Is movement duration predetermined in visually guided reaching? A comparison of finite- and infinite-horizon optimal feedback control

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Background

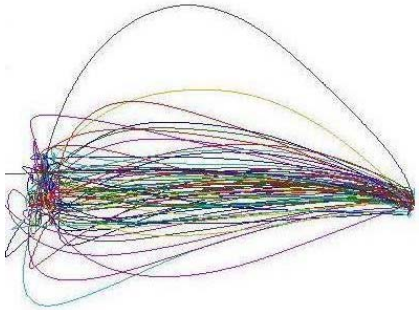
Problems that brain faces during movement

This question had already been answered by many researchers.

How to decide the trajectory? (space)

How to determine the duration? (time)

Whether brain prefixes the movement duration before onset?



Previous study

Answer the question by comparing two theories

Finite-horizon control theory:

Movement duration is determined before onset based on certain criterion and that movement is optimized over that finite duration.

$$J = \int_0^{tf} L[x(t), u(t)]dt$$

Infinite-horizon control theory:

Movement duration is not predetermined and that movement is optimized over infinite period.

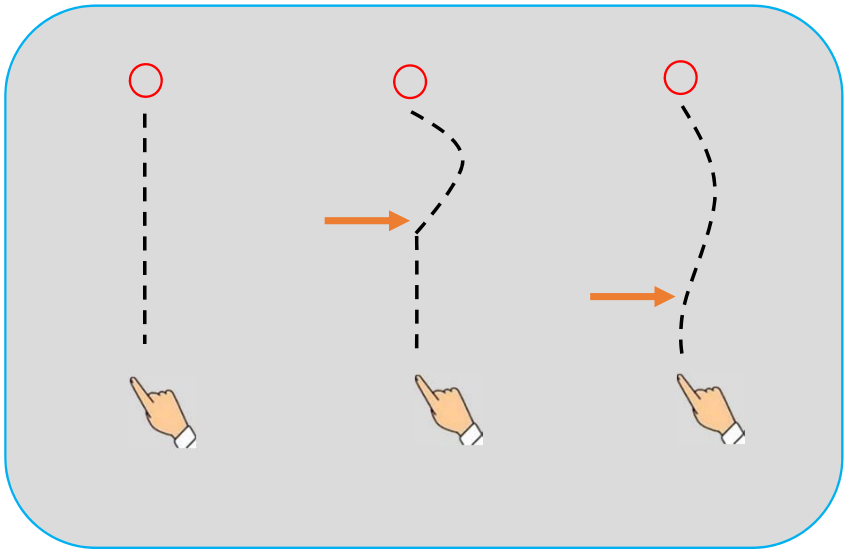
$$J = \int_0^{\infty} L[x(t), u(t)]dt$$

	Finite-horizon	Infinite-horizon
Kalman gain:	$K(t) = P_{22}(t)C^T(DD^T)^{-1}$	$K = P_{22}C^T(DD^T)^{-1}$
Control gain:	$L(t) = (R + \gamma^T(S_{11}(t) + S_{22}(t))\gamma)^{-1}B^T S_{11}(t)$	$L = (R + \gamma^T(S_{11} + S_{22}\gamma))^{-1}B^T S_{11}$

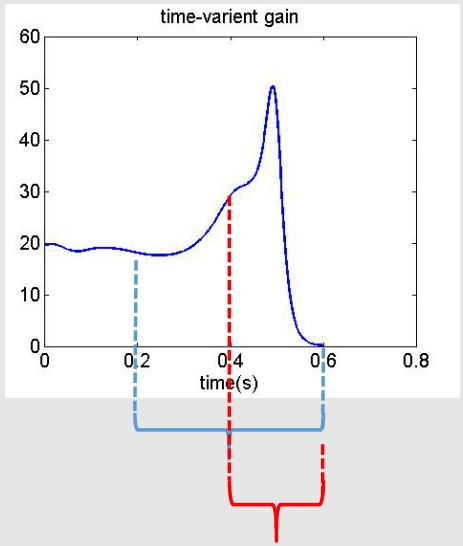
Method

Different kinds of gains lead to different correction styles

Correct perturbations:

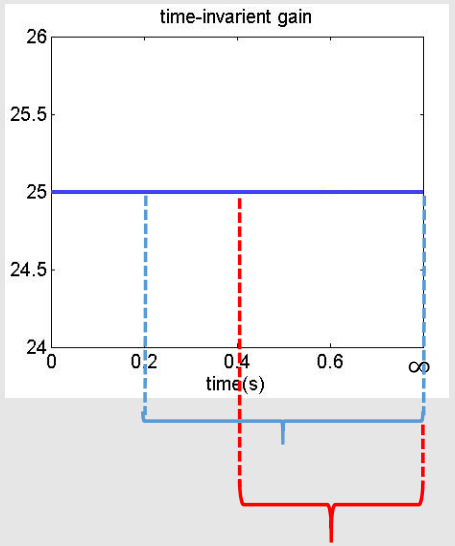


Finite-horizon control



Gains from 0.2—0.6 and gains from 0.4—0.6 are different

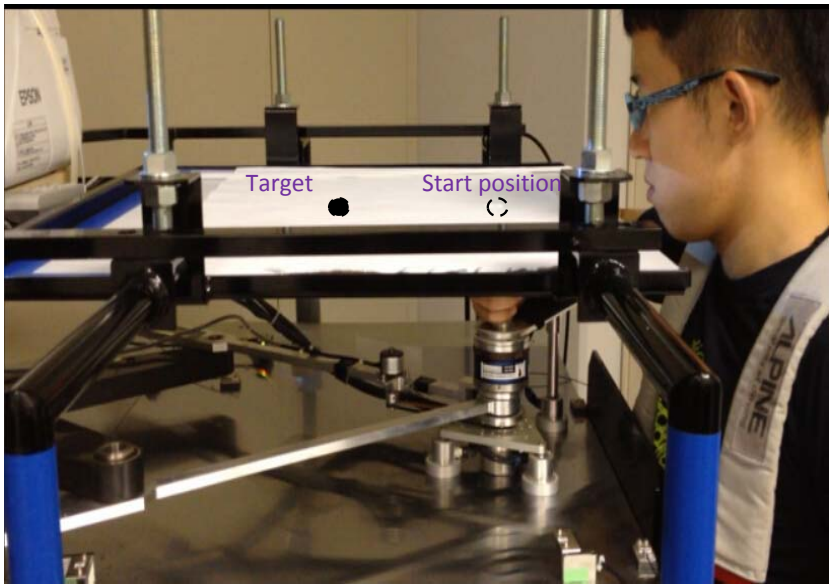
Infinite-horizon control

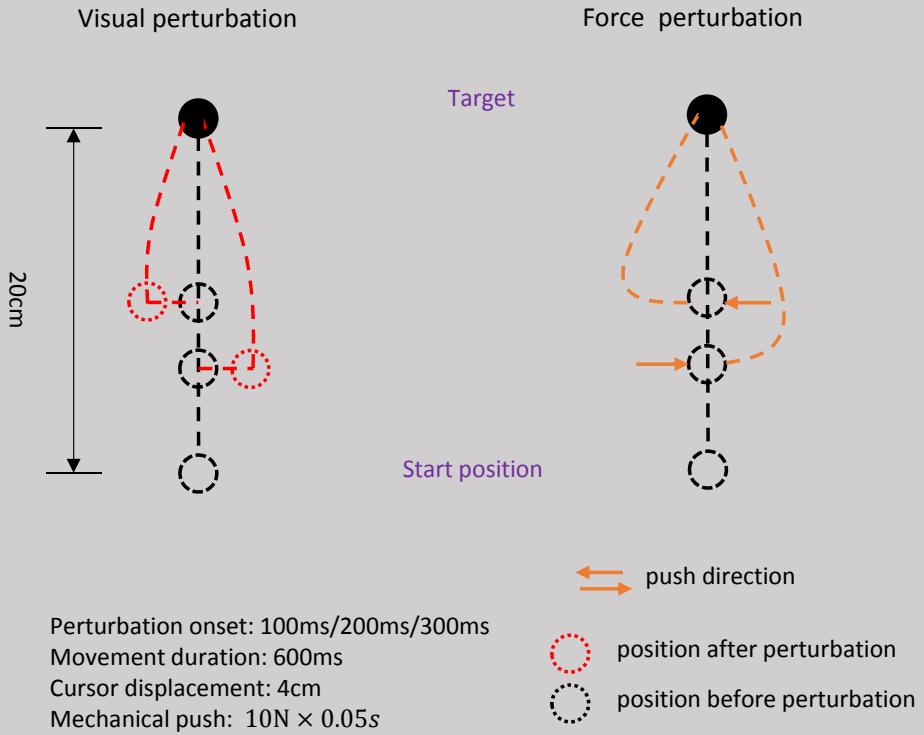


Gains from 0.2—∞ and gains from 0.4—∞ are same

Method

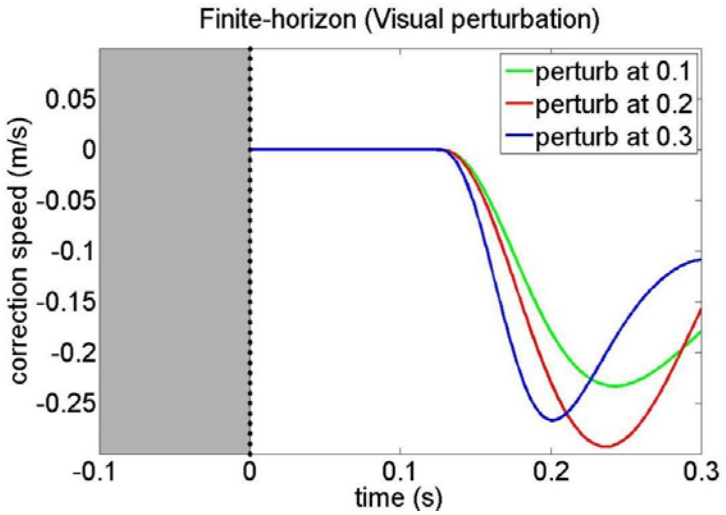
Experiment design

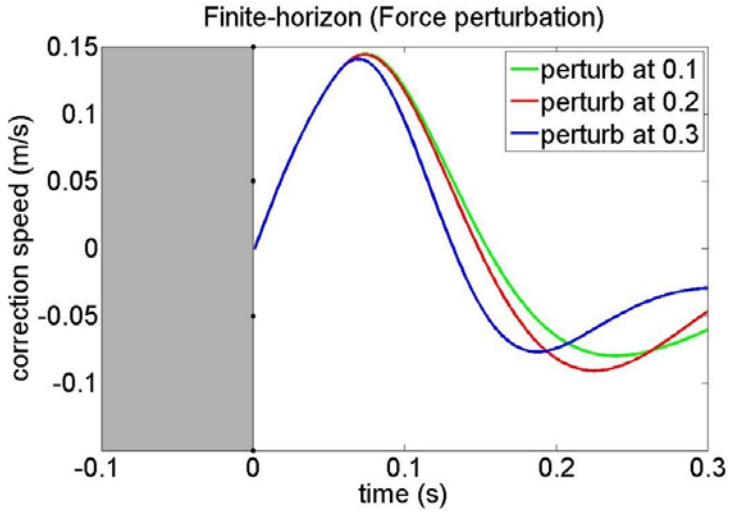


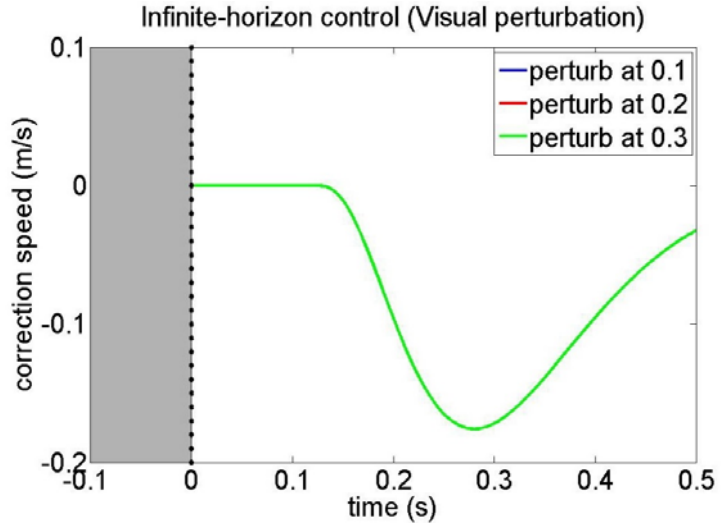


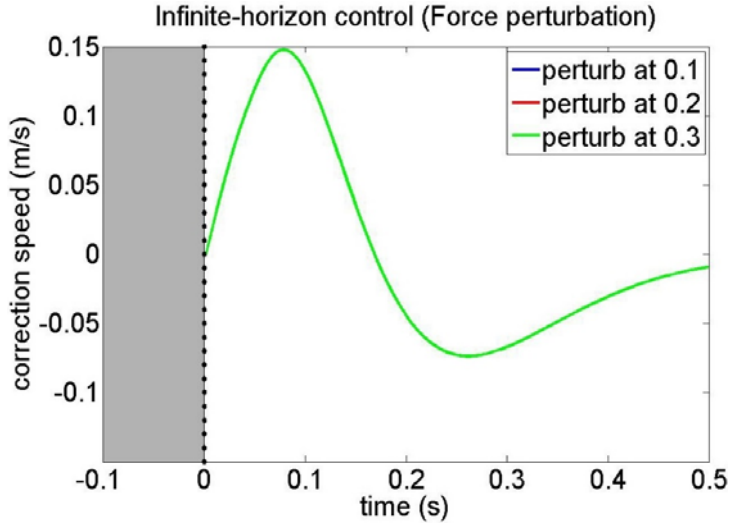
Perturbation onset: 100ms/200ms/300ms
Movement duration: 600ms
Cursor displacement: 4cm
Mechanical push: $10\mathrm{N} \times 0.05s$

Simulation


Finite-horizon (Visual perturbation)
perturb at 0.1
perturb at 0.2
perturb at 0.3
correction speed (m/s)
time (s)


Finite-horizon (Force perturbation)
perturb at 0.1
perturb at 0.2
perturb at 0.3
correction speed (m/s)
time (s)


Infinite-horizon control (Visual perturbation)
perturb at 0.1
perturb at 0.2
perturb at 0.3
correction speed (m/s)
time (s)


Infinite-horizon control (Force perturbation)
perturb at 0.1
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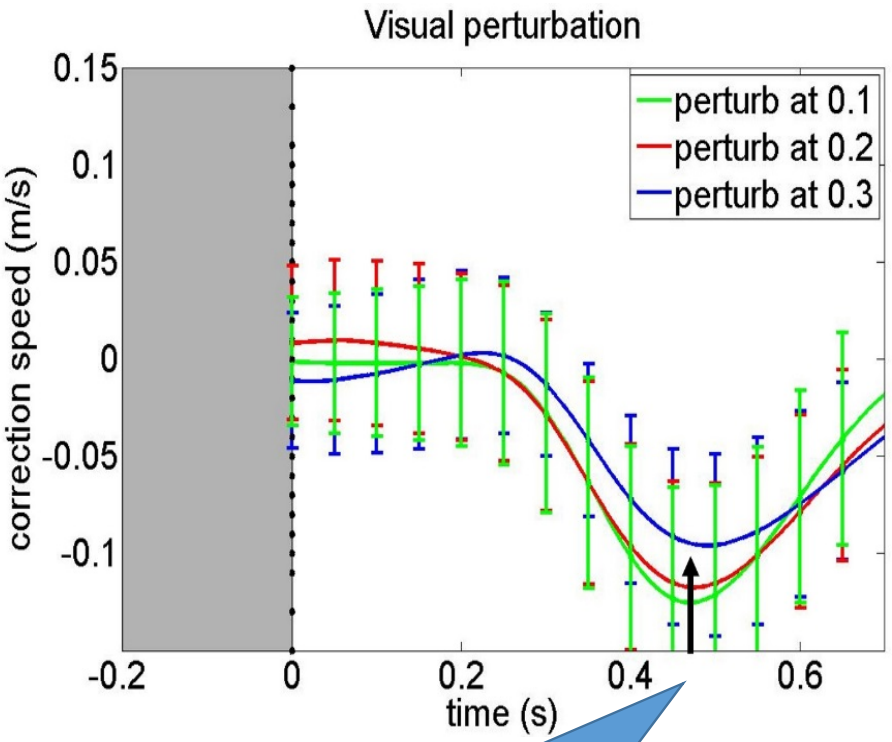
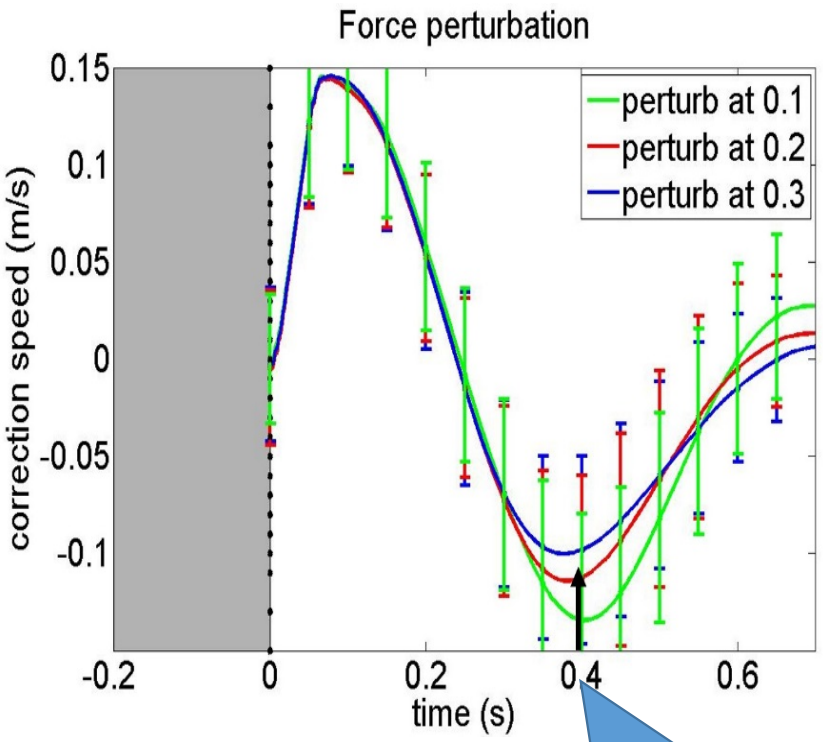
correction speed (m/s)
time (s)

Experiment data



ANOVA: p = 1.08933e-17



ANOVA: p = 1.05755e-23

Summary& Conclusion

Summary:

1. The question “whether brain prefixes a movement duration” can be answered by comparing finite-horizon control & infinite-horizon control.

2. These two theories can be compared by analyzing the corrections against different perturbation onsets.

3. Simulations under different theories are compared with experiment data.

Conclusion:

Current experiment result is consistent with finite-horizon control theory, which means that brain does prefix the movement duration before onset, however, the data comes from only 6 subjects, more data is needed to confirm our conclusion.