and point-to-point reaching tasks along and orthogonal to the primary axis of motion when making reaches of different magnitude. We also test whether humans show differences in error sensitivity for these different lengths of reach.

Learning & variance metrics are sensitive to coordinate frame

Wei & Körding (2009) - W&K in Cartesian

- Error sensitivity for gains scales across reach amplitudes following a given gain.
- In this experiment by Wei & Körding, participants reached from a start point to a target after 5 or 15 cm distant. Endpoint feedback of the cursor was provided when the hand passed the target distance in the x coordinate. The cursor was pseudorandomly perturbed by ±0.1, 2, 4 or 8 cm in sets of 9. The effect of these cursor displacements was measured by sorting all trials immediately following each perturbation, thus isolating the adaptive correction for each perturbation.

Wei & Körding (2009) - W&K in Polar

- Error sensitivity for gains scales across reach amplitudes following a given gain.
- In polar space it is evident that the perturbations were of different size for the two groups. It is clear that the 15cm group adapts more readily to the same group.

W&K Replication with matched perturbations

- Error sensitivity for gains scales across reach amplitudes following a given gain.
- In the task participants made center-out reaches to one of four target reaches at each distance. A trial that had a perturbation of the endpoint hand was assigned at random to one of three distances in pseudorandom order. Each reach direction was sampled in pseudorandom perturbations of the set of four reach directions. After a baseline block of 8 trials, there was a 240 trial abrupt 30 degree rotation block, followed by 60 trials of washout.

Center-Out Task

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The axes of endpoint variability are differentially scaled by reach length

Random Gains Task

- Error sensitivity for gains scales across reach amplitudes following a given gain.
- In this task participants reached to one of three targets in 240 trials made up of 80 trials per condition.
- The mean cursor displacement for every trial was 5 cm, or no perturbation. The primary behavioral measure was change in endpoint error on the trials following a given gain.

Error sensitivity for gains scales across reach amplitudes

- Variance orthogonal to the primary axis of motion is roughly constant if scaled appropriately
- Variance along the primary axis of movement dwarfs orthogonal variance
- Adaptation to perturbations both along and orthogonal to the primary axis of motion are scaled to reach magnitude
- The motor system discounts large errors in both direction and extent

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