Augmentation of Haptic Guidance into Virtual-Reality Surgical Simulators

Group 14

Paper Presentation

Eric Cao

Project Summary

- Problem:
  - Training to perform robotic minimally invasive surgery is time consuming and lacking in real-time feedback
- Objective:
  - To implement haptic feedback into surgical simulators and to test this feedback in a user study

Paper Selection

- Training in divergent and convergent force fields during 6-DoF teleoperation with a robot-assisted surgical system
  - M. M. Coad et al., “Training in divergent and convergent force fields during 6-dof teleoperation with a robot-assisted surgical system,” IEEE World Haptics Conf., 2017, pp. 195–200.

- Similar experimental setup and similar feedback methods
- Well designed user study that serves as a starting point for the design of our own user study

Training in divergent and convergent force fields during 6-DOF teleoperation with a robot-assisted surgical system

Margaret M. Coad, Allison M. Okamura, Sherry Wren,
Yoav Mintz, Thomas S. Lendvay, Anthony M. Jarc, and Ilana Nisky

Stanford University

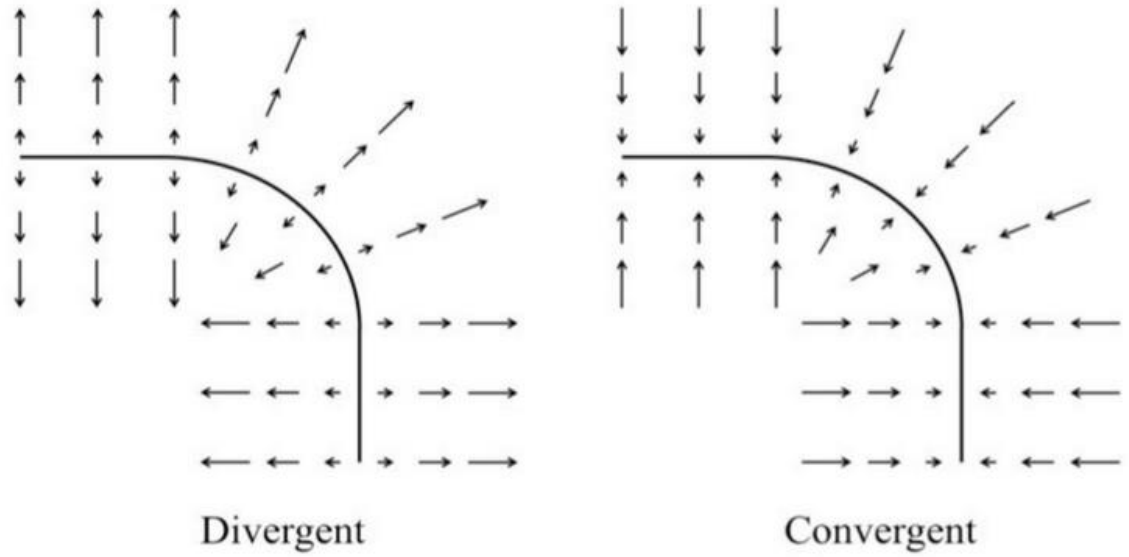
Summary

- “Examined the effect of divergent and convergent force/torque fields on the learning of novice non-medical participants during a 6-DoF peg transfer task using the da Vinci Research Kit (dVRK)” M.M. Coad, et al., 2017
  - Divergent and convergent forces
  - Peg transfer task

M. M. Coad et al., “Training in divergent and convergent force fields during 6-dof teleoperation with a robot-assisted surgical system,” IEEE World Haptics Conf., 2017, pp. 195–200.

Divergent and Convergent Force Fields

- Divergent forces exaggerate negative effects of errors
  - Effective in learning tasks in other fields
- Convergent forces provide guidance towards desired path



M.M. Coad, et al., 2017

$$\vec{F} = -k_{translational} * (\vec{x}_{current} - \vec{x}_{desired}) - d_{translational} * \vec{v}_{current}, \quad (1)$$

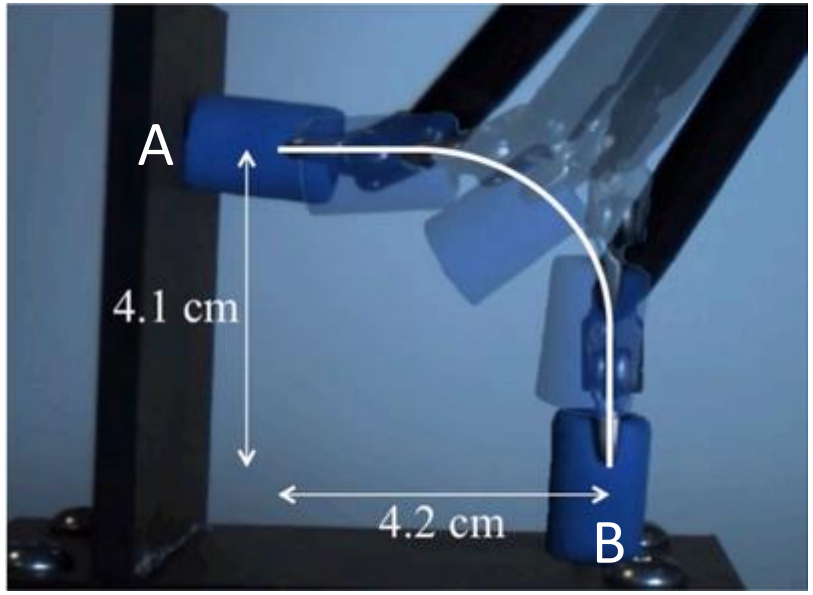
$$\vec{T} = -k_{rotational} * R_{current} * rdiff_{angle} * \vec{rdiff}_{axis} - d_{rotational} * \vec{\omega}_{current}, \quad (2)$$

M.M. Coad, et al., 2017

M. M. Coad et al., "Training in divergent and convergent force fields during 6-dof teleoperation with a robot-assisted surgical system," IEEE World Haptics Conf., 2017, pp. 195–200.

Methods - Task

- Peg Transfer task on dVRK
- Participants are shown picture of desired path and video of several good transfers
- 3 sets of 30 trials each (90 trials total)
- Trials alternate between moving A->B and B->A



M.M. Coad, et al., 2017

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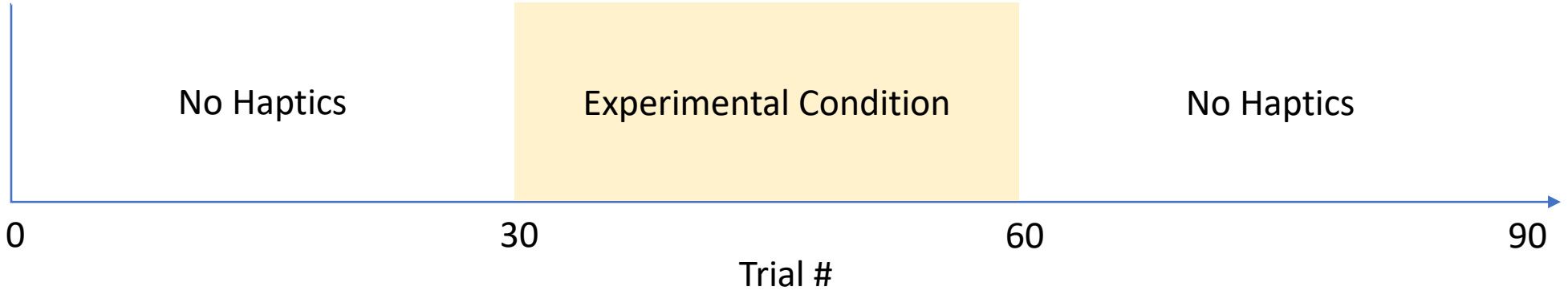
User Study

- 3 sets of 30 trials (90 trials total)
  - Set 1: No Haptic Feedback
  - Set 2: Experimental Condition (control, divergent, or convergent)
  - Set 3: No Haptic Feedback



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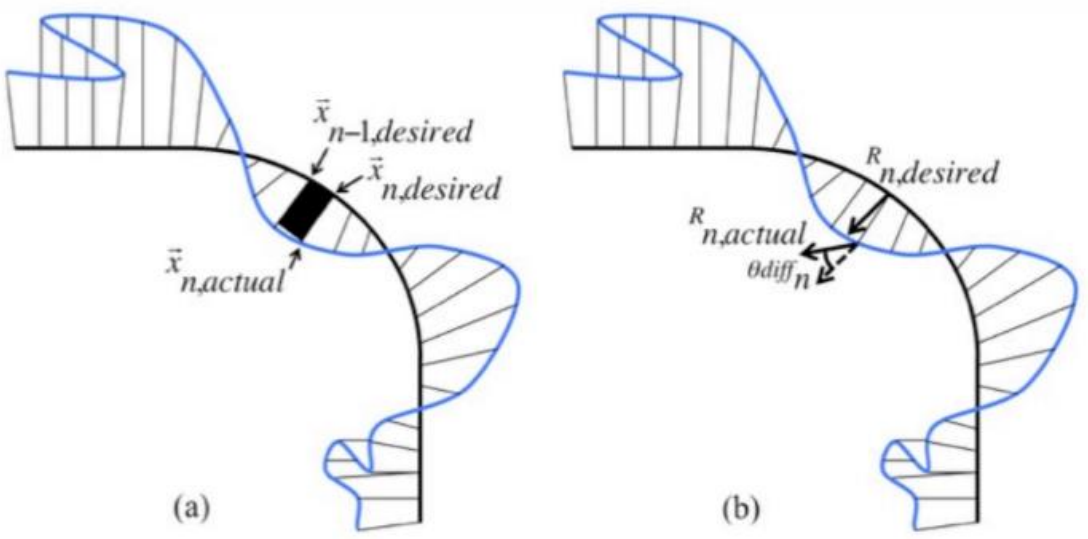
Performance Metrics

- Trial time
- Translational path error
  - Related to classical measure of economy of motion
- Rotational path error
  - Similar to translational
- Combined path error times trial time
  - Combination of other 3 metrics



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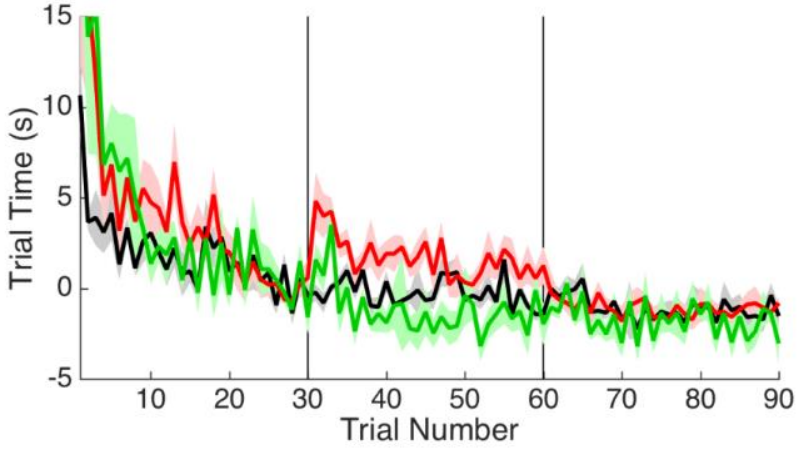
Results



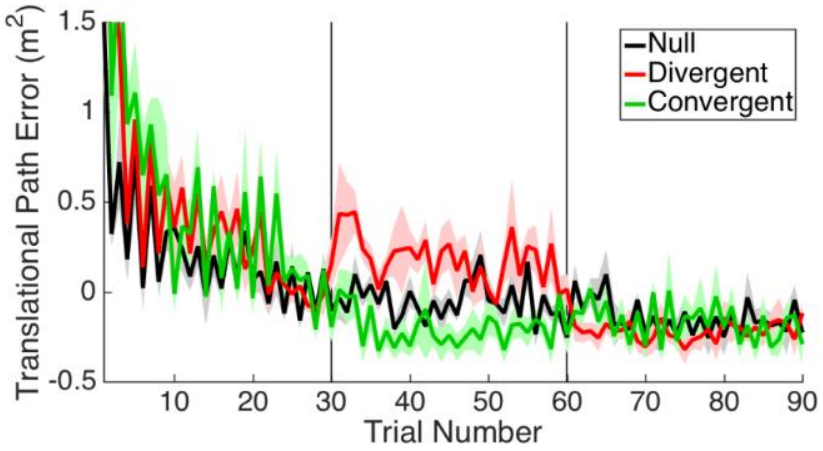


TABLE I. BASELINE ABILITIES IN TRIALS 25-30 (MEANS AND STANDARD ERRORS) THAT WERE SUBTRACTED FROM DATA.

	Null	Divergent	Convergent
Trial Time (s)	6.3 (±1.2)	6.6 (±0.9)	7.7 (±1.0)
Trans. Path Error (m^2)	0.52 (±0.08)	0.60 (±0.10)	0.60 (±0.04)
Rot. Path Error (rad-m)	20 (±3)	21 (±3)	22 (±3)
Error-Time (rad-m-s)	300 (±100)	330 (±80)	390 (±80)

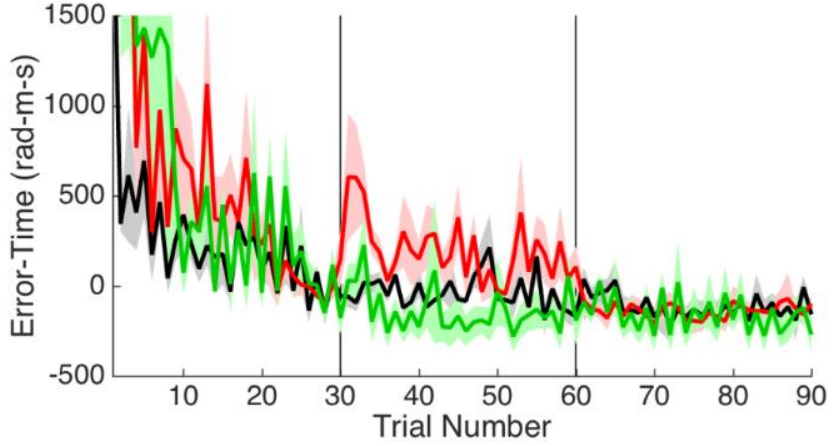
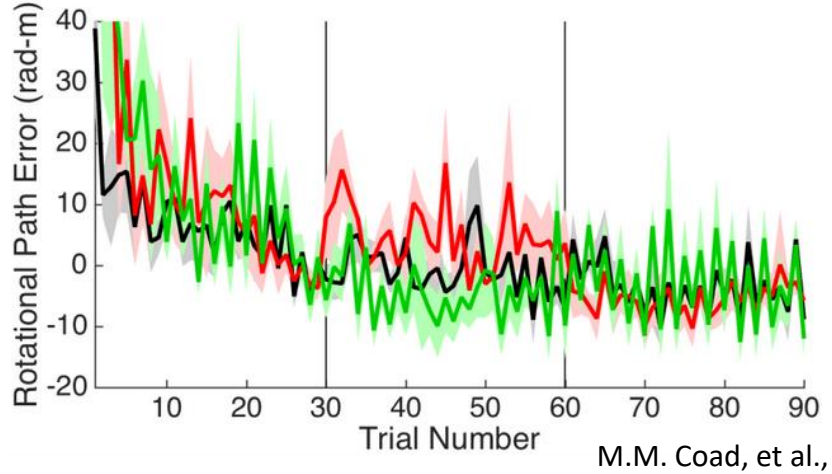


TABLE II. IMPROVEMENTS FROM TRIALS 1-6 TO 25-30 AND 25-30 TO 85-90 (P-VALUES ARE FROM THE WILCOXON RANK SUM TEST).

	Trials 1-6 to 25-30	Trials 25-30 to 85-90
Trial Time (s)	9.01 ($p < 0.001$)	1.46 ($p < 0.001$)
Trans. Path Error (m^2)	1.13 ($p < 0.001$)	0.19 ($p < 0.001$)
Rot. Path Error (rad-m)	37.7 ($p < 0.001$)	3.8 ($p = 0.005$)
Error-Time (rad-m-s)	2600 ($p < 0.001$)	140 ($p < 0.001$)



M.M. Coad, et al., 2017

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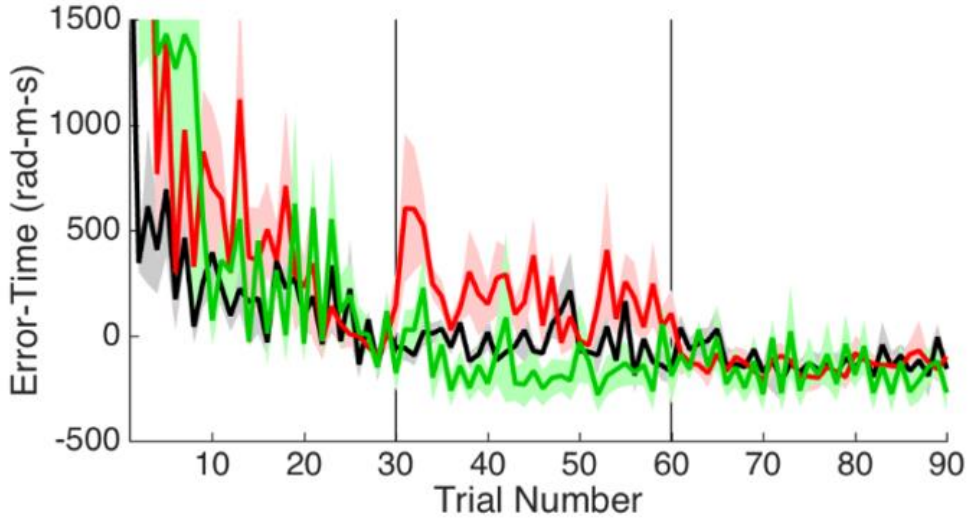
Main Result

- There was no statistically significant difference between the performance of the groups on any metrics at the end of the experiment.



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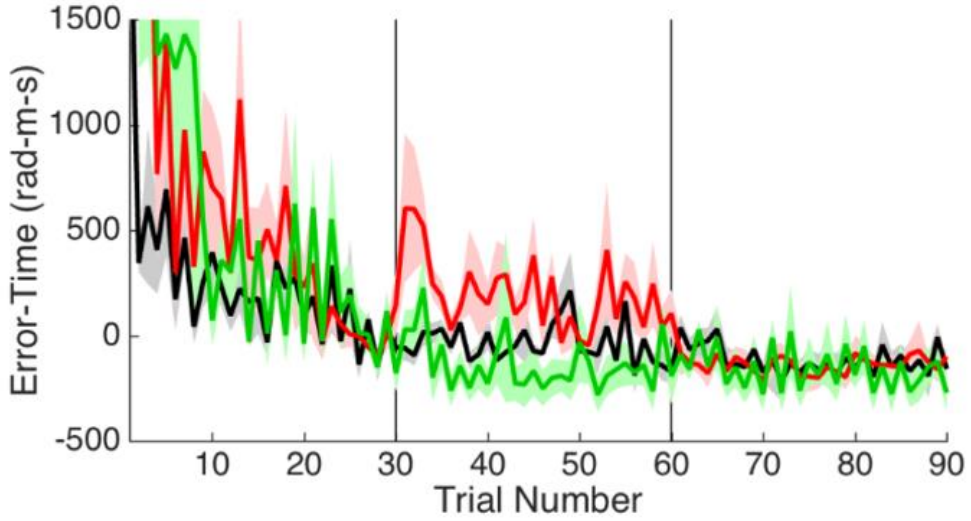
More Results

- During experimental condition set, divergent field group performed the worst and convergent performed the best



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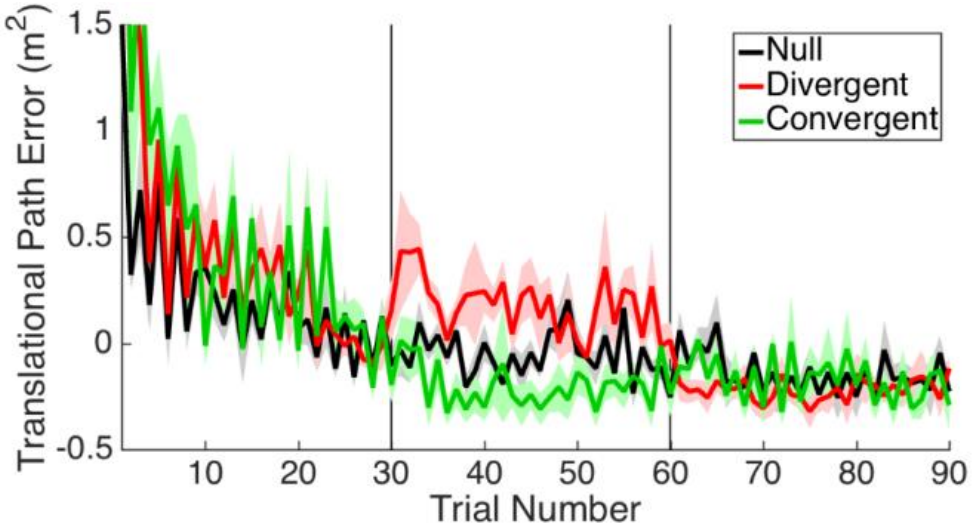
More Results

- Divergent group performed better than other groups on translational path error at the start of the 3rd session



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Paper Assessment

Good

- Clear description of experimental task and setup
- Force field equations with constants given

Improvements

- A->B, B->A task oscillations, unseparated graphs
- Only haptics, no other feedback
- Sets of trials too long

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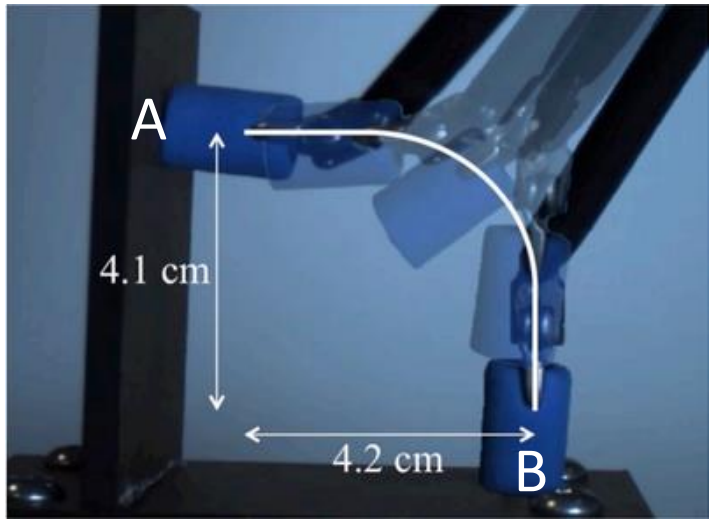
Task Oscillations

- Odd # Trials: Transfer peg from location A to location B
- Even # Trials: Transfer peg from location B back to location A
- Task is slightly different and may not be comparable



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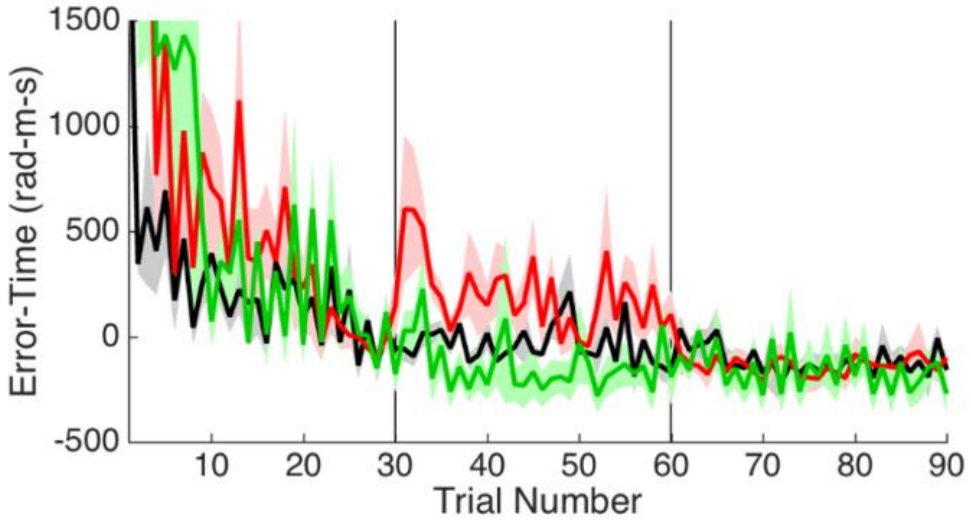
Unseparated Graphs

- Oscillating task results not separated into different graphs
- Resulted in oscillating data



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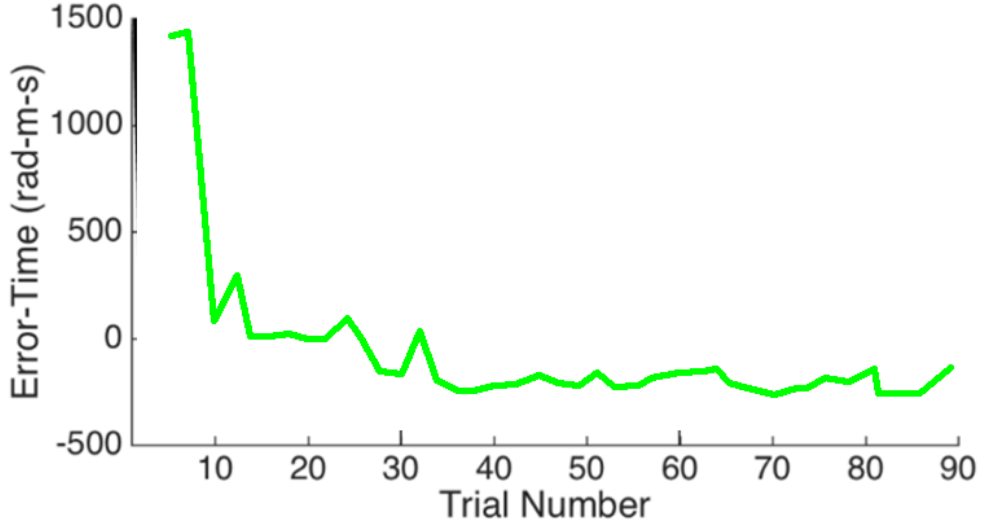

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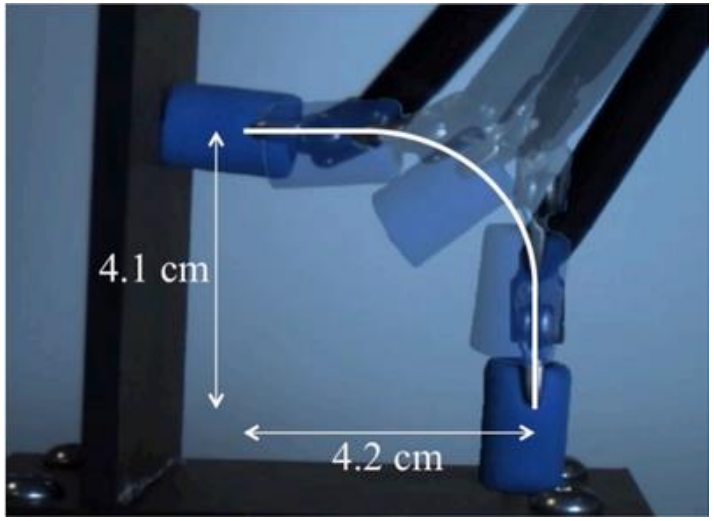
Only Haptic Feedback

- Optimal path is unclear
- Provides feedback to an unknown path



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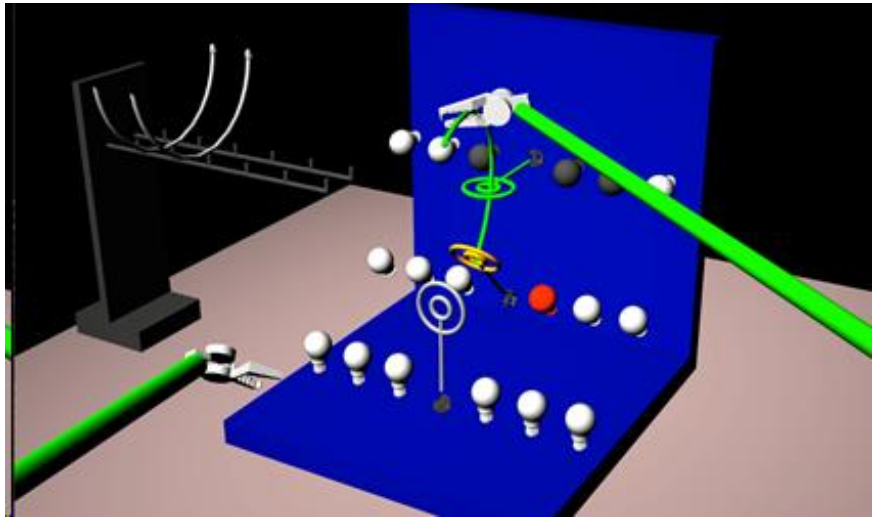

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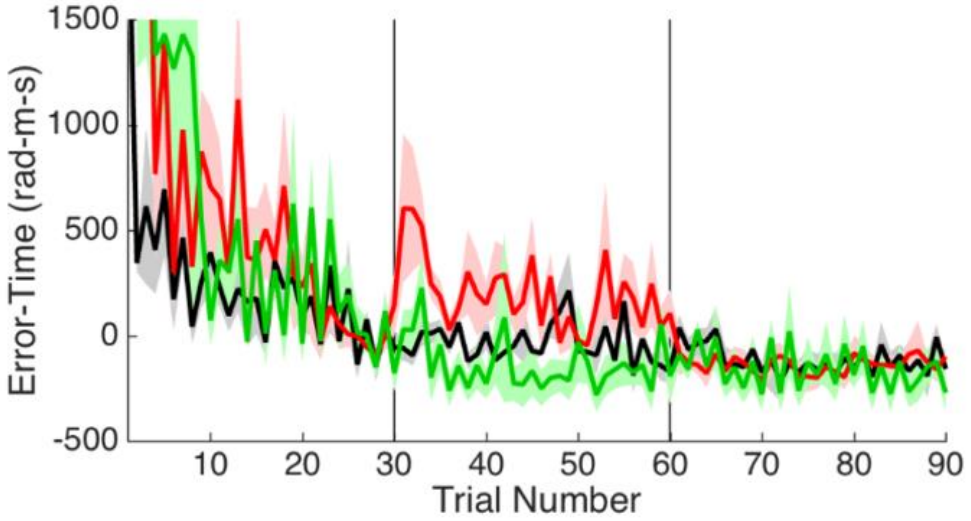
Trial Set Lengths

- Greatest improvement in first set of trials, before experimental condition began



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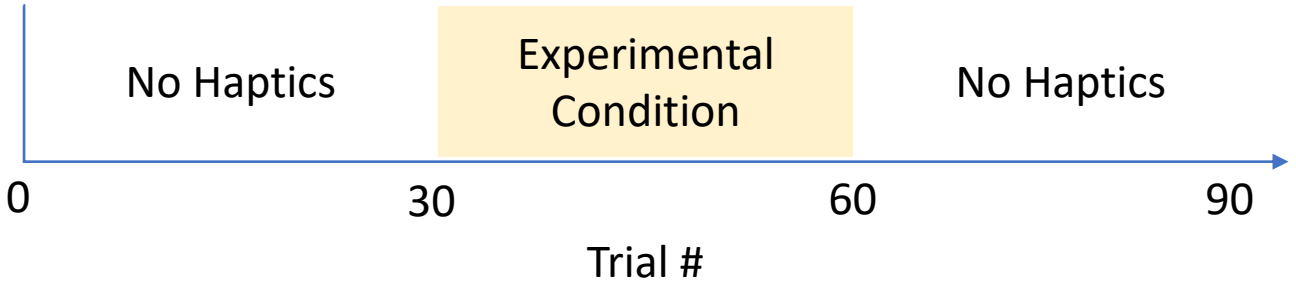

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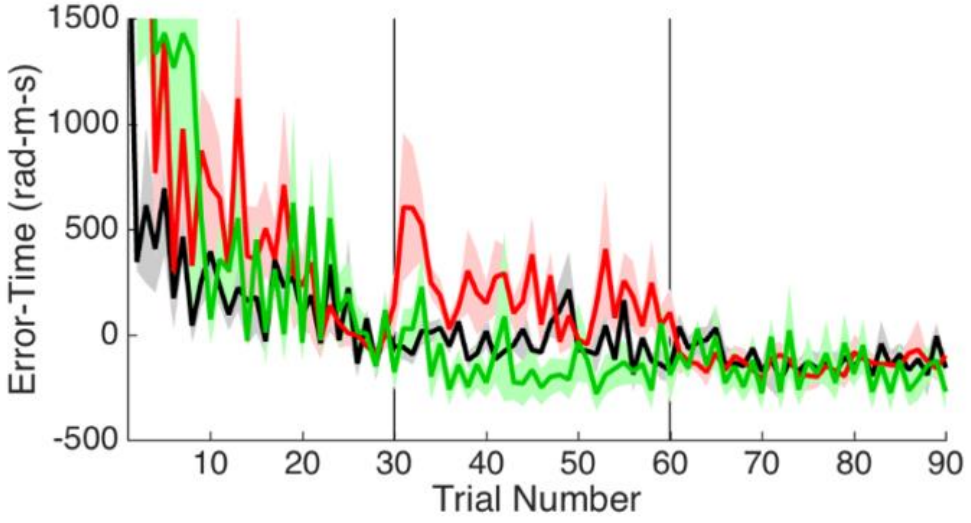
Normalization by Subject Baseline Ability

- Each participant's baseline ability is subtracted from their own data



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Conclusions

- Well designed user study that serves as a starting point for the design of our own user study

Lessons Learned

- Keep trials as similar as possible
- Consider using haptic feedback in conjunction with other feedback
- Find suitable trial lengths for the experimental task
- Consider normalizing by each subject

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References

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