Are reaching movements planned in kinematic or dynamic coordinates?

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Motivation

Do humans plan reaching movements in kinematic (task space) or dynamic (muscle or joint space) coordinates?

Previous work [1] provided evidence that hand paths are planned in kinematic coordinates: when subjects are led to believe their hand motions along a straight line are curved, they adapt their hand motion such that they see a straight line in visual space.

The presented work is designed to investigate whether the same principle applies to velocity: do humans plan movements continuously in time? Do they adapt to manipulation of their movement's velocity?

Methods

Velocity profiles of participants were manipulated according to:

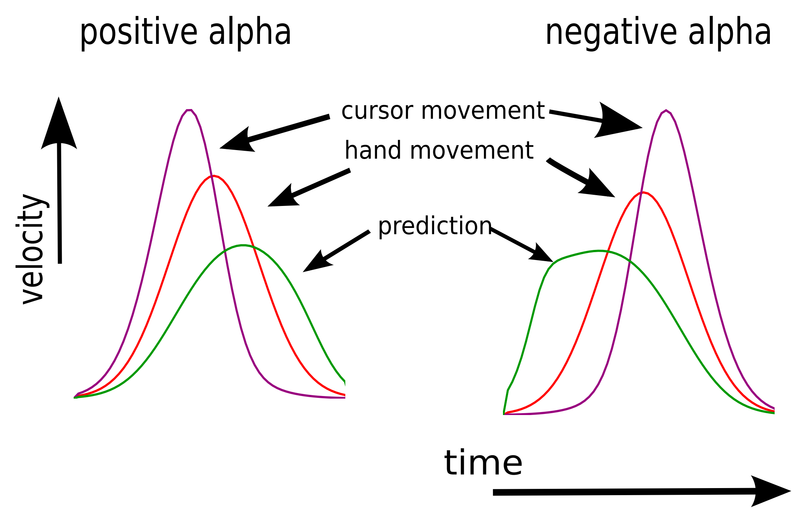
$$\dot{y} = \dot{x} + \alpha \cdot \dot{x} \cdot cos(\pi + \frac{x}{D}\pi)$$

x position of hand

y position of cursor

D total distance covered by movement

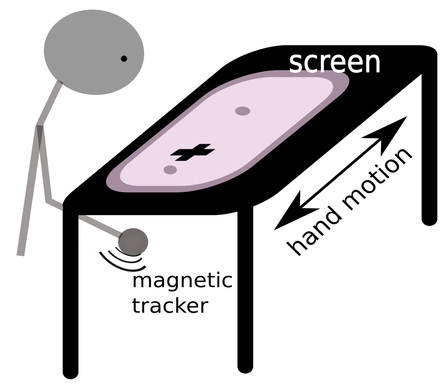
α design parameter controlling amount of manipulation



Experimental Design

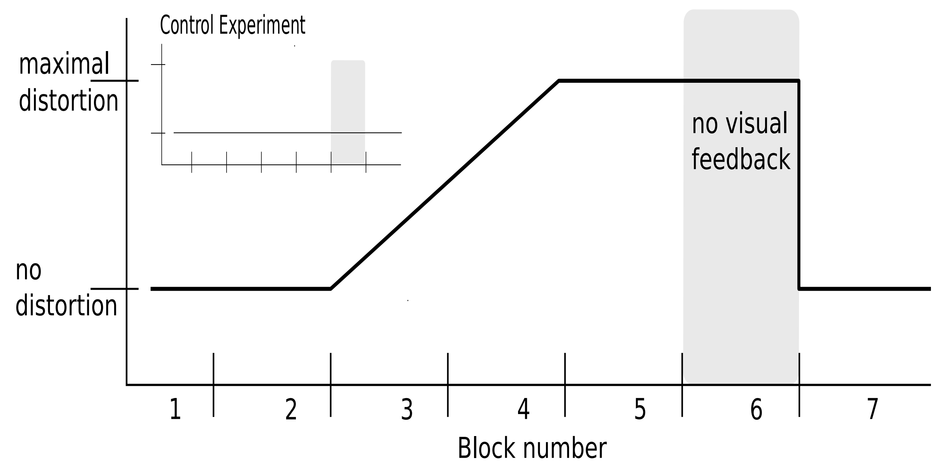
Hand movements were recorded with a magnetic tracker while participants performed point to point reaching movements.

The manipulated or original hand position were displayed on a screen.



Five participants performed two runs of the experiment, one with and one without manipulation.

According to the adaptation paradigm α was increased gradually over the course of 50 trials.



Data Analysis

Motion onset was detected using the method described in [2].

Trajectories of block 5 of the main experiment were compared block 5 of the control experiment (baseline), and to the adaptation predictions.

Trajectories were compared using the features of peak velocity and time needed to reach peak velocity.

Differences were quantified using the non-parametric, repeated-measures Friedman test.

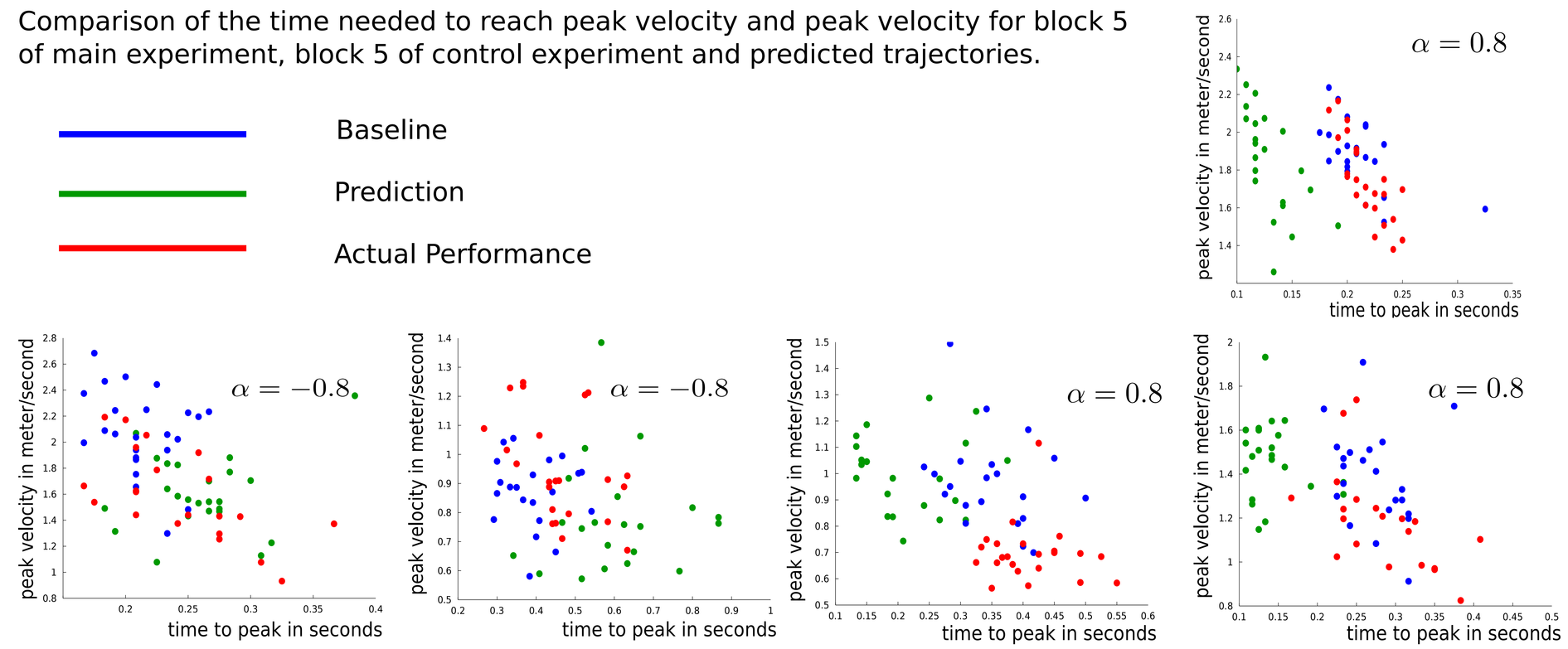
Results

Comparison of the time needed to reach peak velocity and peak velocity for block 5 of main experiment, block 5 of control experiment and predicted trajectories.

Baseline

Prediction

Actual Performance



Quantitative comparison yields mixed results:

For peak height, the differences between predicted and actual outcomes are significant for all participants. For 3 out of 5, the same holds for the time to reach peak velocity. This indicates no adaptation.

However, similar differences are observed between the main and control condition,observed lack of adaptation more likely to occur due to intrablock variance.

p-values of Friedman test:

peak height	H1 $-\alpha$	H2 $+\alpha$	H3 $-\alpha$	H4 $+\alpha$	H5 $+\alpha$
control - main	0.0164	0.1266	0.0011	0.2008	0.0253
prediction - main	0.0000	0.0000	0.0000	0.0000	0.0000

time to peak	H1 $-\alpha$	H2 $+\alpha$	H3 $-\alpha$	H4 $+\alpha$	H5 $+\alpha$
control - main	0.5127	0.0011	0.0000	0.2008	0.0003
prediction - main	0.6547	0.0011	0.000	0.0000	0.0001

Discussion

The preliminary results suggest that no adaptation does occur for changes made to the velocity profile of reaching movements. Possible factors corrupting these results might be:

1) In contrast to the transformation used in [1], our transform has no analytical inverse, which makes it hard to compute what hand motion is required to reproduce a given velocity profile. This might have prevented participants from successfully adapting.

2) The manipulation used might have not entailed large enough errors between the perceived and actual hand position to initiate adaptation.

[1] D.M. Wolpert, Z. Ghahramani, and M.I. Jordan, "Are arm trajectories planned in kinematic or dynamic coordinates? An adaptation study," Experimental Brain Research, vol. 103, 1995, pp. 460–470.
[2] L. Botzer and A. Karniel, "A simple and accurate onset detection method for a measured bell-shaped speed profile," Front. Neuropro, vol. 1, 2009.