Neural models of reaching

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Abstract: Plamondon & Alimi (P&A) have unified much data on speed/accuracy trade-offs during reaching movements using a delta-normal form factor that describes “the asymptotic behavior of a large number of dependent linear systems,” notably neuromuscular systems. Their approach raises questions about whether a large number of systems is needed, whether they are linear, and whether the results disclose the neural design principles that control reaching behaviors. The authors admit that “it is difficult . . . to provide a direct biological interpretation for the system parameters” (sect. 6, para. 4).

Unfortunately, the price for “such generalization” is higher. If a view is too global and generality is too high there is the risk of saying nothing about everything. P&A’s terminology is insufficiently accurate.

Plamondon & Alimi: Speed/accuracy trade-offs in target-directed movements

if a reader does not understand the main issue of the theory, the matter of formalization used is lost and any discussion is moot. In conclusion, P&A write that their kinematic theory “encompasses both similarities and dissimilarities with respect to the other models previously published . . . unlike . . . (Hogan 1984) . . . (Uno et al. 1989), . . . (Feldman 1966; 1986; Polit & Bizzi 1979) . . . [and] (Bullock & Grossberg 1988), . . . kinematic theory provides a global view . . . The price to pay for such generalization is that it is difficult, without further experiments, to provide a direct biological interpretation for the system parameters . . .” (sect. 6, para. 4).

We propose that this is the correct computational format for autonomously learning the coordinate transformations and movement parameters that keep sensory-motor coordination accurate within a growing body (Grossberg et al. 1993; Guenther et al. 1994). P&A note that their approach “does not provide too many clues about the learning process itself.”

P&A say that VITE does not describe “the mechanical properties of the muscles.” This is because VITE concerns itself with outflow positional control. The FLETE model (Bullock & Grossberg 1991) links outflow VITE commands to spinal and cerebellar circuits that maintain positional accuracy of contracting muscles under variable tension. FLETE models identified spinal and motor components, such as Renshaw cells and gamma motoneurons, and simulated the multiple velocity peaks during ballistic movements (Bullock & Grossberg 1992) which P&A consider “one of the most powerful characteristics” of their model. VITE has since been extended to a model circuit for controlling reaching movements of variable speed and force in the presence of obstacles (Bullock et al. 1997). This model simulates the neurophysiological firing patterns of six identified cell types in cortical areas 4 and 5 during a wide variety of behavioral tasks.

P&A mention Weber law control of timed movements. A model of learning in the cerebellum describes how metabotropic glutamate receptors, acting at cerebellar Purkinje cell spines, may control adaptively timed learning that obeys a Weber law (Fiala et al. 1996).

In summary, whereas Plamondon & Alimi provide a stimulating account of how speed/accuracy data may arise from delta-normal processing, recent neural models of reaching behavior provide an alternative view of the design principles and nonlinear mechanisms whereby these data may arise as emergent properties.

Where in the world is the speed/accuracy trade-off?

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Abstract: Even though Plamondon’s kinematic model fits the data well, we do not share the view that it explains movements other than ballistic ones. The model does not account for closed-loop control, which is the more common type of movement in everyday life, nor does it account for recent data indicating interference with ongoing processing.

Plamondon & Alimi (P&A) state two specific goals. The first is to demonstrate the absence of a cohesive account for aimed movements; the second is to advance Plamondon’s kinematic theory as such an account. In general, P&A are successful with respect to these goals and are therefore to be congratulated. However, we have a number of questions, which principally concern real-world application of the findings, consistency with other data, and a potential weakness of the model itself.

It is our contention that P&A’s work only relates to a very small and generally atypical segment of the full spectrum of movement capability. Only under highly constrained and artificial conditions, such as in the experimental laboratory or at sporting events, does any individual regularly engage in ballistic movements occurring at or near their maximum movement velocity. Very few daily skills require performance at the levels of velocity and accuracy typical in the cited research (although an obvious exception is keyboard-
neurons are more likely to fire during movement. The difference in firing of antagonist muscles is consistent with the idea of a motor command that is modulated by the central nervous system. The delay in the firing of antagonist muscles may be due to the propagation of a neural signal along the motor cortex and spinal cord. This delay is necessary to ensure that the two muscles fire in a coordinated fashion, allowing for smooth and accurate movement. Therefore, the findings of this study suggest that the central nervous system has a role in the modulation of antagonist muscle activity during movement, which is crucial for the execution of coordinated movements.

In conclusion, the delay in the firing of antagonist muscles observed in the study of Flanders and Soechting (1996) highlights the importance of the central nervous system in the modulation of muscle activity during movement. This delay is essential for the coordination of antagonist muscles and the execution of accurate and smooth movements. Further research is needed to understand the mechanisms underlying this delay and how it contributes to the overall control of movement.