Speed-Accuracy Trade-Off and Noise Correlates: Limited Capacity or Constraints across Timescales?

Wijnants, M. L.[1], Cox, R. F. A.[1], Hasselman, F.[1], Van Orden, G. C.[2], & Bosman, A. M. T.[1]

1.Behavioural Science Institute, Radboud University Nijmegen, the Netherlands

2. Center for Cognition, Action, and Perception, University of Cincinnati, OH

Introduction

The duration of rhythmical aiming movements is well predicted by Fitts' law across a wide range of task constraints. This consistency is traditionally understood as the limited throughput of an information processing channel, which results in a speed-accuracy trade-off. An alternative hypothesis is that the trade-off results from the incompatibility of constraints across timescales, which reduces the capability of the multi-component system to self-organize.

A prediction is that the inability to compromise task-organism constraints is visible across timescales of performance: Constraints operative on timescales faster than a movement may change dynamical patterns emerging over a long sequence of perception-action cycles. The fractal nature of these patterns provides an index for emergent coordination, and should reflect control over the speed and accuracy task dimensions.

Results

Table 1. Correlations Between Movement Duration (MD), Accuracy (ACC), Harmonicity (H), Fractal Dimension Movement Duration (1/f MD), and Fractal Dimension Movement Amplitude (1/f MA).

	MD	ACC	H	1/f MD	1/f MA
MD	-	.77(**)	-.82(**)	.62(*)	-.58(*)
ACC	0.04	-	-.90(**)	.71(**)	-.45(M)
H	-0.32	0.16	-	-.60(*)	.55(*)
1/f MD	-0.04	0.07	-0.17	-	-.57(*)
1/f MA	0.4	0.25	-.51(M)	.61(*)	-

DIFFICULT

EASY

Discussion

Motor control processes change over multiple timescales simultaneously. In difficult tasks, this coupling reveals trade-off phenomena at each individual timescale when constraints like task instruction, energy minimization, and emergent coordination are in conflict. Assuming a softly-assembled motor system, harmonicity (control parameter), and 1/*f* noise (order parameter) could reciprocally provide control over speed and accuracy through self-organization. The observed reflection of participant strategies in dynamical patterns extending over an entire experiment requires extraordinary post-hoc explanations for component-dominant (i.e. mechanistic, discrete, programmed) theories of human cognition.

TASK CONSTRAINTS

EASY — ID=3.0

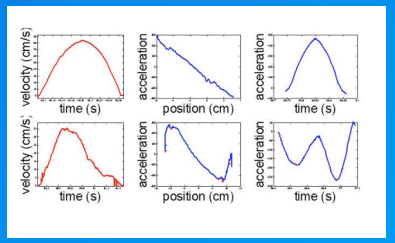
DIFFICULT — ID=6.9

"Draw lines back and forth the targets as fast and as accurately as possible "

WITHIN A TRIAL → HARMONICITY

EASY

DIFFICULT



Full recycling of kinetic energy into potential energy

Requires additional squirt of energy to close the cycle

ONE TRIAL → SPEED, ACCURACY

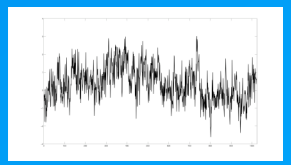
For accurate movements:

$MT = a + b \log_2 (2D/W)$

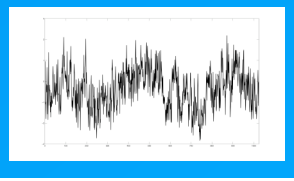
OVER TRIALS → 1/*f* NOISE MD, 1/*f* NOISE MA

WIN-WIN or TRADE-OFF

Movement Duration



Movement Amplitude



FASTER TIMESCALE — ONE TRIAL — SLOWER TIMESCALE