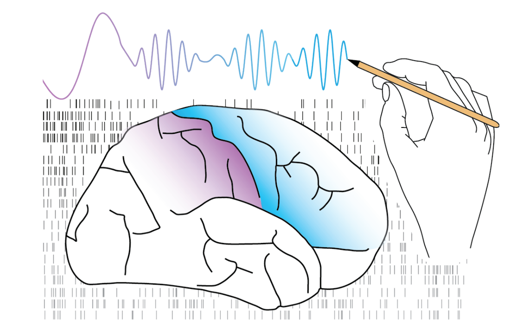
A paradigm to study the role of tactile contact events in learning and execution of object manipulation behavior



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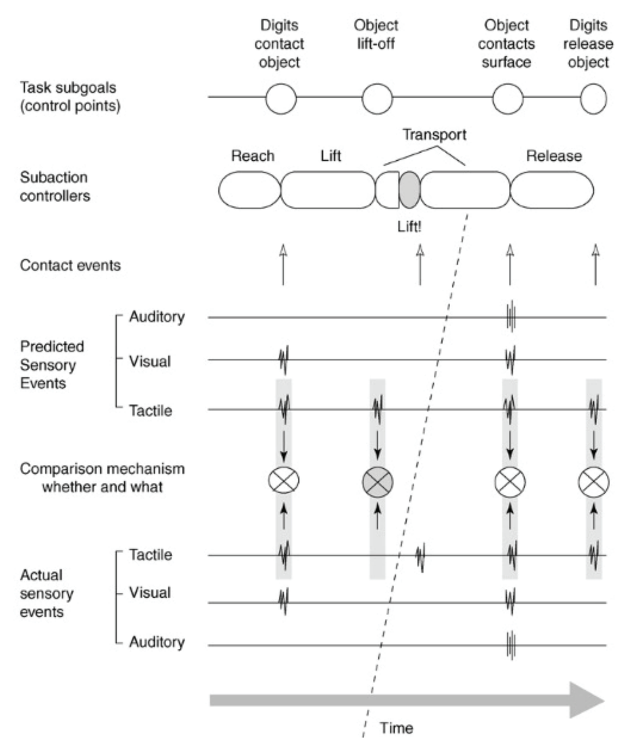
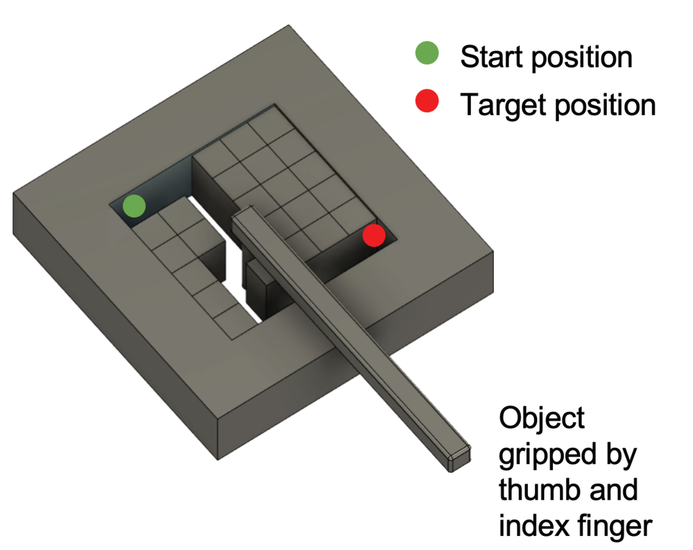
Background

- Many of our activities of daily living consist of sequences of movements involving object contact and manipulation.
- Sequence object manipulation tasks rely on intermediate contact events to proceed from one movement phase to the next
- Existing approaches for studying how sensory feedback updates movements are reliant on participants responding to errors, such as cursor and target jumps and adaptation paradigms.
- We seek to understand how predicted, task-relevant contact events update control of movement



Flanagan et. al. 2006

Approach: Maze navigation task



- Unseen maze, navigation with sense of touch
- Submovements punctuated by contact events
- Sensorized object
  - 1) grip force sensor
  - 2) 2D force sensor to detect collisions
  - 3) object 2D position sensor

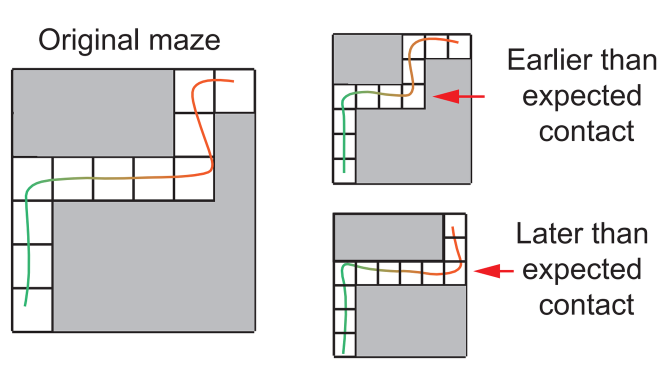
Task Design Considerations

- Object monitors grip force to study predictability of upcoming events

Flanagan & Wolpert 2003

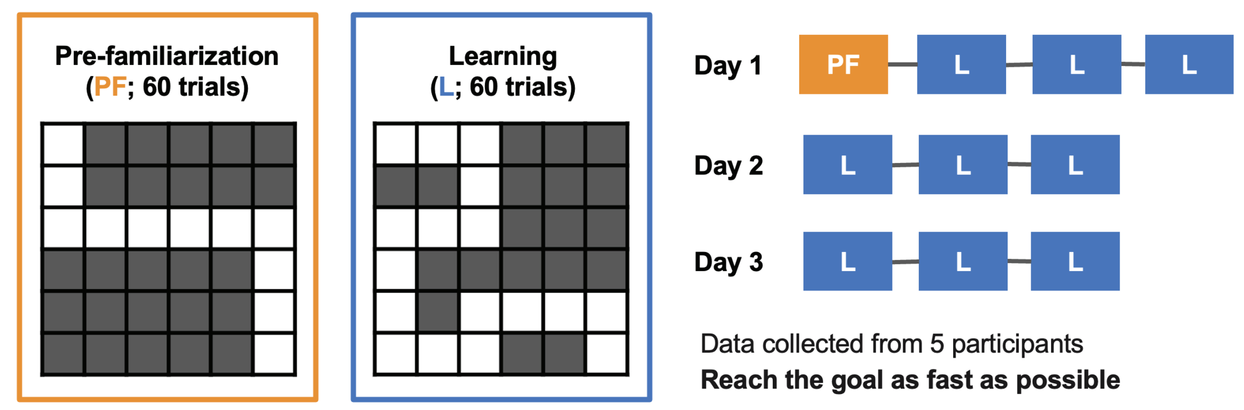
- New mazes can be presented to study how contact events are used during sequence learning

- Maze modifiable on trial-to-trial basis to study how changes in contact event locations influence movement



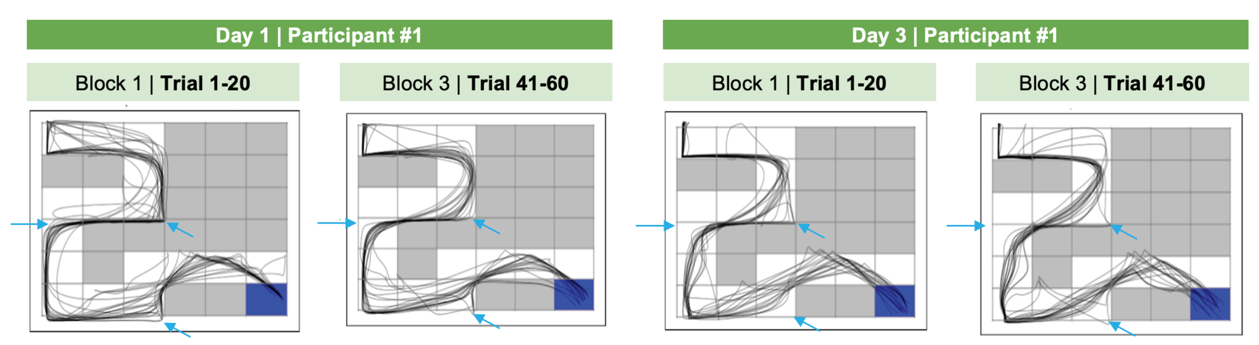
Pilot experiment design

Pilot dataset objective:
1) Maze learning: timing and trajectory changes
2) How contact events are used

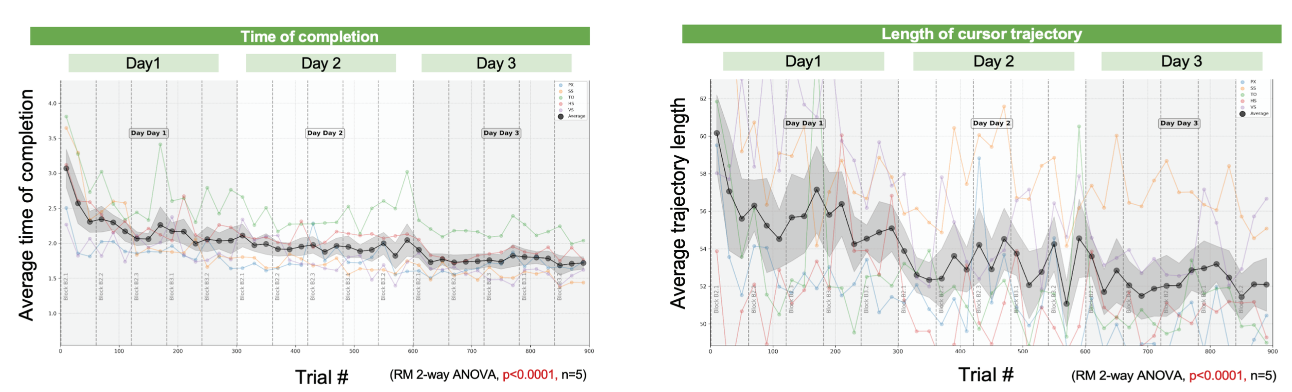


1) Maze task learning effects

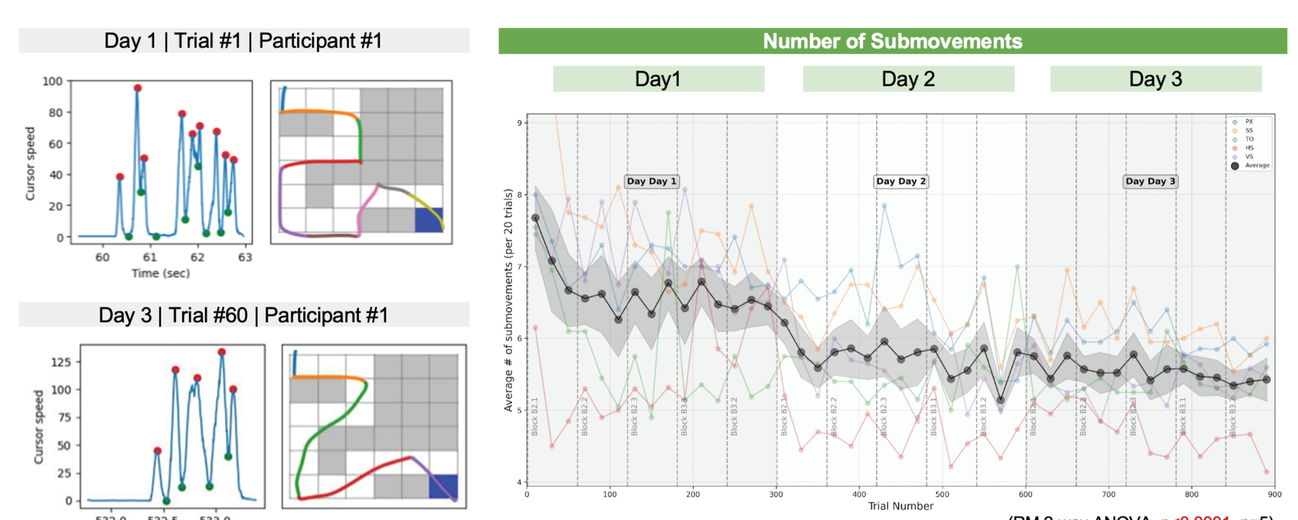
Example data from a single participant



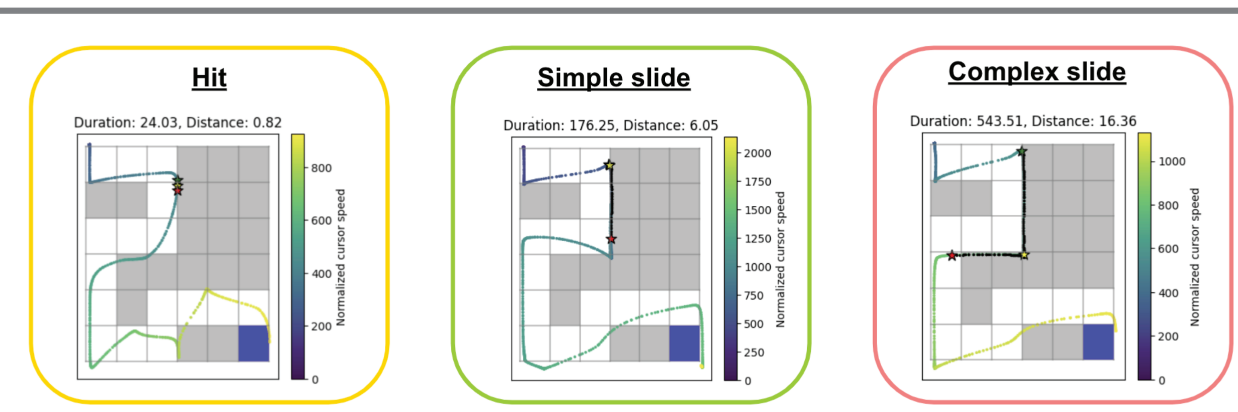
Movement time & trajectory length decrease with practice



Number of submovements decreases with practice



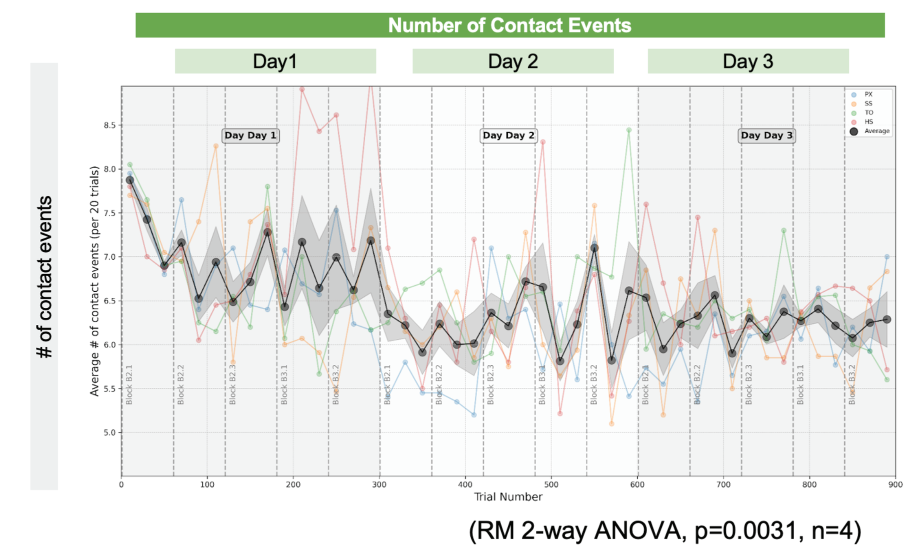
Contact event types



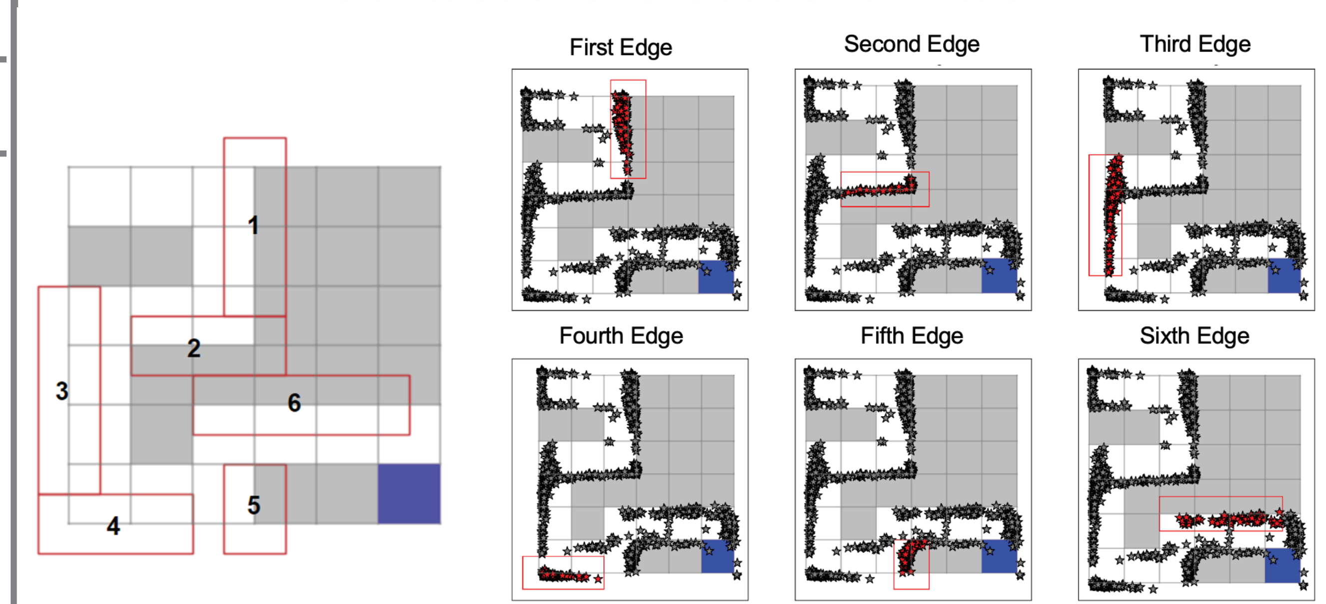
2) Dynamics around contact events

Reduction in contact events with practice

However, still used throughout execution of the trajectory

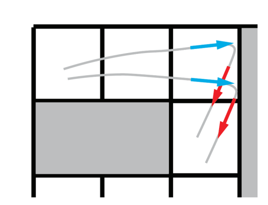


Contact event locations in task



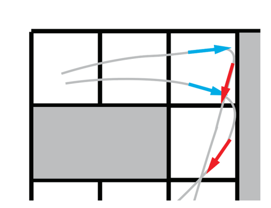
How do contact events update movement?

Hypothesis 1:
Contact events trigger stereotyped next movements independent of previous movement



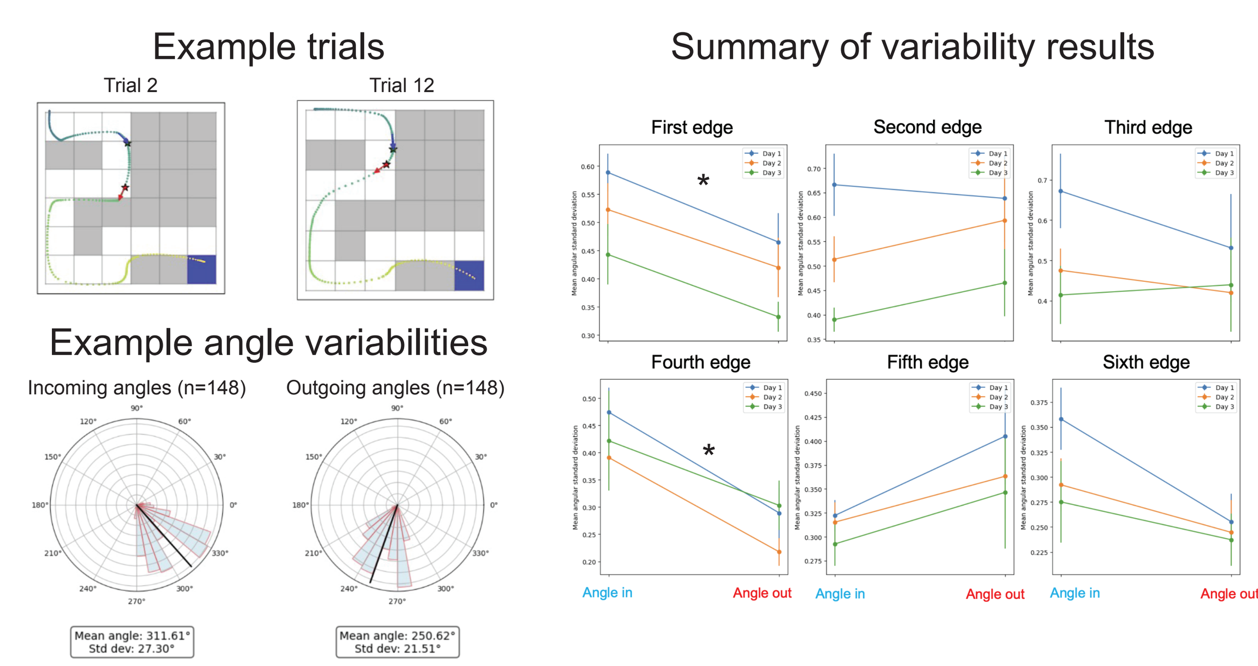
1. Var(In angle) > Var(Out angle)
2. No dependency of out angle on position or on in angle

Hypothesis 2:
Contact events trigger history-dependent next movement



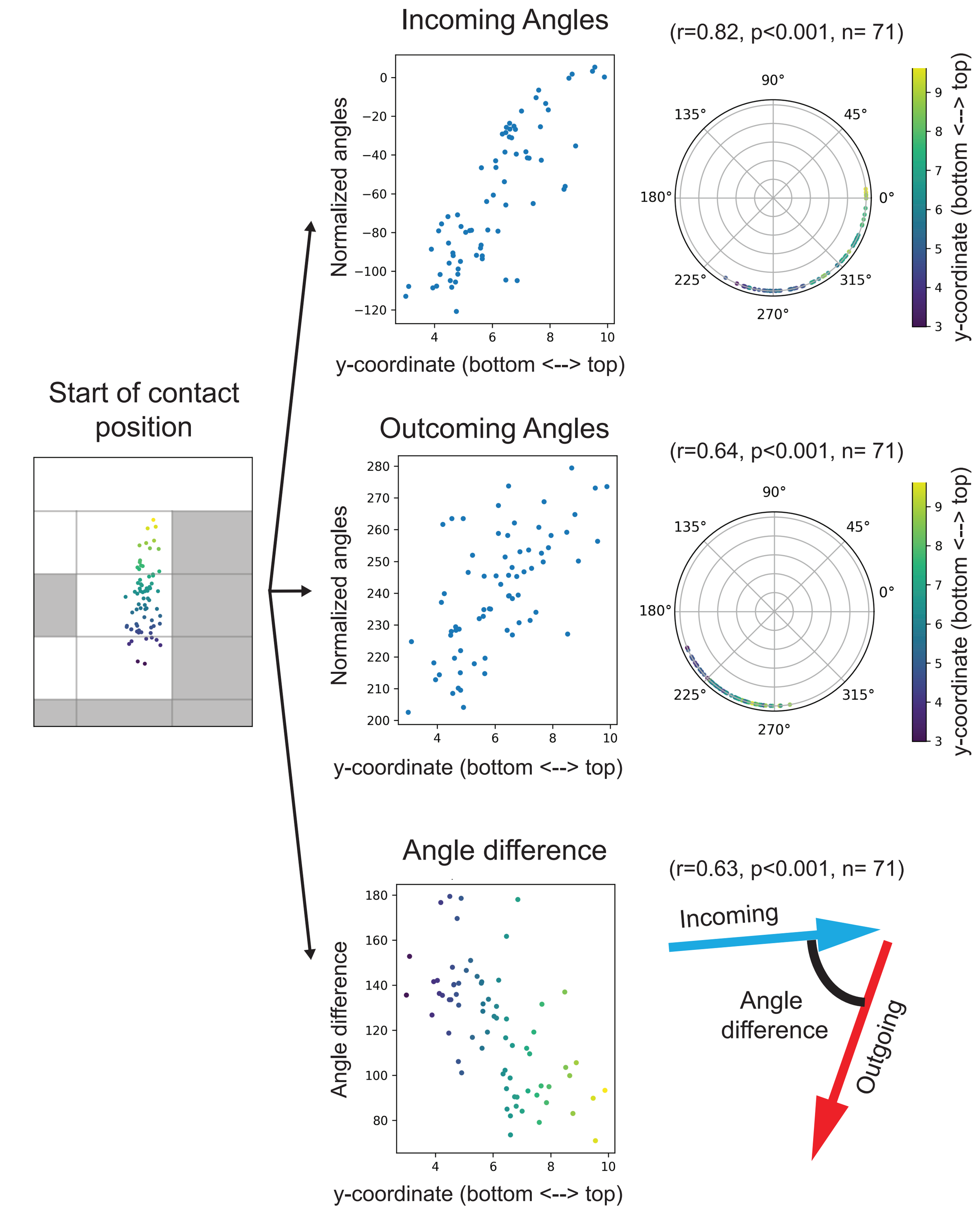
1. No systematic change for in vs. out angular variability
2. Outgoing angle depends on incoming angle, position of hit

Incoming vs. outgoing angular variability



For some contact event locations, outgoing angle variability is sig. lower than incoming angle variability -- potentially related to accuracy requirements
Some edges support hypothesis 1

Output angle dependency on input angle & contact event position

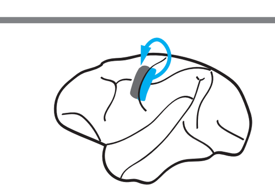


Correlations significant in all 6 edge -- Supports hypothesis 2

Conclusions:

- Participants showed clear learning over time, optimizing movement with shorter trajectories and fewer submovements.
- They continued to rely on contact events during learning
- The outgoing angle was found to correlate with incoming angle, position of hit, and in some cases showed reduced variances, supporting both hypotheses 1 and 2

Future work: Neural dynamics of contact event updates



Simultaneous motor cortex (M1) and somatosensory cortex (S1) electrophysiology recordings