Control strategies in object manipulation tasks

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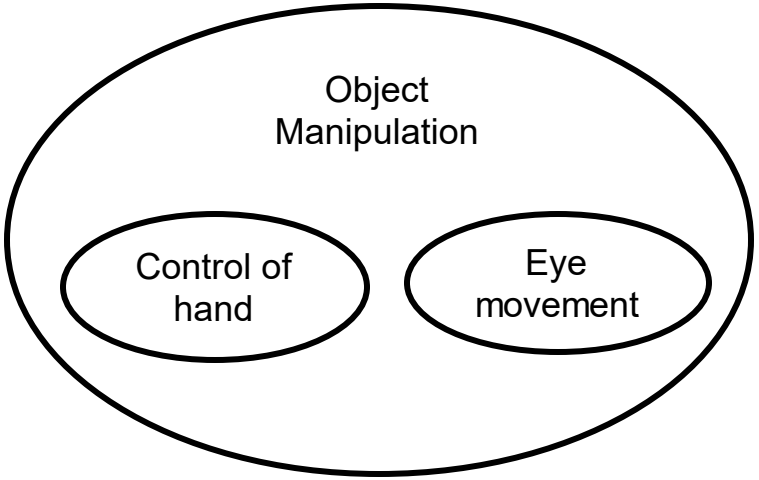
Introduction

1. Remarkable manipulative skill of the human hand
   - Manual tasks are organized and controlled by nervous system

2. Successful manipulation requires predictions about motor commands and sensory events

Goalkeeper predicts the direction of the ball

Introduction

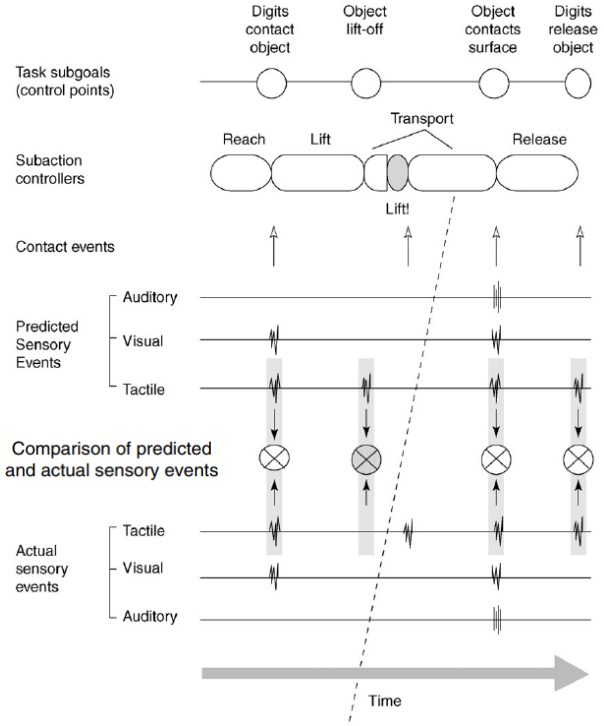


1. Object manipulation is a model system for the study of sensorimotor and cognitive control strategies governing skilled behavior in humans.

2. Review recent works on the **control of hand** and **eye movements** in Object manipulation

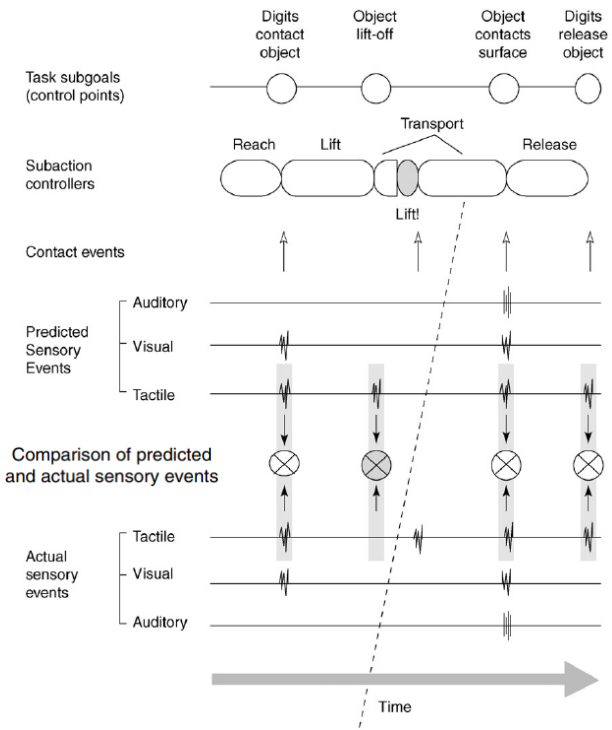
3. **Contact events** and **predictive control mechanisms** that are based on knowledge of object properties.

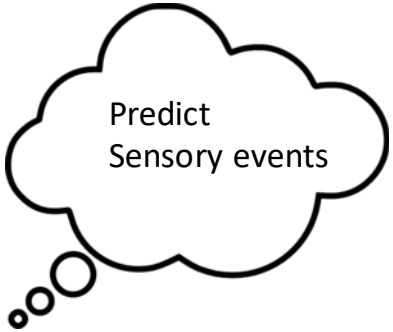
Sensorimotor control points



1. Contact events give rise to distinct sensory events
2. These sensory events are characterized by a specific afferent neural signature
3. These sensory events have a crucial role in the sensory control of manipulations.

Sensorimotor control points

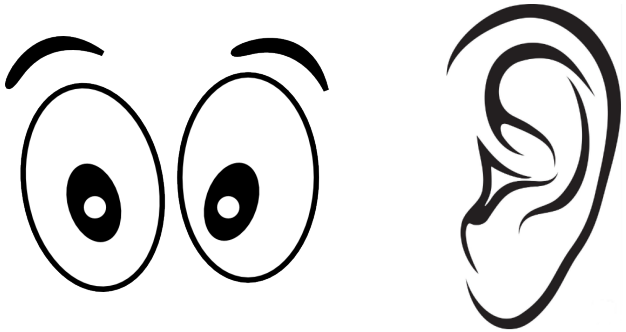




Our brain compares the predicted sensory events with the actual sensory events to monitor task progression and adjust subsequent motor commands

Sensorimotor control points

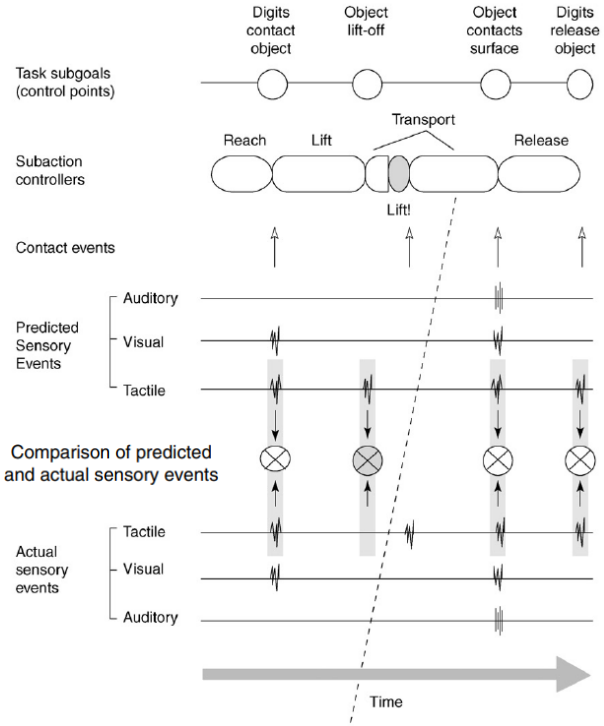
1. Tactile signals, especially from contact events, are essential for skilled and dexterous manipulation



2. Contact events can also give rise to distinct signals in other sensory modalities, including proprioception, vision and audition

Sensorimotor control points

sensorimotor control points that have three crucial functions



1. The sensorimotor system can simultaneously monitor multiple aspects of task performance by comparing actual and predicted sensory events in multiple sensory modalities

2. They provide an opportunity for sensorimotor integration and intermodal alignment that might facilitate learning and upholding of multimodal sensorimotor correlations

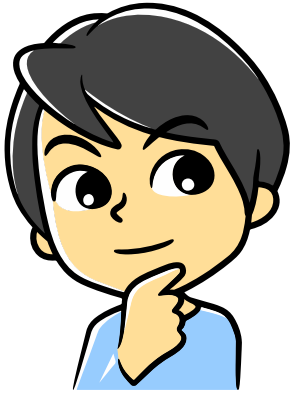
3. The predicted sensory consequences of contact events can directly furnish initial state information for subsequent phases of the manipulation tasks

Prediction and rapid updating

- Skilled manipulation relies on predictions about the properties of objects

Tennis ball lifting

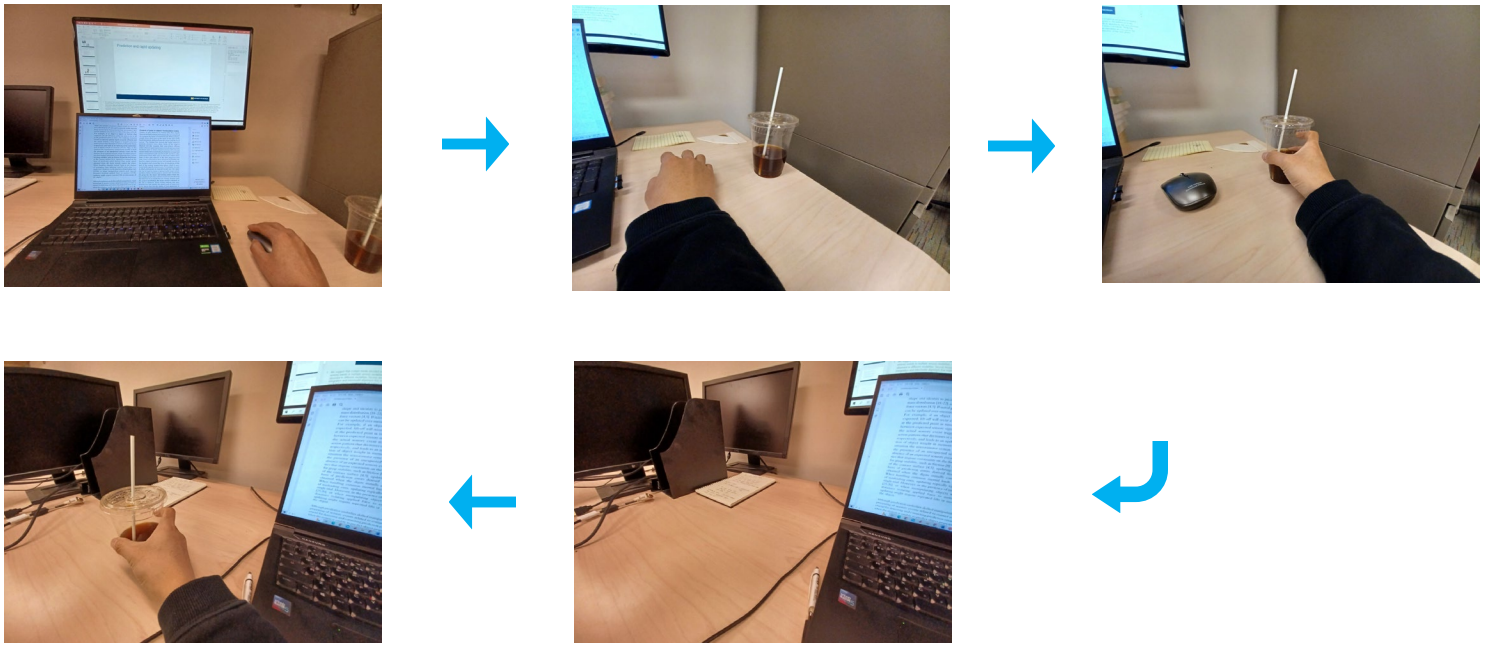
Prediction and rapid updating



- The sensorimotor system reacts quickly to both the presence of an unexpected sensory event and the absence of an expected sensory event.
- For example, if an object is lighter or heavier than expected, lift-off will occur either too soon or not at all at the predicted point in time

Control of gaze in object manipulation tasks

- Gaze arrives at each location ahead of the hand but, on average, remains until the grasp is established



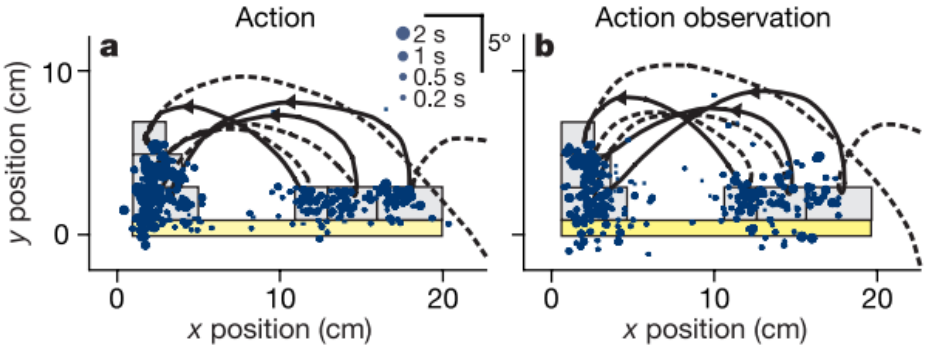
Control of gaze in object manipulation tasks

1. Visual events related to contact are registered in central vision, because gaze is aligned in both time and space with the contact events marking task subgoals

2. Gaze plays a complementary role in the monitoring of task progression and the upholding of sensorimotor correlations important for prediction

Sensorimotor control points in action observation

- An important hypothesis in psychology and neuroscience is that understanding others' actions results from a mechanism that maps observed action onto sensorimotor representations of that same action in the observer's brain.



Neural systems that are engaged when performing actions are also active during action observation

Action plans used in action observation J. Randall Flanagan & Roland S. Johansson

Sensorimotor control points in action observation

In manipulation tasks, contact events have a key role in linking the actor and observer.

Gaze behavior in visuomotor learning

1. The acquisition of most motor skills requires learning novel transformations relating actions to their sensory consequences

2. Recently, the authors investigated gaze behavior during learning of a novel visually guided manual task. Land and McLeod reported differences in gaze behavior across skill levels in cricket batsman; however, previous studies have not examined gaze during the course of skill acquisition.

Gaze behavior in visuomotor learning

1. Participants were required to move a cursor to successive targets presented on a screen by applying forces and torques to a rigid tool held between the two hands.

2. Three distinct stages of learning

   1) an initial exploratory stage

   2) a skill acquisition stage

   3) a skill refinement stage

Gaze behavior in visuomotor learning

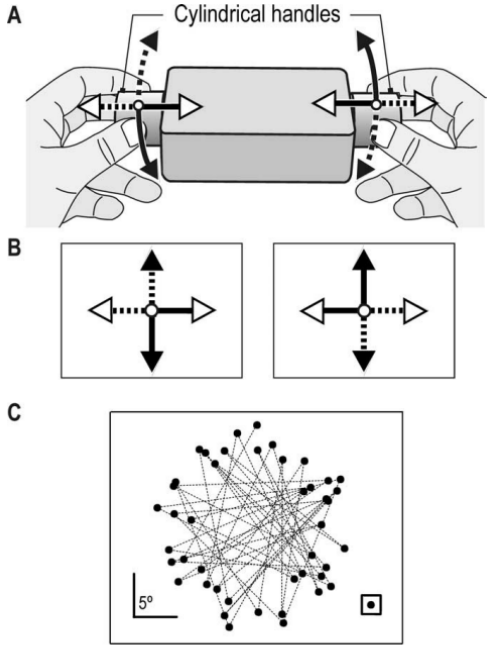
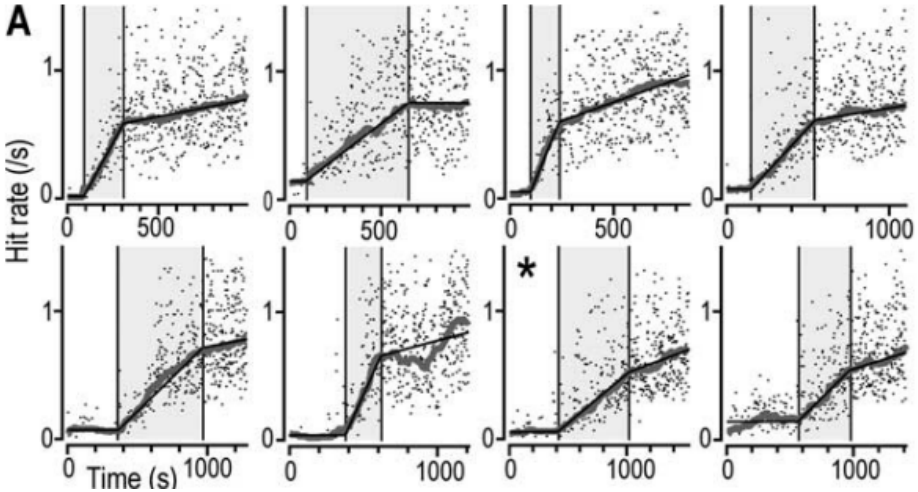


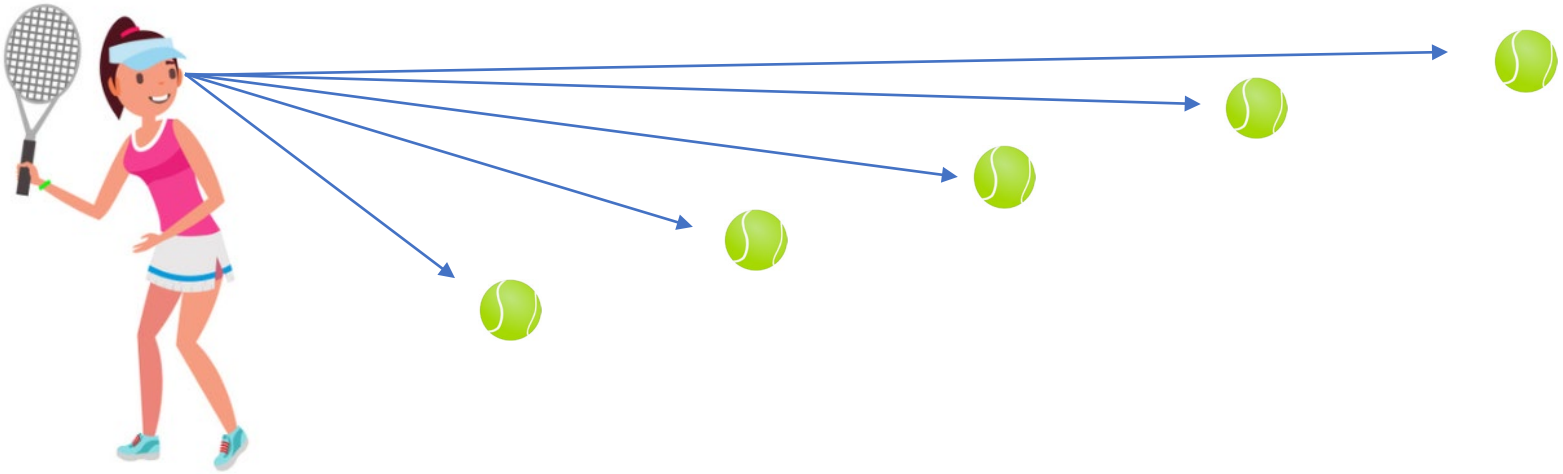
Figure 1. Apparatus and target distribution on screen. ***A***, Tool used by the subject to control a cursor on the screen by bimanually applying forces and torques about the long axis of the tool. ***B***, The corresponding arrows in ***A*** and ***B*** indicate the two different mapping rules relating hand forces and torques to cursor movements. ***C***, Distribution of target positions (filled circles) in which consecutively appearing targets are connected with a line; the target shape (square) is shown to scale in the bottom right corner.

- Three distinct stages of learning
  1) an initial exploratory stage
  2) a skill acquisition stage
  3) a skill refinement stage



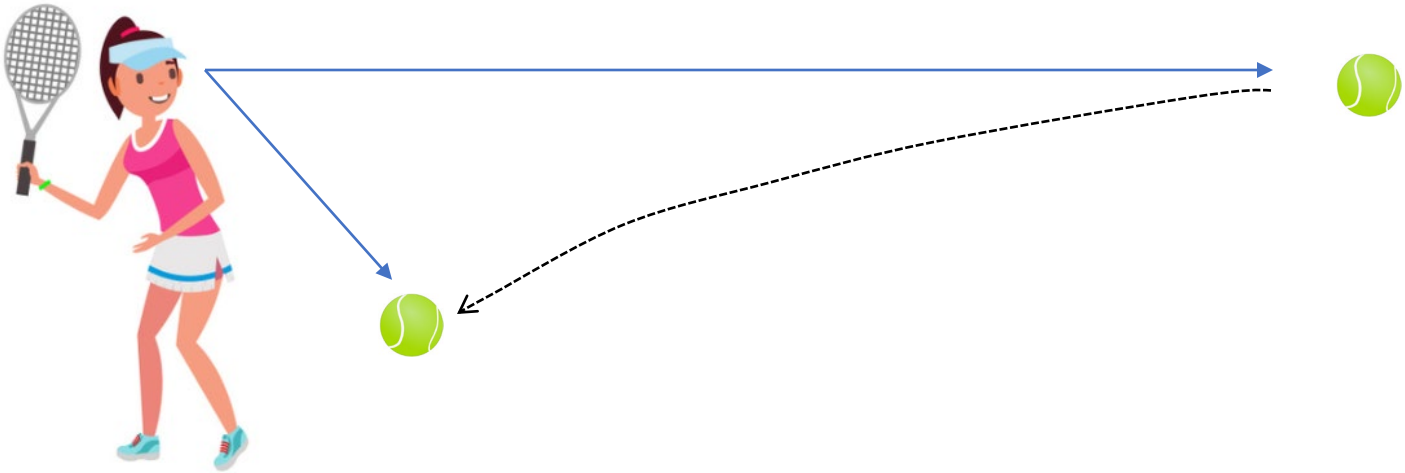
Gaze behavior in visuomotor learning

- The exploration stage

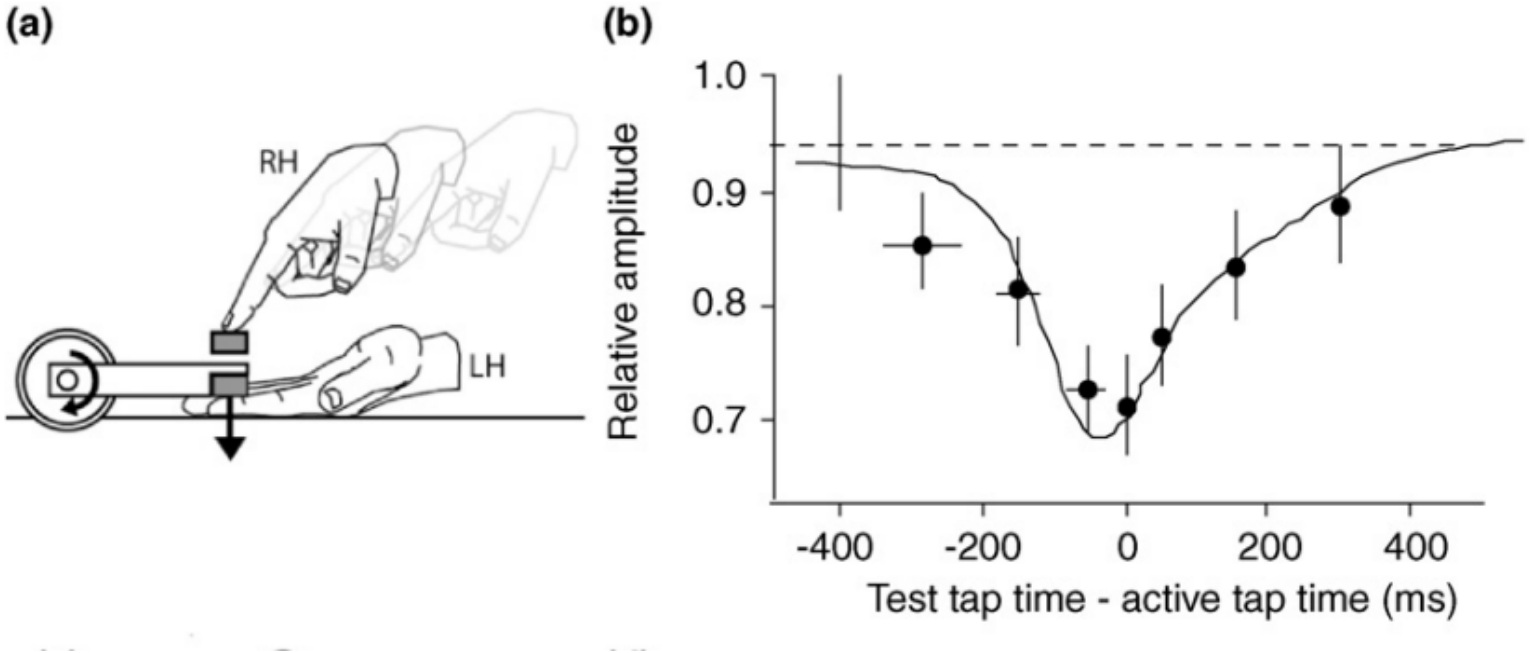


Gaze behavior in visuomotor learning

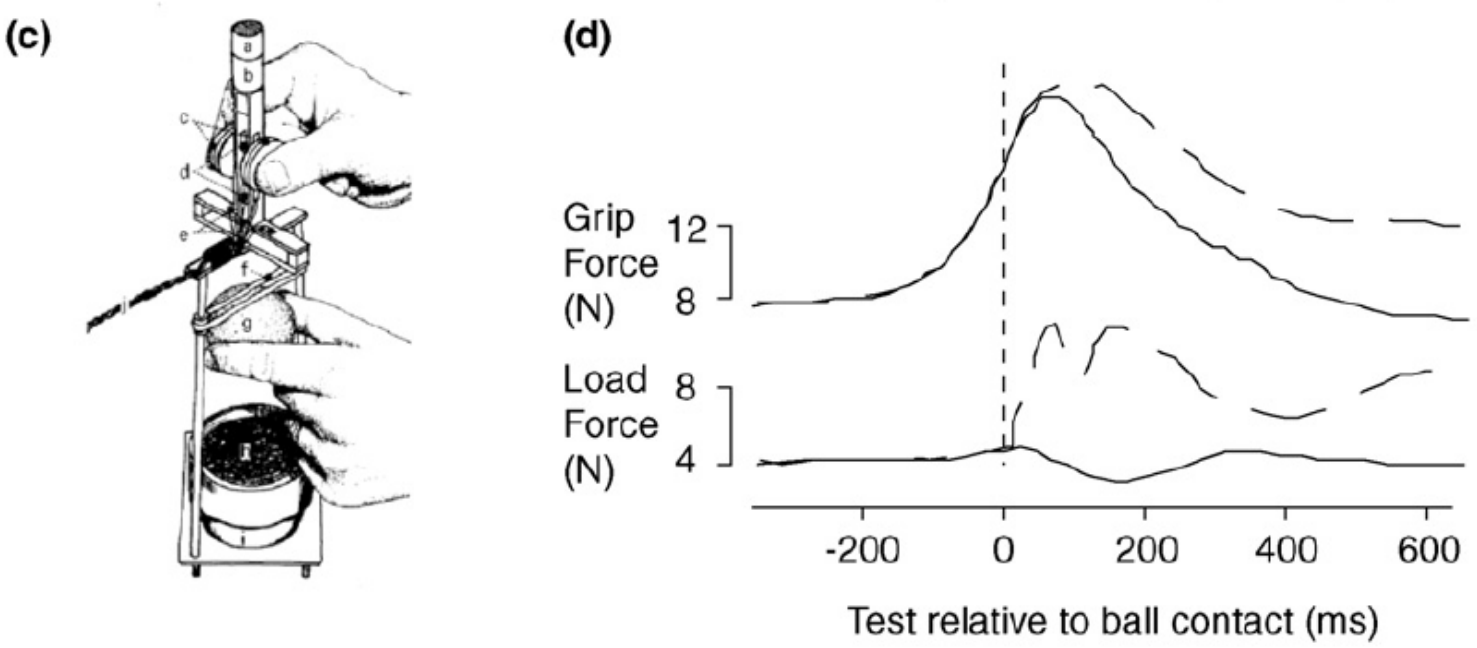
- The refinement stage



Sensory cancellation and contact events

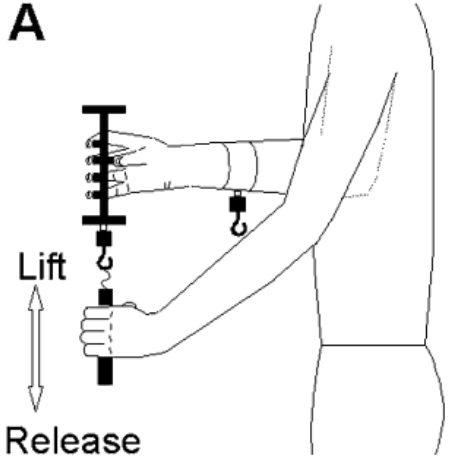


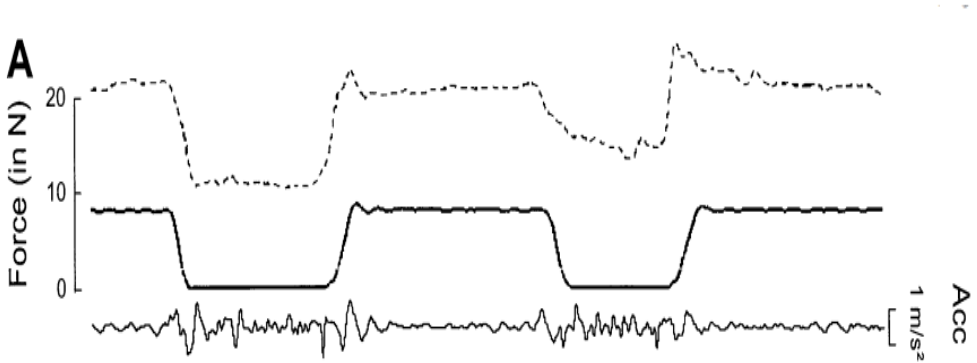
Sensory cancellation and contact events



Representing object dynamics in manipulation

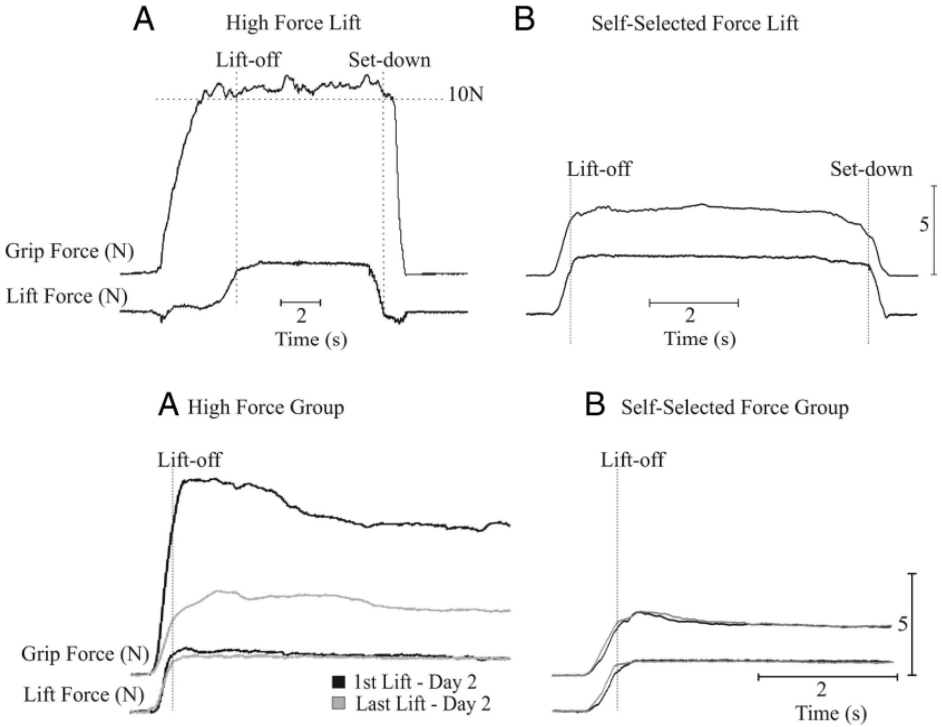
Arm motor commands and grip motor commands are independently controlled.





The time course of grip force (dashed line) and load force (solid thick line)

Representing object dynamics in manipulation



- separate internal representation of object properties could be used to predict grip and load forces when lifting

Conclusion

1. The authors highlights the important role of contact events in object manipulation tasks.

2. During action observation gaze is also directed to contact points and observers predict and monitor sensory events in the same way that actors do

3. There is now ample evidence that people make use of internal models of object dynamics in skilled tasks

Discussion

Discussion

1. Which topic is the most interesting?

   Sensorimotor control points

   Prediction and rapid updating

   Control of gaze in object manipulation tasks

   Sensorimotor control points in action observation

   Gaze behavior in visuomotor learning

   Sensory cancellation and contact events

   Representing object dynamics in manipulation

2. How can we make a connection to Computer vision or Robotics?

Discussion @62_f1

Haoyuan Ma 10 hours ago

The author in the paper mentioned that our brain is constantly predicting sensory information after each movement of the hand and update our action based on the error between the predicted and actual sensor feedback. I would say the mechanism is very similar to Kalman Filter. However, does our brain generate separately the prediction for different sensory or does our brain generate one integral prediction? For people losing part of the sensors does their brain still generate prediction for that particular sensor?

Discussion @62_f2

Oliver A Wang (oliveraw) 10 hours ago

I was interested by the section which described sensory cancellation. We're not able to tickle ourselves and we feel a reduced sensation from self-taps compared to "external" taps. But if this is truly coming from a difference in "prediction error" where we feel heightened sensations from external sources, why wouldn't this error decrease from knowing something is about to happen? Why is there such a difference in prediction error between me tickling myself and another person tickling me, even if I know it will happen and how it will feel? Is the prediction error purely that of your own actions? Wondering if anyone has additional thoughts or insights.