Seminar Presentation

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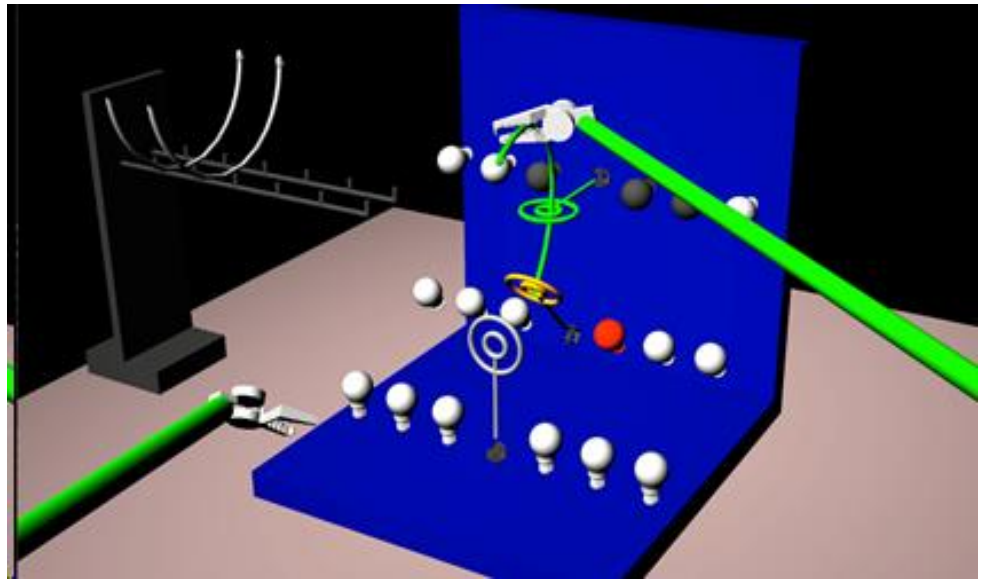
Group 14: Augmentation of Haptic Guidance into Virtual- Reality Surgical Simulators

- Problem: Robotic Minimally Invasive Surgery (RMIS) trainees currently lack a means for real time feedback while performing practice tasks and can ingrain bad habits as a result
- Goal: Develop and evaluate the effectiveness of real-time haptic feedback and corrective guidance in surgical task simulators of complex trajectories (ie. suturing task)
  - Two Methods of Haptics:
    - Guidance: Persistent force encouraging user along an optimal 3D path
    - Forbidden Region: Forces applied only upon navigating into region



Paper Selection

- *Evaluation of Haptic and Visual Cues for Repulsive or Attractive Guidance in Nonholonomic Steering Tasks*
  - R. J. Kuiper, D. J. F. Heck, I. A. Kuling and D. A. Abbink, "Evaluation of Haptic and Visual Cues for Repulsive or Attractive Guidance in Nonholonomic Steering Tasks," in *IEEE Transactions on Human-Machine Systems*, vol. 46, no. 5, pp. 672-683, Oct. 2016.
    doi: 10.1109/THMS.2016.2561625
- Reasons:
  - Implemented methods of Haptic Feedback (repulsive and attractive) heavily influenced the design of our two methods
  - Interesting to see a setup so similar to ours with a different application (virtual steering of vehicle vs. virtual surgical task simulator)
  - Thorough user study collecting a variety of metrics which can help us determine what metrics are important for our own study

Summary of Problem

- Teleoperation is more difficult than direct manipulation due to limited sensory feedback of the task
  - To combat this, add artificial task-related feedback
- Goal: Evaluate several approaches to feedback (support systems) and compare their efficacy in assisting the task
  - Repulsive Haptic and Visual
  - Attractive Haptic and Visual
- Hypotheses:
  - Due to quick reflexes, haptics will result in improved performance compared to visual
  - The more difficult the task, the more useful the additional information

Key Results

- Predicted trajectory of the vehicle and suggested path information improved task performance
  - No difference was found between haptically or visually reflected information
- Reflection of predicted trajectory resulted in improved performance visually but not haptically
- More difficult environments resulted in larger benefits for all support systems

Significance of Key Results

- Indicate that in general, additional information improves performance, especially when difficulty is high
- If both types of information (haptic and visual) are available, it is beneficial to reflect them both
  - In general, it is more important to evaluate the task and application in order to choose how to present information

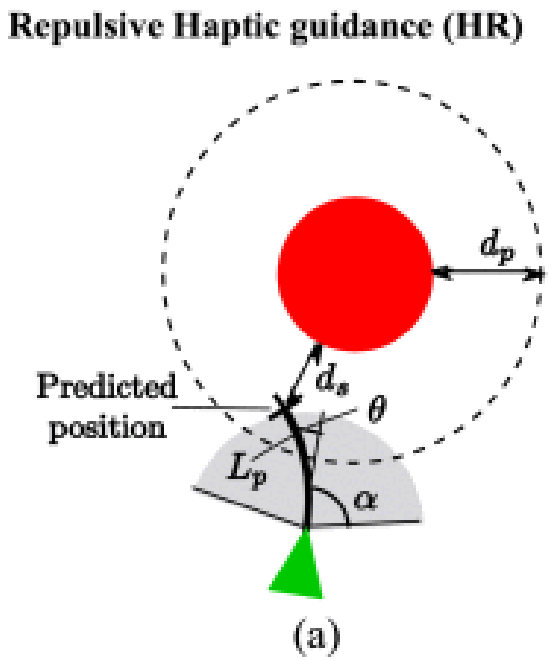
Necessary Background

- Basic understanding of forbidden regions, forces and torques
  - Explained well in the paper
- Comfortability with statistics and RM-ANOVA to interpret several large results tables
  - Tables provided with easier to understand graphs

Technical Approach

- Repulsive Haptic Guidance around Obstacles
  - Virtual Potential fields around obstacles (and an attractor around goal)
  - Generated based on predicted position of the slave after translation of L_p = .01m
  - Gain k_p = 6 N/m, penetration depth d_p, slave distance d_s
  - Forces only reflected when with angle α = 90°
  - Parameters tuned to be over-rulable

$$\tau_{\mathrm{HR},i} = \begin{cases} k_p L_p \left(d_p - d_{\mathrm{si}}\right), & \text{if } d_{\mathrm{si}} \leq d_p \text{ and } |\theta_i| \leq \alpha \\ 0, & \text{else.} \end{cases}$$



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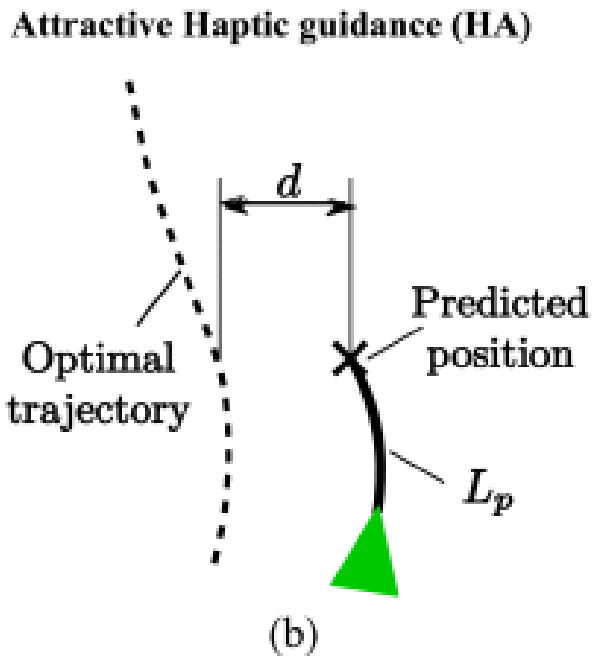
Technical Approach

- Attractive Haptic Guidance to a Suggested Path
  - Guide toward predefined suggested path
  - Torques computed from virtual guidance force acting on arm L_p = .01m
  - Gain k = 5 N/m
  - Distance d between suggested path and predicted position of slave
  - Presented to subjects as torsional stiffness on master

$$\tau_{\mathrm{HA}} = kL_p d.$$



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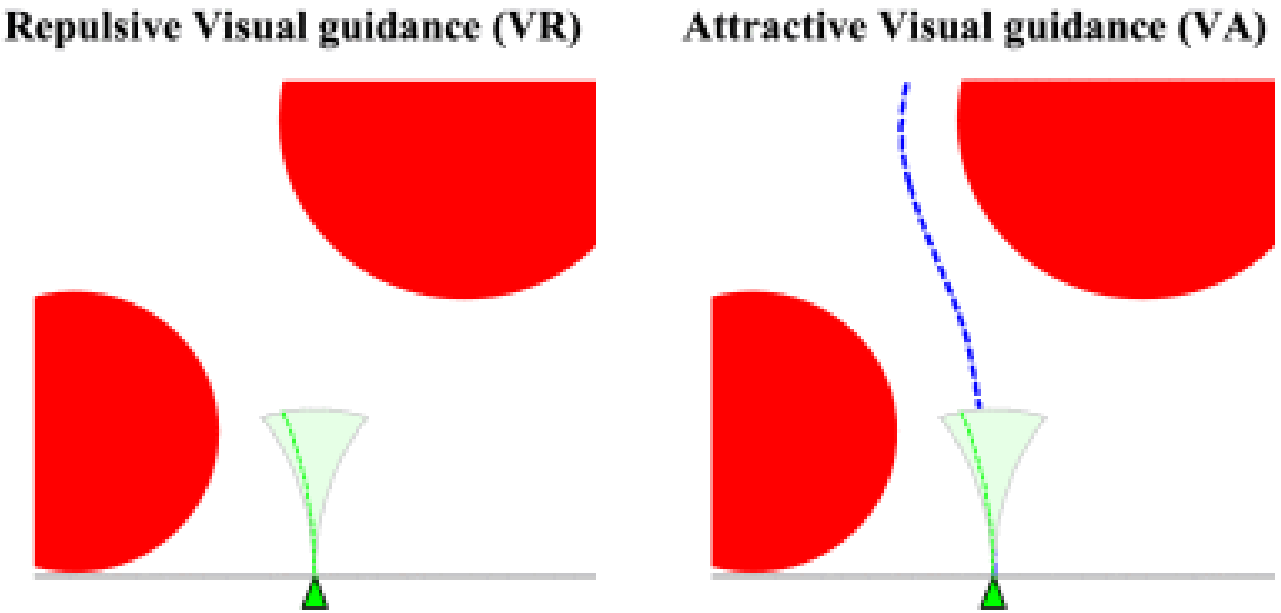
Technical Approach

- Visual Equivalent Support Systems
  - Designed to be similar to corresponding haptic system
  - Repulsive is based on predicted path, so in repulsive visual that is shown only
  - Attractive is based on predicted location and optimal path, so both are shown



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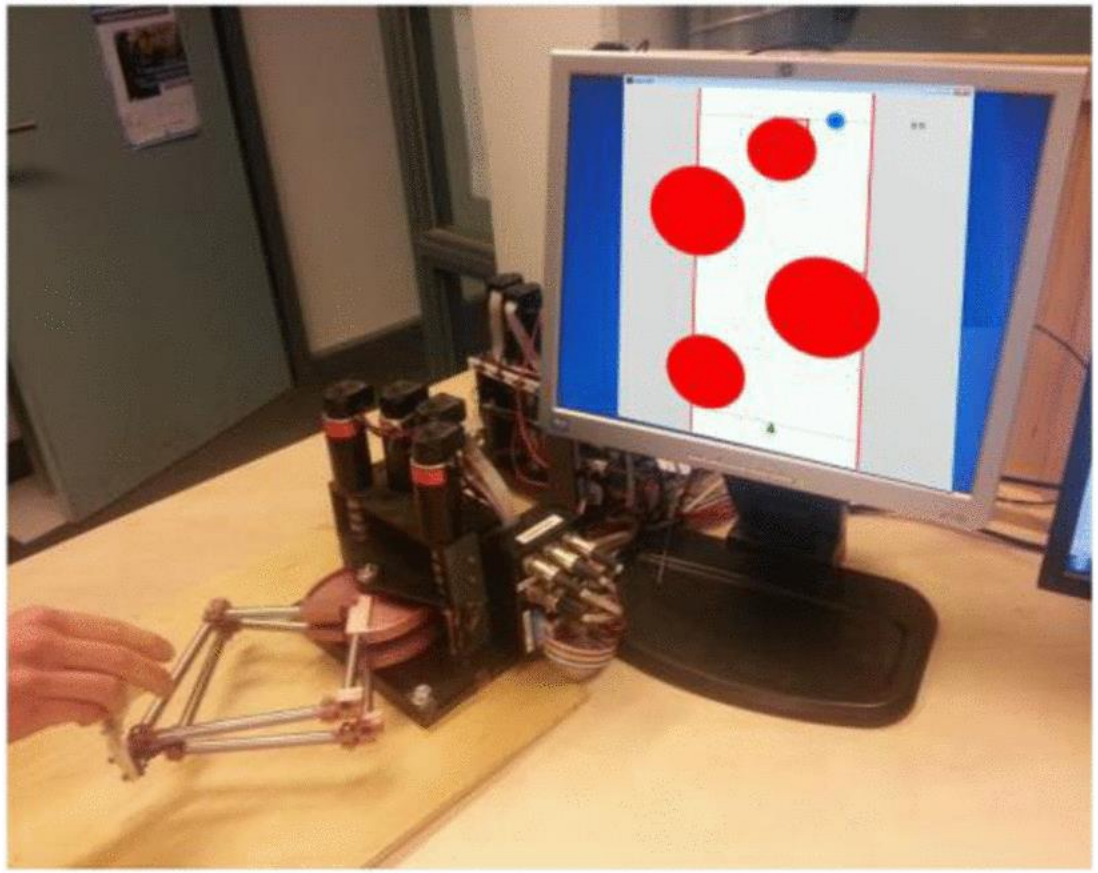
Experimental Design

- A user study involving 15 subjects
- Subjects controlled a three DOF planar parallel master device
  - Forward translation coupled to translation of the slave.
  - Rotation of the master was coupled to steering
- 5 blocks (one each experimental condition) of 8 trials
  - 4 different environments shown twice (regular and mirrored)
  - Additional catch trial on difficult environment to investigate dependency on support



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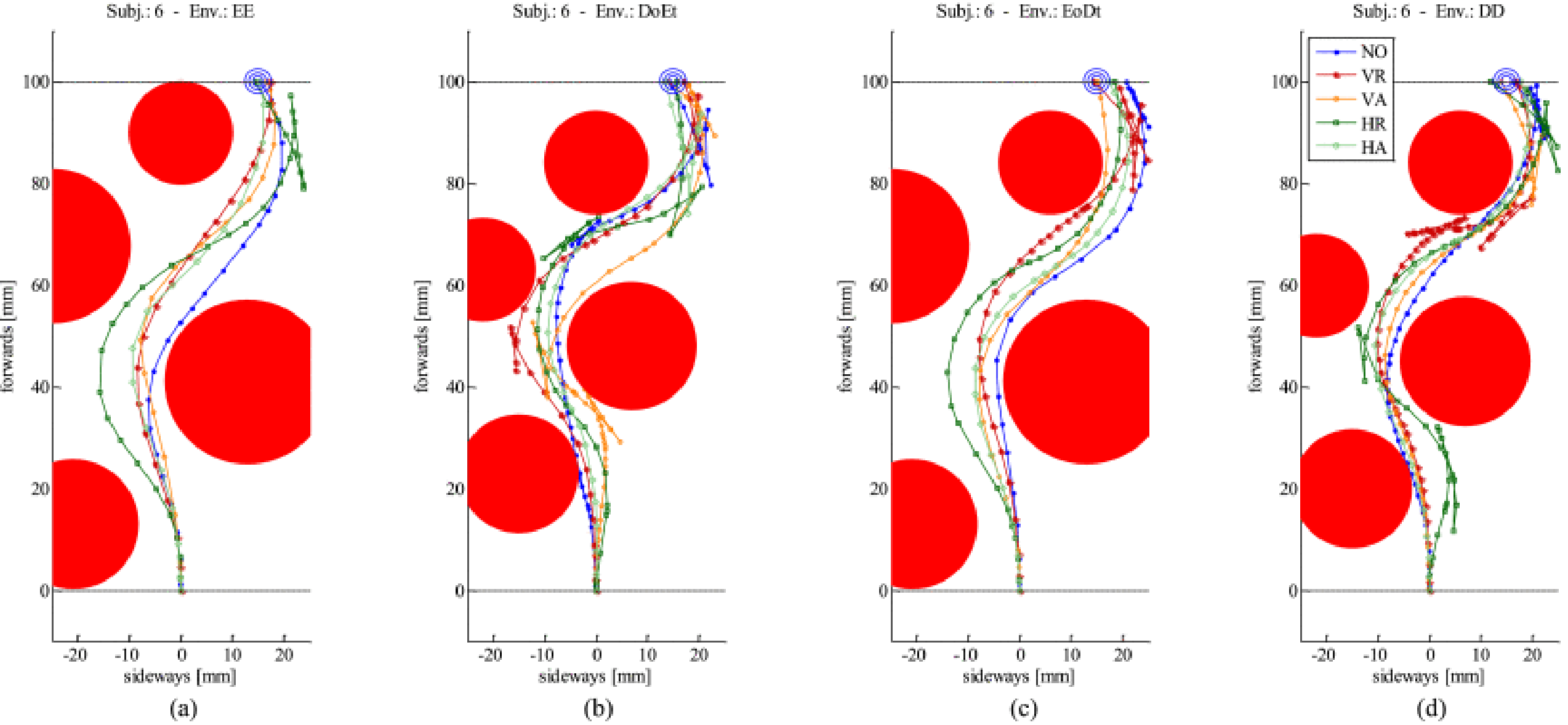

Markers are 300ms time intervals.

EoDt –easy obstacle difficult target reaching

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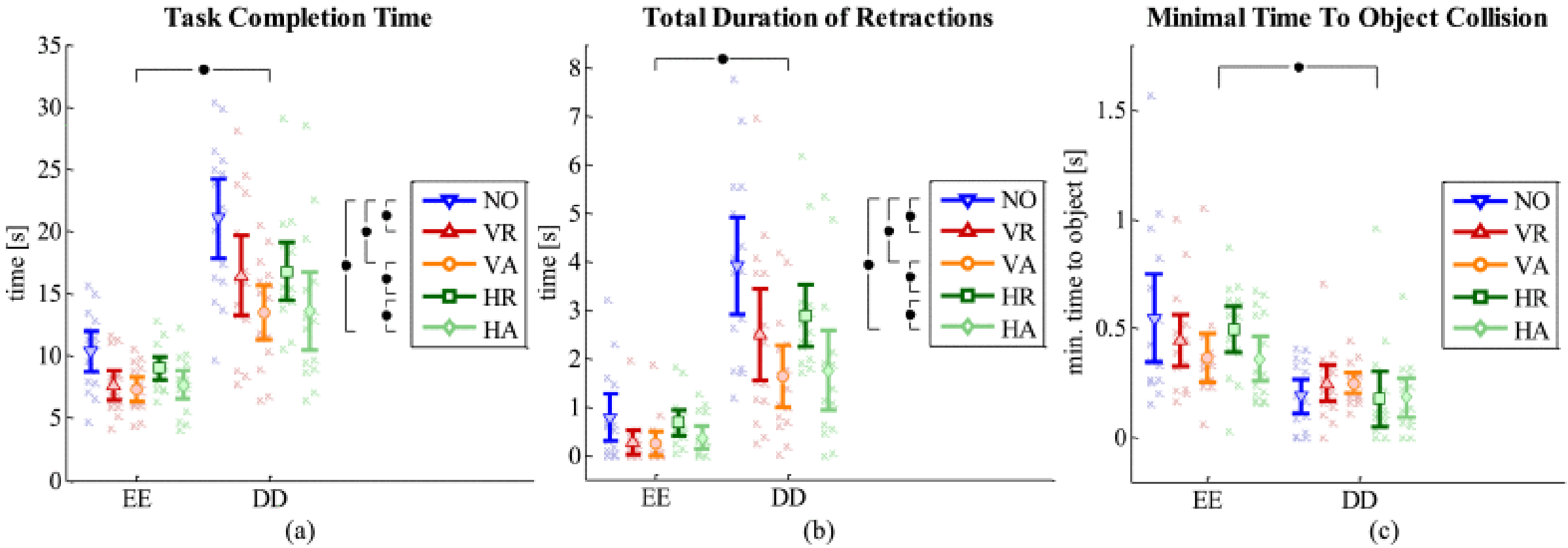
Collected Metrics

- Task Completion Time
- Targeting Accuracy
- Number of slave Retractions
- Total duration of retractions
- Number of collisions
- Minimum time to obstacle collision
- Distance to obstacles

Results



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Assessment

- Importance
  - Provides support that haptic AND visual feedback is beneficial in task, especially as they become more difficult
  - Fails to convince me that haptics alone is useful
- Relevance
  - Provides basis for evaluating visual and haptic cues in a simulated environment

Assessment

- Good points
  - Thorough explanation of approach, experimental design
  - A very complete look at haptics and visual cues
  - Changing environment helped to teach user a skill not memorize a path
- Bad Points
  - Collected a lot of metrics and the presentation on these was dense
  - Tested for a lot of things and many variables were changed (every user experienced every possibility)
- Further Work Suggestion
  - An attempt to model the operator (ie through brain stimulation) could help generalize the results to other tasks

Conclusions

- Presented a refreshing view on haptic and visual cues in a simulated environment
- Indicated that providing additional information to the user is beneficial especially in tasks with greater difficulty (a seemingly obvious result)
- Cast more doubt on my personal belief in the efficacy of haptics as a sole provider of feedback

Questions?

References

- R. J. Kuiper, D. J. F. Heck, I. A. Kuling and D. A. Abbink, "Evaluation of Haptic and Visual Cues for Repulsive or Attractive Guidance in Nonholonomic Steering Tasks," in *IEEE Transactions on Human-Machine Systems*, vol. 46, no. 5, pp. 672-683, Oct. 2016. doi: 10.1109/THMS.2016.2561625