

Do humans plan continuous trajectories in kinematic coordinates?

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Motivation

Unresolved if humans represent continuous trajectories in kinematic space.

Do we track an optimal trajectory with an internal model?

Humans have been shown to adapt to increasing curvature away from straight movement (Wolpert et al., 1995).

Objective

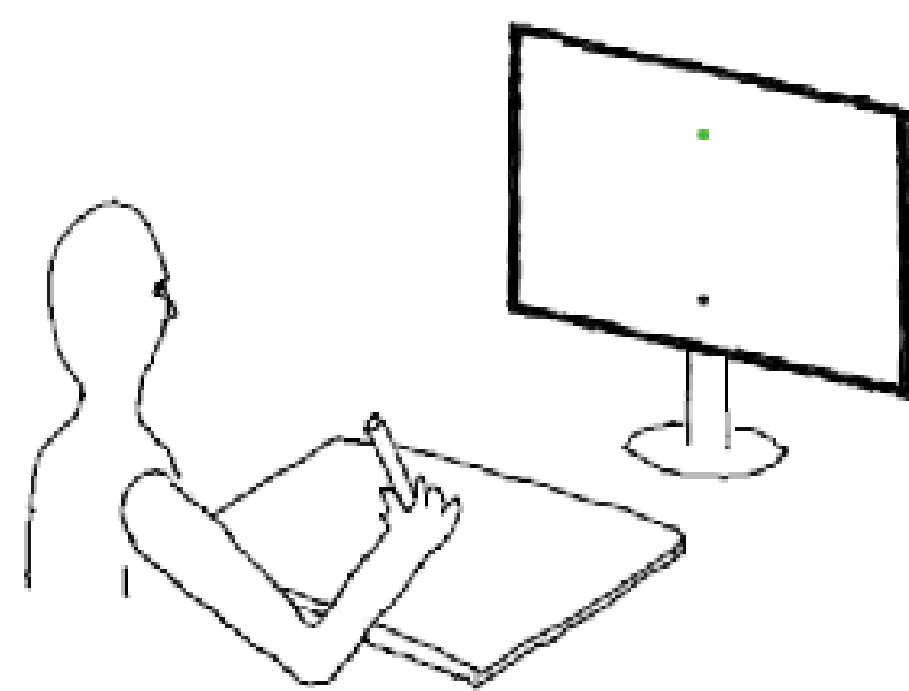
Do humans adapt to a manipulation of the velocity profile if the trajectory shape remains unchanged?

Methods

Subjects need to move a hand between two points and are presented with continous feedback about the hand's position.

5 naive subjects, right-handed

Experiment 1



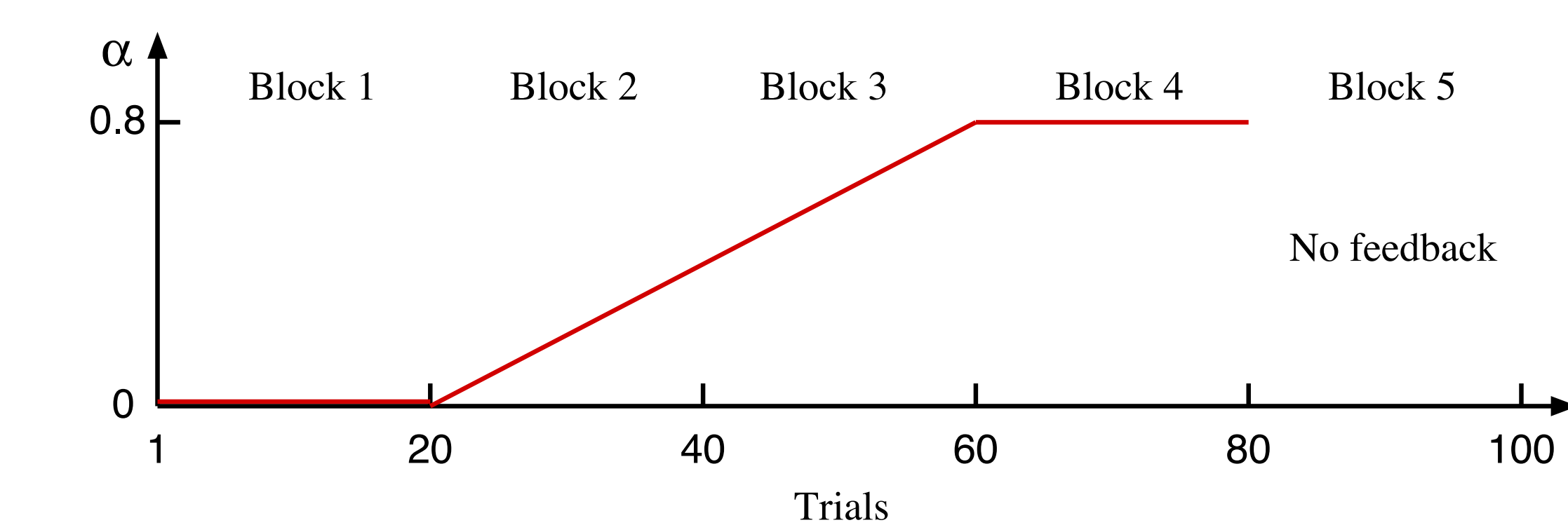
Experimental setup I

Manipulation of fed-back velocity:

$$v' = v + \alpha v \cos(\pi + \pi y/D)$$

For a symmetric velocity profile, the above manipulation does not alter the position of the movement end point.

The velocity was gradually manipulated.



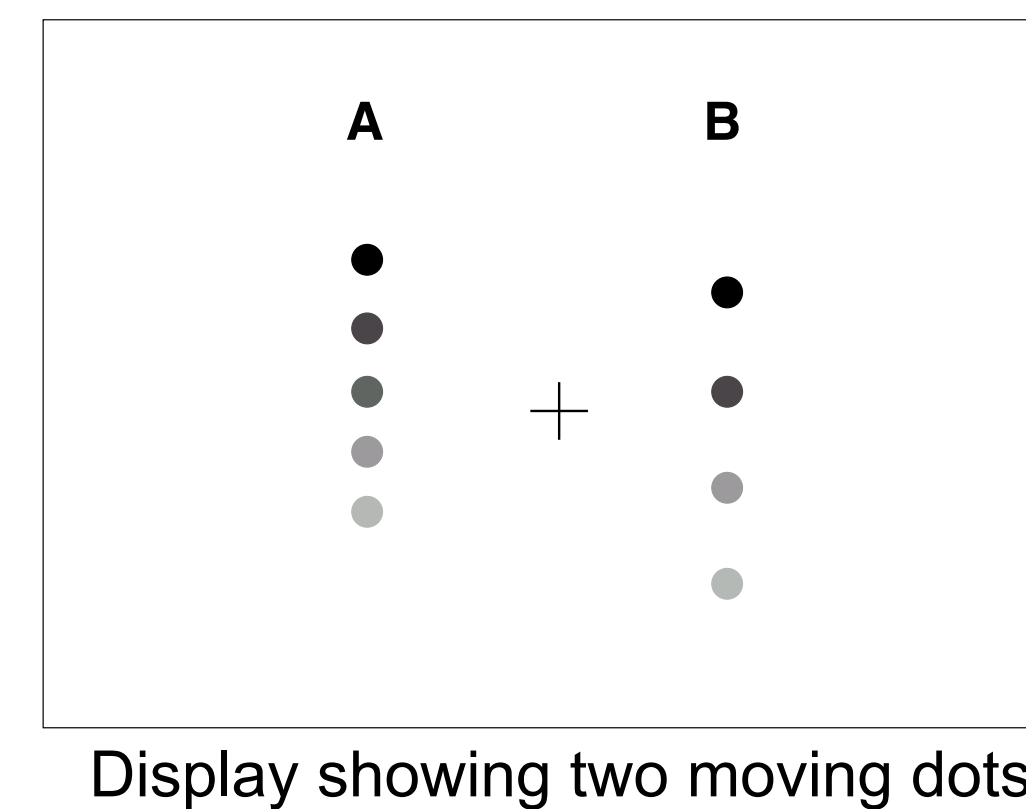
Trial-by-trial change of α .

Experiment 2

We did a control experiment to test if subjects could perceive the change in velocity of the feedback manipulation.

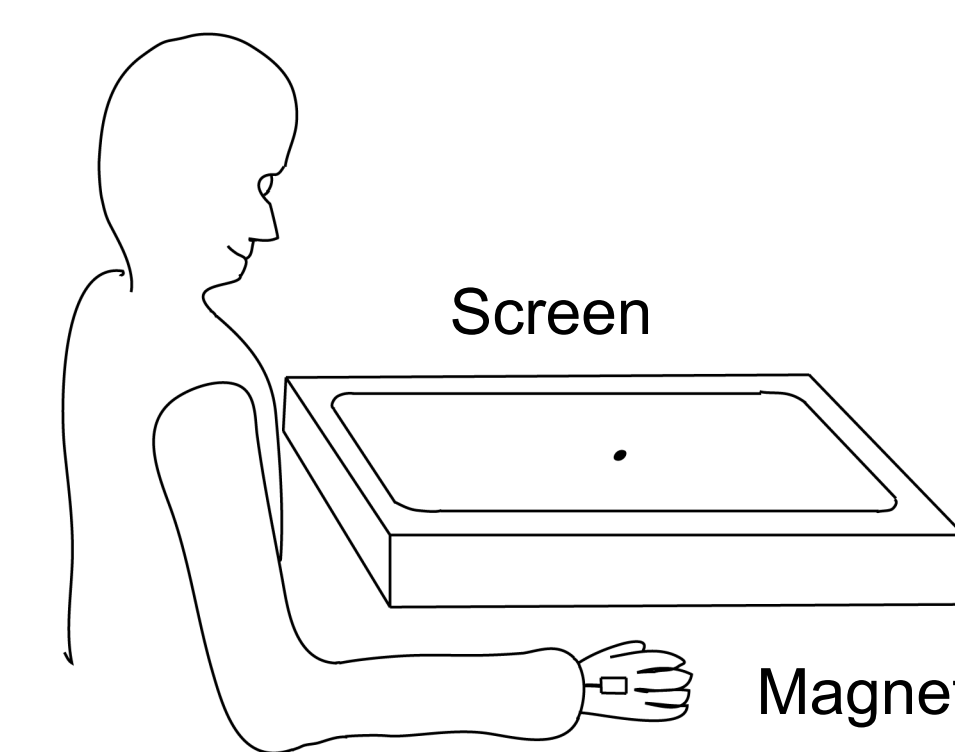
In 200 trials, subjects were asked which movement was faster (by typing 'a' or 'b').

The start times were randomized.
Reference velocity v_1 was presented for 500 ms.
 $v_1 = 0.16$ m/sec = 12 deg/sec.



Display showing two moving dots

Experiment 3



Experimental setup II

Experiments 3 was like experiment 1, but using a different setup, longer learning period (25 trials per block), and different α .

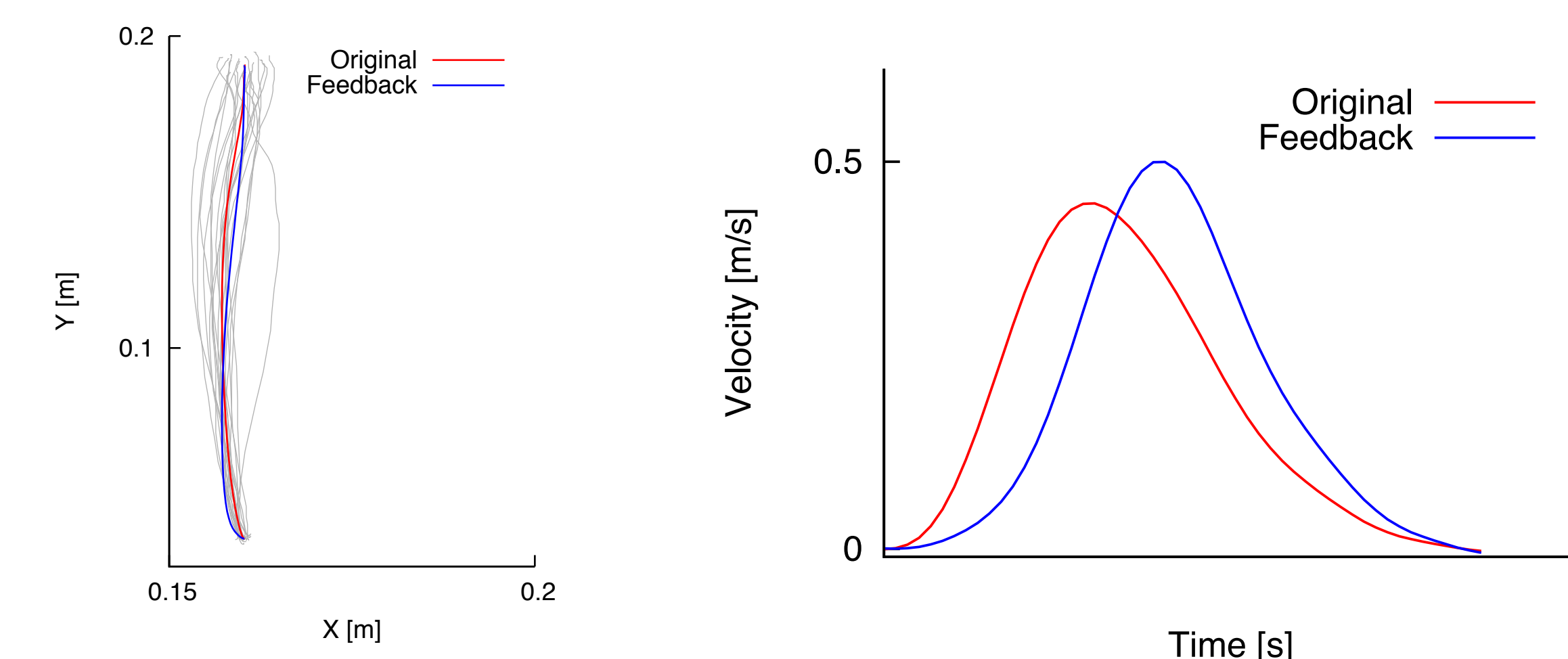
Experiment 4

Experiment 4 was like experiment 2, but using setup II.
The reference velocity v_1 was presented for 300 ms. $v_1 = 0.11$ m/sec = 23 deg/sec.

Results

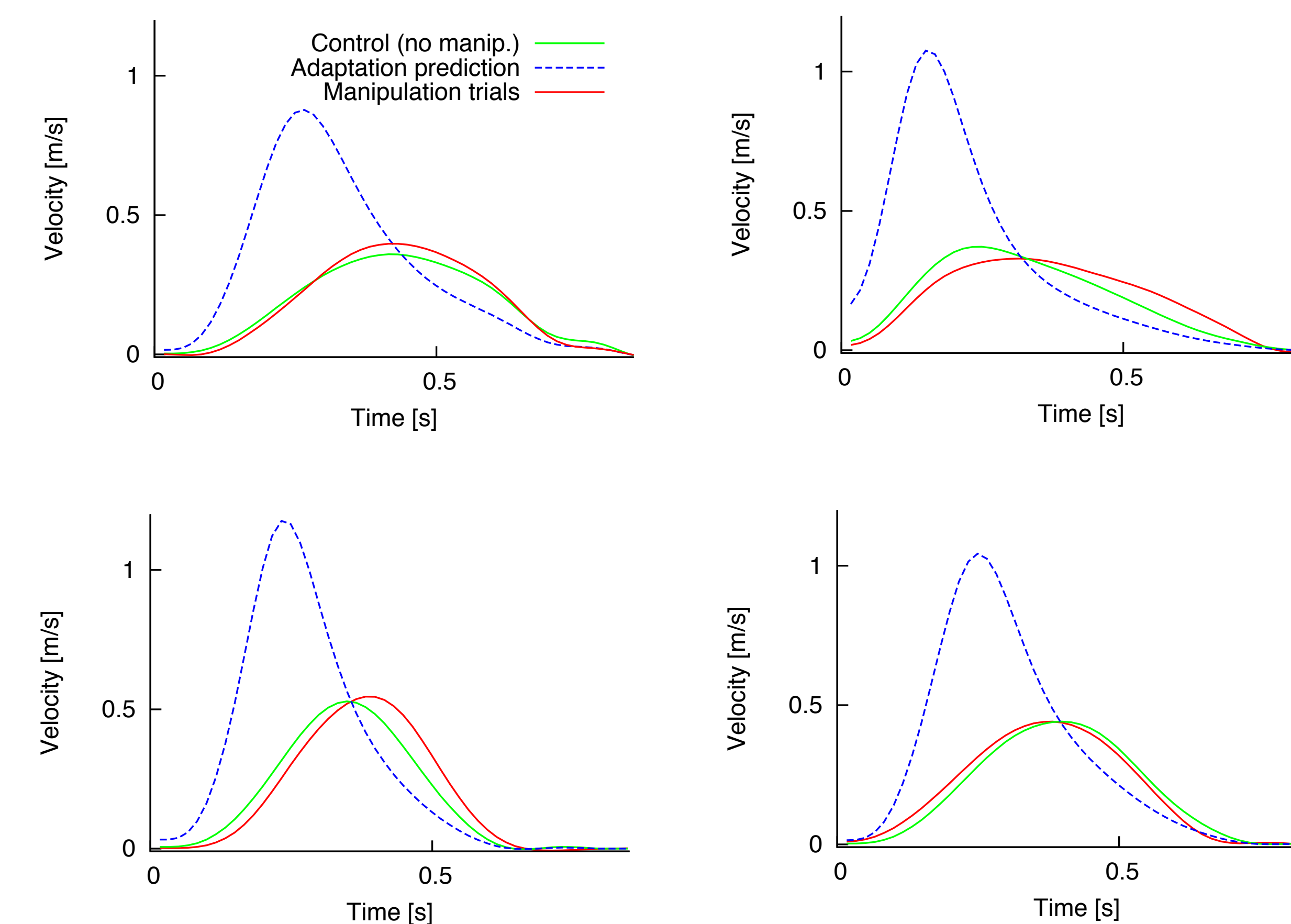
Experiment 1

The feedback manipulation did not alter the shape of the hand trajectory, but the velocity profile.



Result of manipulation in block 4. (Left) Hand trajectories, raw (gray) and average (red). (Right) Velocity (Y direction) of average trajectories.

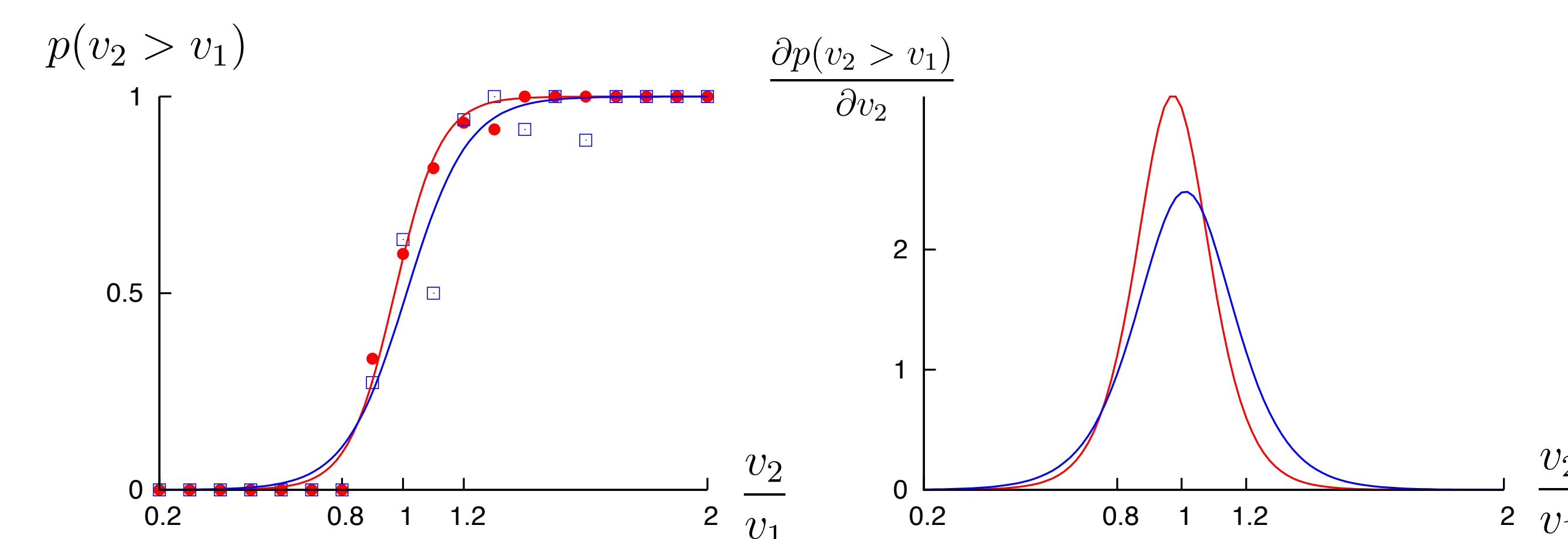
Subjects did not adapt to the manipulated velocity profile.



Comparison of velocity (in Y direction) for block 5 trials, shown for all 4 subjects of experiment 1. Graphs show velocity of mean trajectory.

Experiment 2

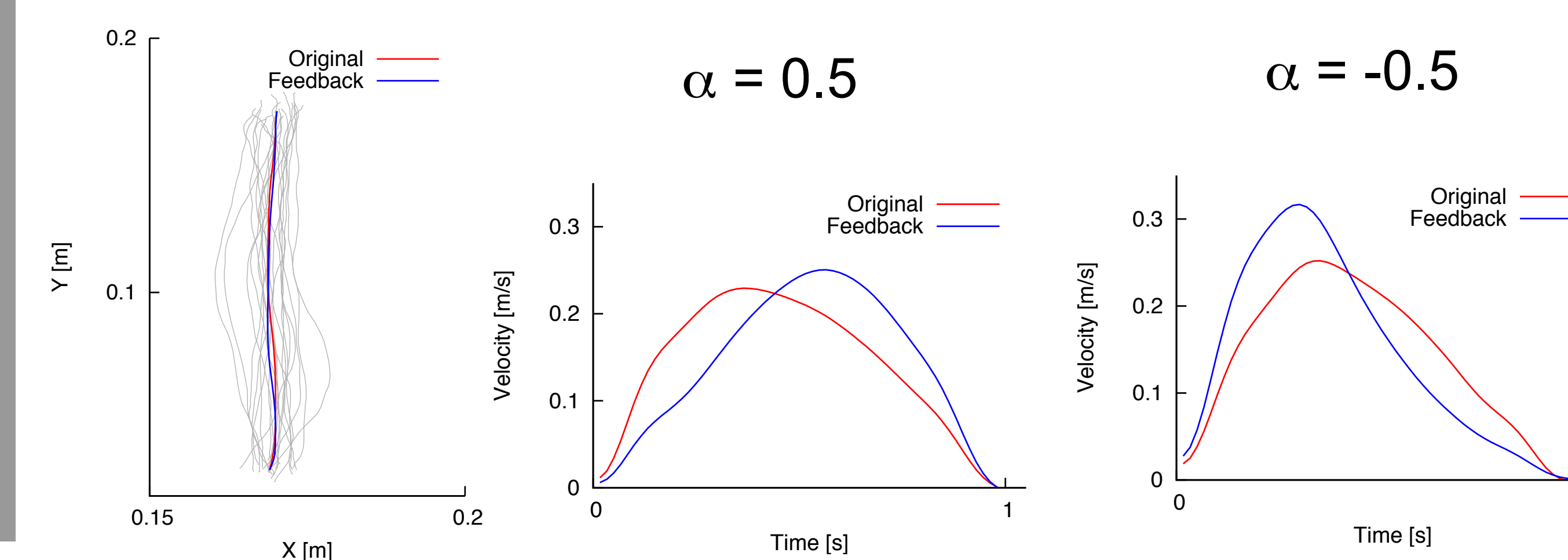
The sensitivity of speed perception was smaller than the magnitude of the speed manipulation.



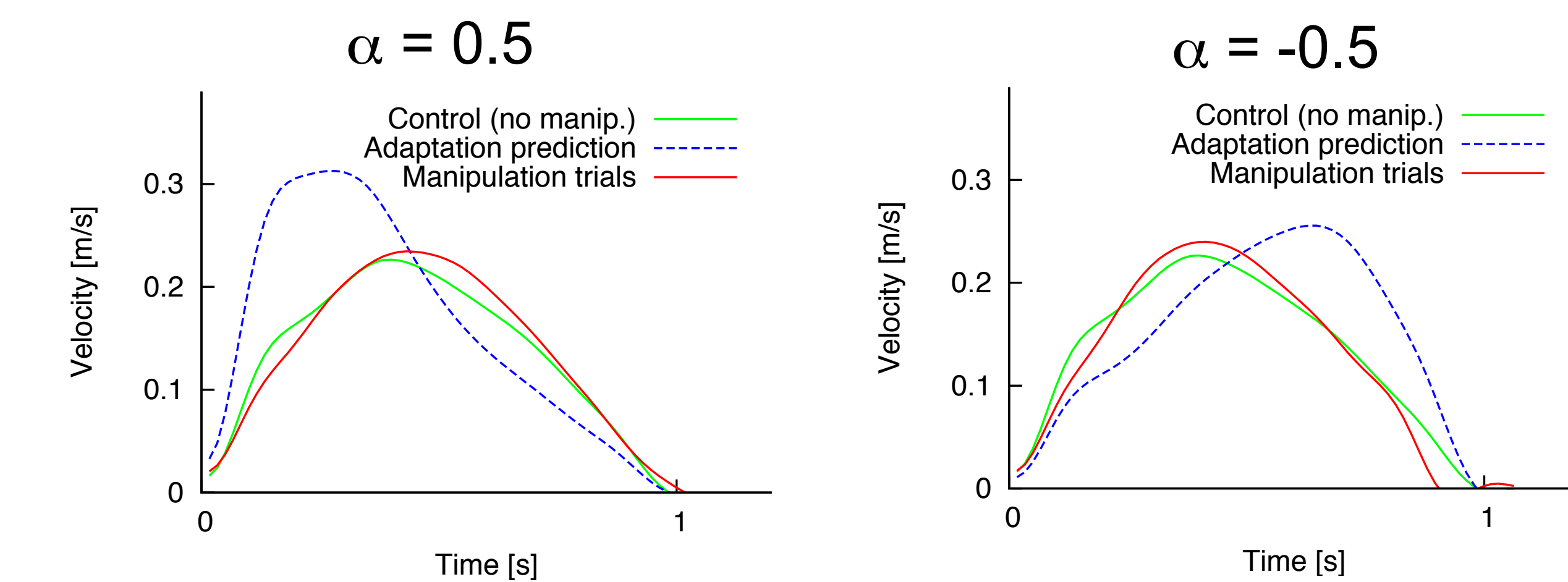
Psychometric function and its derivative shown for two subjects (red and blue).

Experiment 3

The velocity profile was skewed in two different directions.



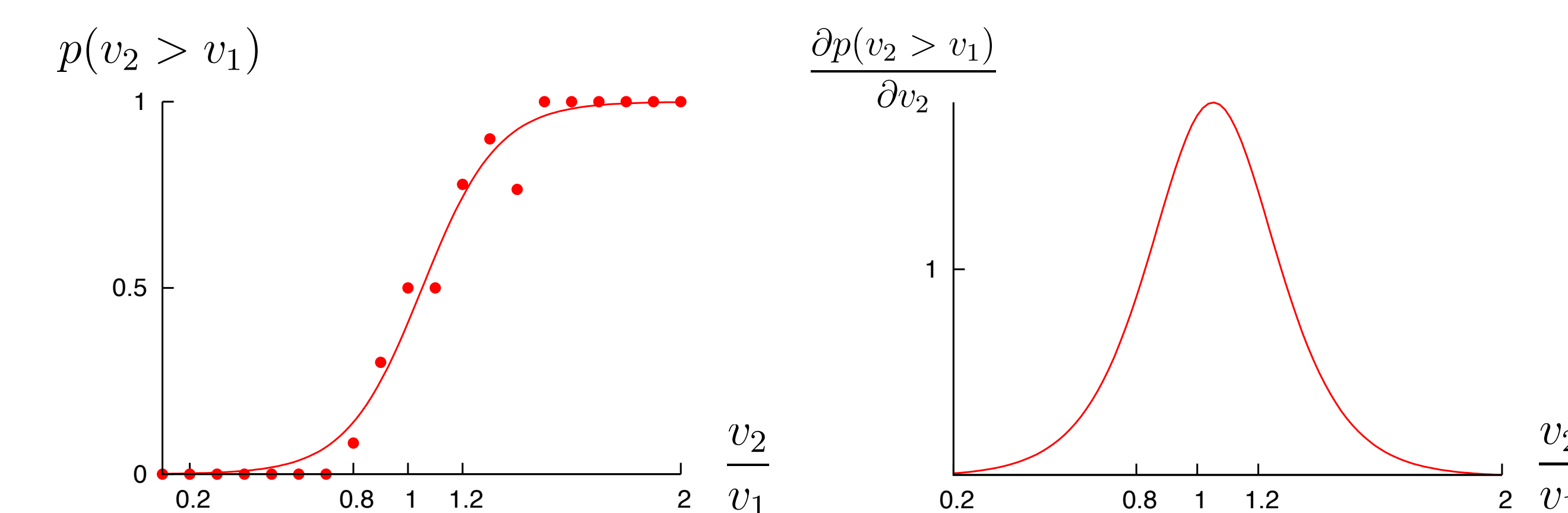
In both skew conditions, the subject did not adapt its movement.



Comparison of velocity (in Y direction) for block 5 trials of experiment 3. Graphs show velocity of mean trajectory.

Experiment 4

The sensitivity of speed perception was smaller than the magnitude of the speed manipulation.



Psychometric function and its derivative shown for the same subject as in experiment 3.

Discussion

Subjects did not adapt to a manipulation of the velocity profile.

These results are not consistent with the hypothesis that we track with an internal model a continuous reference trajectory.

A possible hypothesis could be that we use only a small set of control commands, and the dynamics of the musculoskeletal system result in the observed continuous trajectory.

Subjects did not notice that the velocity was manipulated. Thus, possibly, they update a visuomotor forward model of the hand position.

References

Wolpert DM, Ghahramani Z, and Jordan MI (1995).
Are arm trajectories planned in kinematic or dynamic coordinates?
An adaptation study.
Experimental Brain Research 103: 460-470