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Kinematic analysis of reaching in the cat

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Abstract The present study examines the kinematic features of forelimb movements made by cats reaching for food in horizontal target wells located at different heights and distances. Wrist paths consisted of two relatively straight segments joined at a "via-point" in front of the aperture of the food well. In the initial *lift* phase, the paw was raised to the via-point in front of the target. In the second, or *thrust* phase, the paw was directed forward into the food well. During the lift, the paw was moved toward the target primarily by elbow flexion, accompanied by a sequence of biphasic shoulder and wrist movements. Thrust was accomplished primarily by shoulder flexion while the wrist and the paw were maintained at near-constant angles. The animals varied the height of the reach primarily by varying elbow flexion with proportional changes in elbow angular velocity and angular acceleration and with corresponding variations in wrist speed. Thus, cats reached for targets at different heights by scaling a common kinematic profile. Over a relatively large range of target heights, animals maintained movement duration constant, according to a simple "pulse-height" control strategy (isochronous scaling). For reaches to a given target height, animals compensated for variability in peak acceleration by variations in movement time. We examined the coordination between the shoulder and the wrist with the elbow. Early during the lift, peak shoulder extensor and peak elbow flexor accelerations were synchronized. Late during the lift phase, wrist extensor acceleration was found to occur during the period of elbow flexor deceleration. We hypothesize that these linkages could, in part, be due to passive mechanical interactions. To determine how the angular trajectories of the different joints were organized in relation to target location, we plotted joint kinematic changes directly on the wrist and MCP joint paths. These plots revealed that for all target heights and movement speeds, wrist extensor deceleration occurred at approximately the same spatial location with respect to the target. This analysis also demonstrated that the second phase of MCP flexion occurred when the paw was below the lower lip of the food well, while the subsequent extension occurred after the tip cleared this obstacle. During thrust, wrist and MCP angles were maintained, reflecting the need to align the paw within the food well. Our findings suggest that cats plan the reaching phase of prehension as a sequence of discrete movement segments, each serving a particular goal in the task, rather than as an single unit. The presence of straight trajectory segments suggests that cats, like humans, plan movements of their paw in extrinsic rather than joint space.

Key words Reaching · Multijoint arm movement
Trajectory formation · Kinematics
Movement planning · Prehension

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Introduction

The study of prehension in cats has provided important insights into the contributions of different neural systems to the control of reaching. In particular, lesion studies have shown the importance of particular spinal interneuronal systems in different aspects of prehension and have suggested new roles for supraspinal signals that impinge upon them. For example, interruption of the C3-C4 propriospinal projection to forelimb motor nuclei disrupts reaching but not the grasping component of prehension (Alstermark et al. 1981). In contrast, lesions destroying the inputs from the corticospinal and rubrospinal tracts to interneurons located in lower cervical segments only impair grasping (Alstermark et al. 1981). Recent anatomical studies suggest that the C3-C4 propriospinal neurons receive inputs primarily from a rostral subregion of motor cortex (Martin 1993). Inter-