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Speed/Accuracy Trade-Offs in Target-Directed Movements

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Boston University Center for Adaptive Systems and
Department of Cognitive and Neural Systems
677 Beacon Street
Boston, MA 02215

BBS COMMENTARY

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Speed/accuracy trade-offs in target-directed movements

NEURAL MODELS OF REACHING

by

Commentator: Stephen Grossberg¹
Department of Cognitive and Neural Systems²
Boston University
677 Beacon Street
Boston, MA 02215
steve@cns.bu.edu

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Plamondon and Alimi have unified many data on speed/accuracy trade-offs during reaching movements using a delta-lognormal 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”.

The VITE model (Bullock and Grossberg, 1988) of neural trajectory formation implies Fitts’ law, and various failures, as emergent properties of trajectory dynamics. VITE was derived to explain how motor *synergies* form, and how synergies contract *synchronously* at variable *speeds*. These three S’s of reaching behavior imply Fitts’ law, as well as asymmetric velocity profiles and their invariances. They do so using a single weakly-nonlinear system rather than a large number of linear systems.

VITE multiplies a difference vector, or DV - which codes the difference between desired target position and an outflow representation of present position - and a volitional GO signal. Are there other neural systems that use DV-style computations and that are cascaded together to provide multiple VITE-like contributions to Fitts’ law, none of which involves neuromuscular computations?

The VITEWRITE model (Bullock, Grossberg, and Mannes, 1993) embeds VITE into a movement planning circuit for generating handwriting movements. The script letters are an emergent property of circuit interactions which enable writing to preserve its form as volitional acts flexibly change its size or speed. The script letters have an invariant representation as a spatial pattern of synergy-controlling DV’s that are stored in a working memory. As in VITE, GO volitional signals can alter their speed of execution. GRO volitional signals alter their size by multiplying the DV that is read-out of working memory before this product inputs to the VITE circuit. Feedback from VITE to the working memory releases the next working memory DV only when the VITE DV is maximal or zero. Complex data about stroke coordination, such as the “two-thirds power law” of Lacquaniti, arise as emergent properties of these feedback interactions. Nowhere does the circuit need the virtual targets or minimization principles that the authors mention.

DV’s also occur during visually-guided control of motor-equivalent reaching to targets in space. The DIRECT model (Bullock, Grossberg, and Guenther, 1993) shows how accurate reaches can be made with novel tools of variable lengths, with clamped joints, with distortions of visual input by a prism, and with unexpected perturbations. The coordinate transformations from retinal, to head-centered, and finally to the body-centered coordinates that control reaches also use DV computations. Why are DV’s so ubiquitous in the spatial planning and motor execution of reaches?

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). Plamondon and Alimi note that their approach “does not provide too many clues on the learning process itself”.

The authors 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 and 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 simulates the multiple velocity peaks during ballistic movements (Bullock and Grossberg, 1992) which Plamondon and Alimia 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, Cisek, and Grossberg, 1995). 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.

The authors mention Weber law control of timed movements. A model of learning in cerebellum describes how metabotropic glutamate receptors, acting at cerebellar Purkinje cell spines, may control adaptively timed learning that obeys a Weber law (Fiala, Grossberg, and Bullock, 1996).

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

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