HOW TO THROW ACCURATELY

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When throwing to hit a target accurately, we preferentially use an underarm or overarm style depending on how far the target is. To understand why this might be so, we ask if differences in accuracy between these throwing styles underlie strategy? Accuracy of a throw is governed by how errors in release timing and release velocity of the projectile propagate to cause deviations from the desired target. We quantify this in terms of a simple model of throwing where the arm is modeled as a controllable hinged bar of length R, that can release a projectile at any angle with respect to the horizontal (ϕ) and angular velocity (ω) of the arm. The parabolic trajectory of the projectile leads to a parametrization in terms of (ϕ, $\omega(\phi)$) for which the projectile accurately strikes the target. We quantified the amplification of initial errors $\delta\phi$ and $\delta\omega$, using the largest singular value of the appropriate Jacobian. Then, the release parameters with the minimum of the largest singular value correspond to the preferred throw. We find that the style of throwing changes with increasing target distance and height. For nearby targets at or below the pivot of the arm, an underarm strategy is preferred. For targets above the arms pivot and farther away than arm length, an overarm strategy is preferred. For very far targets, both an underarm and overarm strategy are almost equally preferred as expected for a model with no strength differences between an overarm and underarm throw. We present a detailed exploration of the parameter space of throwing with this simple model and discuss implications to understanding the motor control of accurate throwing in humans and other primates.

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