Haptic guidance improves the visuo-manual tracking of trajectories

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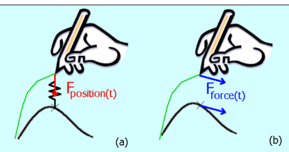
Context

Learning to perform new movements is usually achieved by following visual demonstrations.
Haptic guidance by a force feedback device is a recent and original technology which provides additional proprioceptive cues during visuo-motor learning tasks.
However, the effects of two types of haptic guidances - control in position (HGP) or in force (HGF) – on visuo-manual tracking ("following") of trajectories are still under debate.

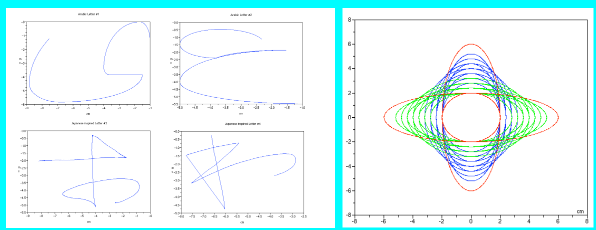


Schematic view of haptic guidances
(a) Haptic guidance in position (HGP); the force felt by the user at time *t* is proportional to displacement between the current user position and the theoretical position on the model trajectory;
(b) Haptic guidance in force (HGF); the force felt by the user at time *t* is the same as the force existing for the theoretical trajectory at the same time.

Experiment

Task

Three training techniques of haptic guidance (HGP, HGF or control condition, NHG, without haptic guidance) were evaluated in two experiments. Movements produced by adults were assessed in terms of shapes (dynamic time warping) and kinematics criteria (number of velocity peaks and mean velocity) **before** and **after** the training sessions. Trajectories consisted of two Arabic and two Japanese-inspired letters in Experiment 1 and ellipses in Experiment 2.



Trajectoires used in Experiments
Left: Letters proposed in experiment 1: Letters 1 and 2 are Arabic and letters 3 and 4 are "Japanese-like" letters.
Right: All ellipses used in experiment 2: In red, the three references trajectories used before and after each training session; In green and blue, the trajectories used during the training sessions, equidistant in the choice of their diagonals (eccentricity)

Participants and Experimental Setup

23 subjects (Expe. 1) and 24 subjects (Expe. 2) were asked to learn to track visuo-manually trajectories with the stylus as accurately and as promptly as possible.

Trajectories were presented on a user-friendly interface, designed to be as close as possible to the usual handwriting task. A modified force feedback device's pen was used provide haptic information to the subject.

Subject undergoing the experiment
"What You See Is What You Feel" interface. The force feedback device's stylus served as a pen over a simple flat screen, which served as a paper

Results

Experiment 1: Letters

➢We observed that the use of HGF globally improves the fluency of the visuo-manual tracking of trajectories while no shape damage was observed.
➢No significant improvement was found for HGP or NHG.

	No Haptic Guidance	Haptic Guidance in Position	Haptic Guidance in Force
Number of velovity peaks	NS	NS	Significant reduction from 10.82±1.16 to 8.58±1.16
Mean velocity	NS	NS	Significant increase from 4.97±0.4 cm/s to 6.34±0.52 cm/s
Shape matching score (DTW)	NS	NS	NS

Experiment 2: Ellipses

➢We observed that both HGP and HGF reduces the number of velocity peaks but only HGF increase the mean velocity
➢No shape damage was found.
➢No significant improvement was found for NHG.

	No Haptic Guidance	Haptic Guidance in Position	Haptic Guidance in Force
Number of velocity peaks	NS	Significant reduction from 14.48±2.37 to 10.19±1.58	Significant reduction from 14.19±1.91 to 9.20±1.38
Mean velocity	NS	NS	Significant increase from 4.62±0.48 cm/s to 6.23 ±0.48 cm/s
Shape matching score (DTW)	NS	NS	NS

Conclusion

➢Haptic Guidances (HGF and HGP) do not influence the shape quality, mainly guided by visual feedbacks.

➢HGF better improved the fluidity of movements than HGP for these trajectories.

➢The global superiority of HGF over HGP suggested that learned information for this specific motor activity could be stored as internal inverse model, encoded in force coordinates.