Wheelchair Interface Usage Assessment Tasks and Performance Measures for Assistive Robots

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1 Motivation

- Unique physical abilities of an individual determine the interface used to control an assistive device such as a powered wheelchair.
- Shared-autonomy can offset interface limitations to improve performance [1].
- Usage characteristics differ across interfaces, which affect prediction errors and human-robot team performances (Fig.1) [2].
- Characterizing interface usage can enable customized assistance to powered wheelchair users.

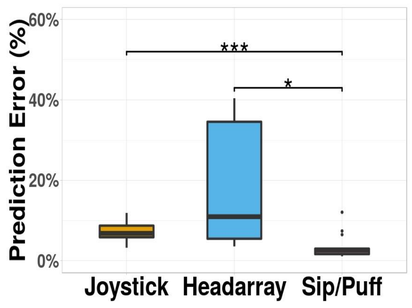
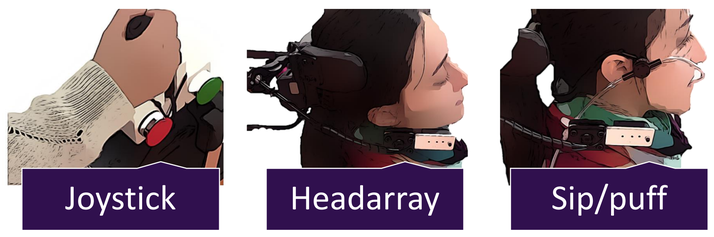


Fig 1: Prediction error for inferred goal per interface.

Objective:

1. Establish interface usage tasks and performance measures as an assessment tool for common powered wheelchairs.
2. To quantitatively compare usage characteristics across three common powered wheelchair interfaces, by persons with and without spinal cord injury (SCI).

2 Design of Experiments

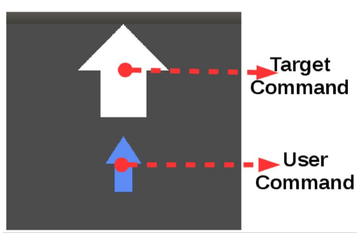


Tasks:

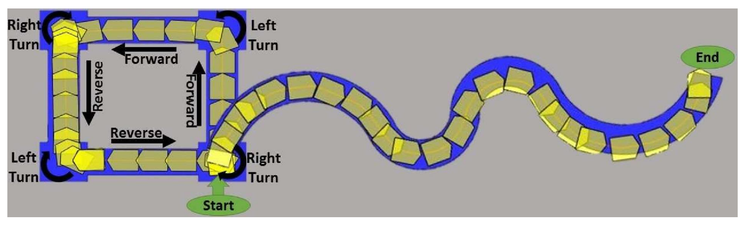
1. ***Command following***: Assess ability to respond to a visual stimulus in terms of **accuracy**, **time**, and **steadiness** of command issuance.

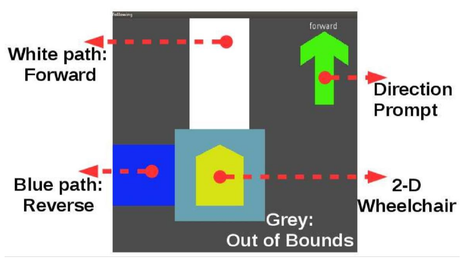
Instructions:

- As soon as the target command prompt appears, issue that same command.
- Continue issuing the command uninterrupted for the duration of the prompt.



2. ***Trajectory following***: Assess ability to follow a trajectory with a single known goal.





Instructions:

- Stay within the path and do not go into the out-of-bounds gray area.
- If you do go out-of-bounds, immediately come back inside the path.
- The green arrow indicates the direction of motion within the path.

Cross-sectional Study Design:

- 2x3 mixed ANOVA design
- Within-group factor: interface, novelty**
- Between-groups factor: SCI vs. uninjured

***Only a factor for the SCI group since they were experts with the interface they use when controlling their personal wheelchair.*

Participants:

- 9 SCI full-time wheelchair users (ASIA complete and incomplete between C3-C6) and 14 uninjured.

Pilot Protocol:

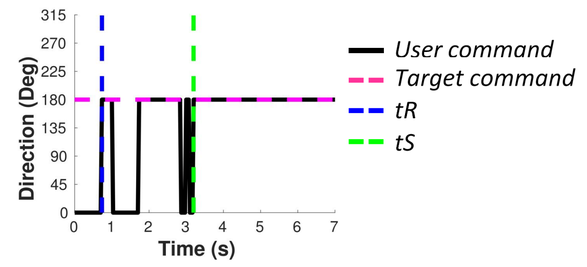
- Each participant performed both tasks with all 3 interfaces*.
- Task and interface condition order was randomly balanced.
- Participants were trained on interface condition prior to each trial.

* SCI only used interfaces they were able to safely control.

3 Main Outcomes

Command Following:

- Average response time (tr)
- Successful response percent (%R)
- Average settling time (tS)
- Successful settling percent (%S)

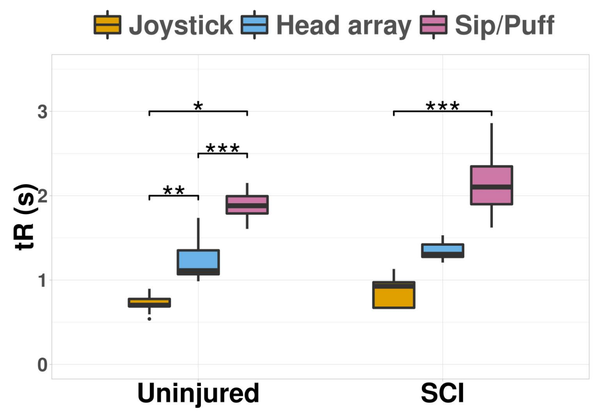


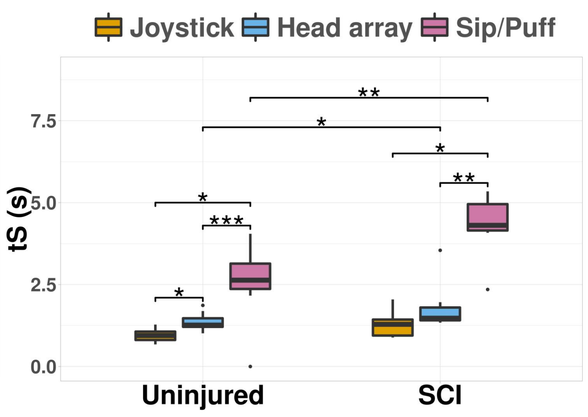
Trajectory Following:

- Number of times breaking barrier (nBB)
- Percent time out of bounds (tOB)

4 Results

Interface and Group Differences

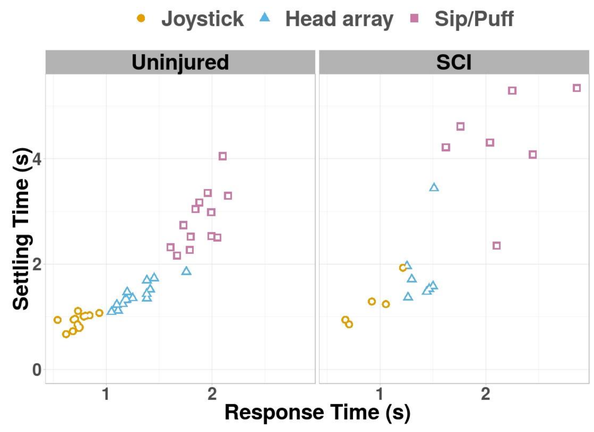




- Similar response times between groups, but difference in stability.
- Difference in response times between interfaces for both groups.

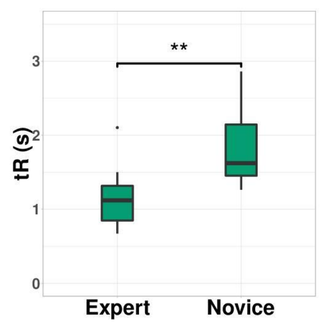
Modeling and Prediction

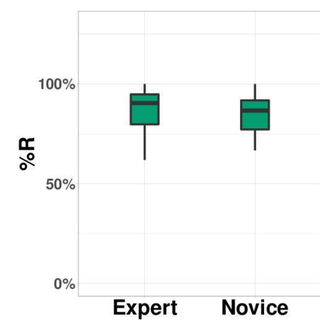
- Second order polynomial regression
- R^2=0.96, RMSE = 0.34
- Interface classification using **kNN** with **5-fold** cross validation
- Prediction accuracy of **96%**



Effect of Novelty

- No difference in the percentage of accurate responses based on novelty, but expertise can reduce response times.





5 Results

- The **type** of interface, **injury** level, and **expertise** have a significant effect on interface **usage** performance measures.
- These measures **correlated** and can further **predict** usage characteristics.
- Interface-aware algorithms can be designed based on interface **features** rather than interface **type**.

6 Conclusion and Future Work

- The established tasks and measures can be used as an assessment and training tool for common interfaces.
- These tools can facilitate training in a safe and controlled setting, without the need to drive a powered wheelchair.
- Quantitative performance measures can be used by seating clinicians to assess the user's ability to safely and skillfully control a wheelchair.

7 References

1. C. Ezeh, P. Trautman, C, Holloway, and T. Carlson, "Comparing shared control approaches for alternative interfaces: a wheelchair simulator experiment", *Proceedings SMC*, 2017.
2. M. Nejati Javaremi, M. Young, and B. Argall, "Interface Operation and Implications for Shared-Control Assistive Robots", *Proceedings of ICORR, 2019.*