Assessing And Improving Attention In TBI Patients Using Virtual Reality Environments With Haptic Robots

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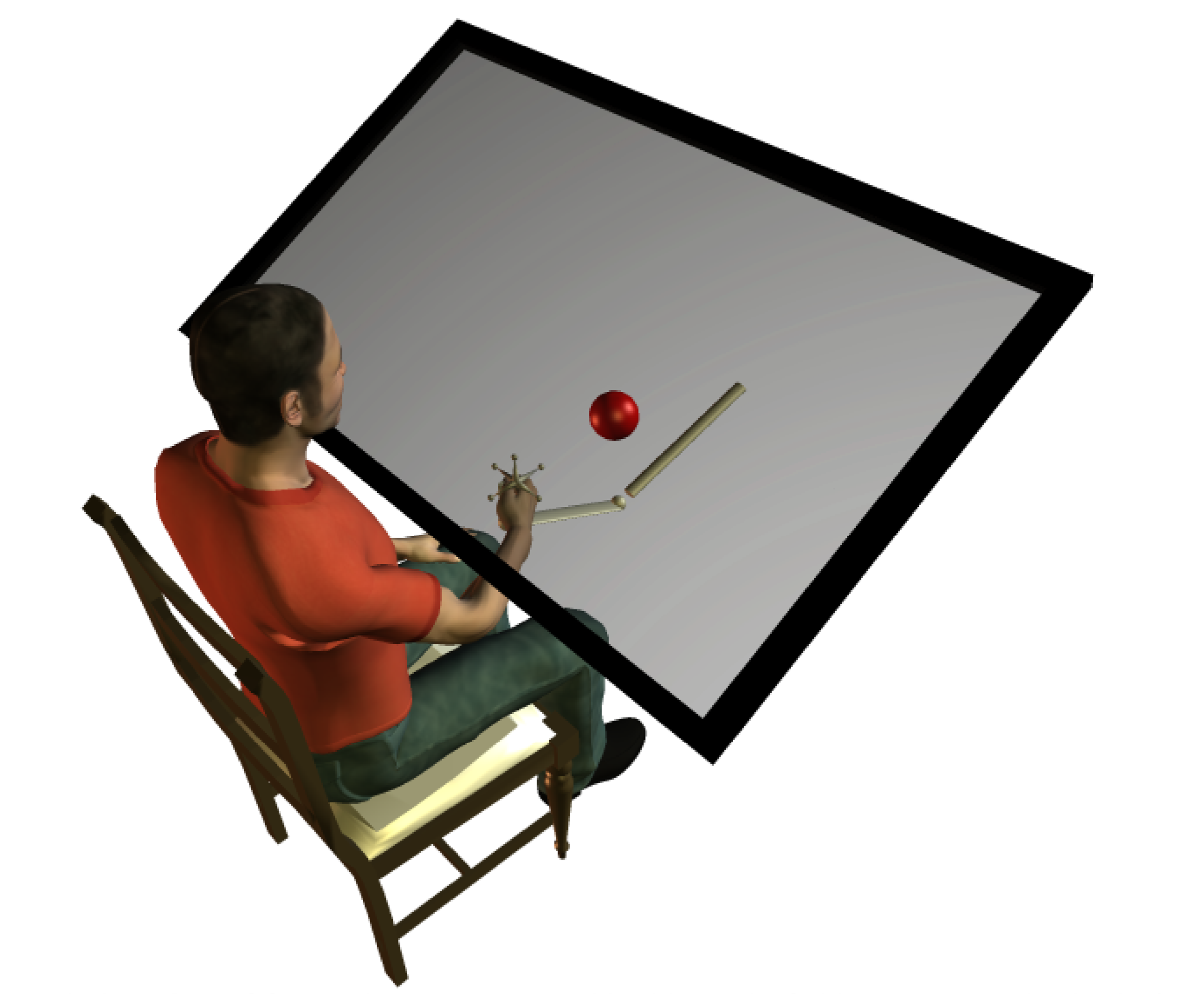
Introduction

- Traumatic Brain Injury (TBI) is a principal cause of life-long disability.
- Attention deficits are frequently observed after TBI.
- Various therapeutic methods for improving attention, including training in engaging virtual environments, have been used for TBI survivors. [1-2]
- Although successful, these methods have shown to improve attention in chronic and higher functioning patients. To date, there have been no studies on how training in virtual environments may improve attention in the inpatient TBI population.
- Spatial attention has been shown to be crossmodally linked between vision and touch, such that haptic activation of attention automatically captures and directs visual attention to the same physical space.
- A previous study in our lab showed that the TBI inpatients do tolerate and enjoy haptic/graphic reality environments and that the environment was able to assess attentional deficits. [3]
- Recent advances in virtual reality allow the augmentation of virtual environments with physical space, allowing the use of a haptic devices within virtually generated environments.

AIM:
To develop a minimalist, interactive haptics/graphics virtual environment to assess and improve attention in the early stage of recovery in the inpatient TBI population.

HYPOTHESES:
- Subjects will accumulate proficiency throughout the experiment.
- During loss of attention as evidenced by decrease in movement speed, exertion of a haptic nudge will capture and redirect subjects' attention to the task at hand.
- Breakthrough forces will provided an engaging environment, aiding the subject to remain on task.



Rendering of VRROOM environment as used in this study. Subject sees a red spherical target and a jack cursor. Cursor is spatially colocated with hand/haptic device, but hand and haptic device are *not* visible.

Methods

Subjects were immersed in a 3D wide field of view virtual environment (using a haptics/graphics system called the Virtual Reality and Robotic Optical Operations Machine (VRROOM) [4]). Correct perspective and stereo projections of the scene were updated using the head position and orientation supplied by a 'Flock of Birds' tracking sensor attached to the stereo shutter glasses (Crystal Eyes, StereoGraphics Inc.).

The minimal interactive virtual environment consisted of a cursor and a target in the field of view that can be both seen and felt, with no distractions. Virtual targets (generated as 3D ball-shaped targets) appeared one at a time in different locations in space.

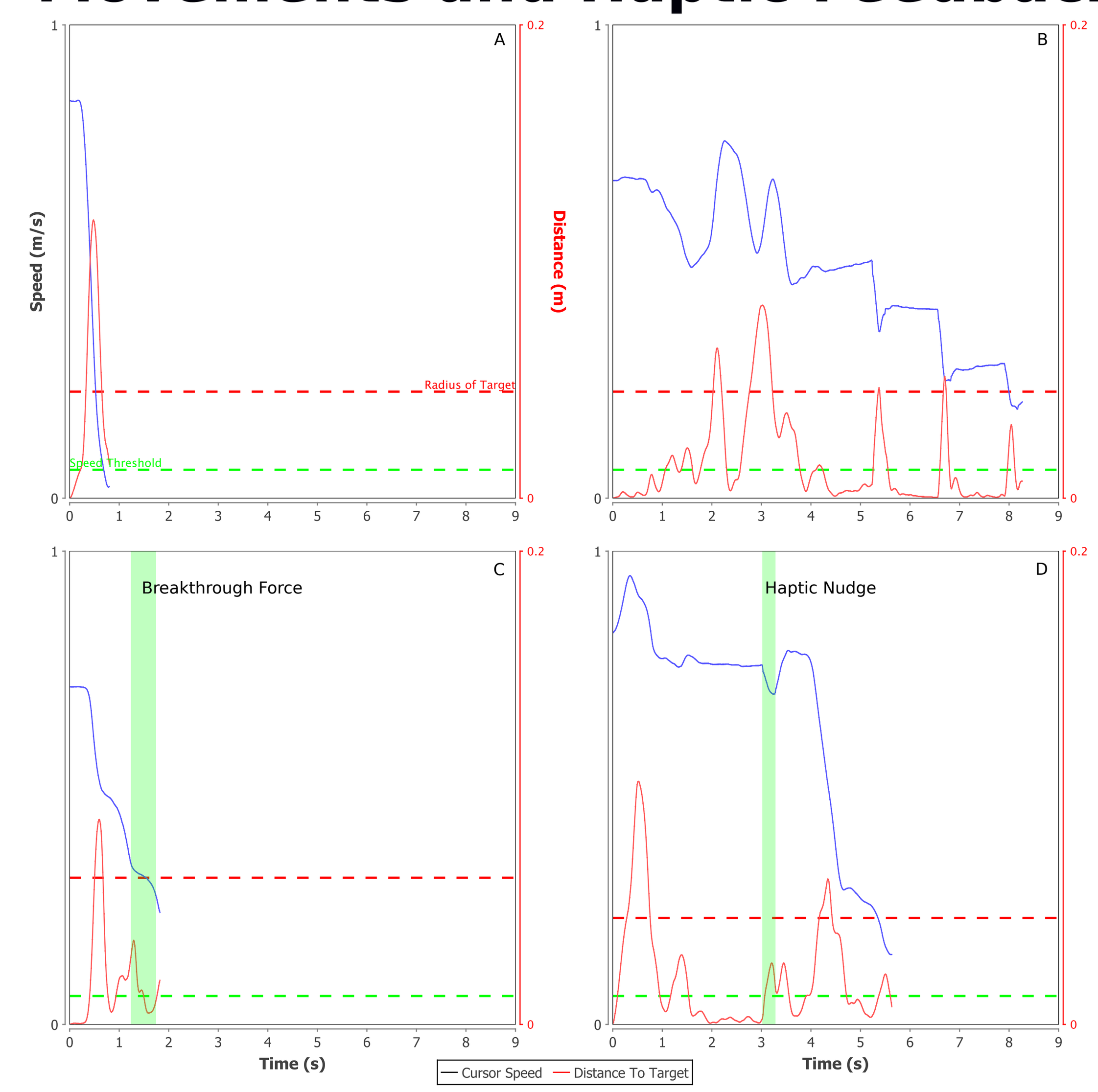
Each patient made two visits on successive days. During each visit, patients reached toward targets, completing three treatment phases. Each phase consisted of two blocks of four minutes each, and one of the following haptic feedbacks:

- **Control** No haptic feedback
- **Balloon** A "breakthrough" force at 1 cm from target which gives way to a small attractor force once within the target, similar popping a balloon.
- **Nudge** A 1 N, 250 ms nudge exerted in the direction of the target after one second of no movement over a threshold.

In each block, the subject held the handle of a PHANToM 3.0 robot and moved the handle toward the targets with their right hand. A target disappeared and the next target appeared in the scene when the subject entered the cursor to the target or 10 sec elapsed

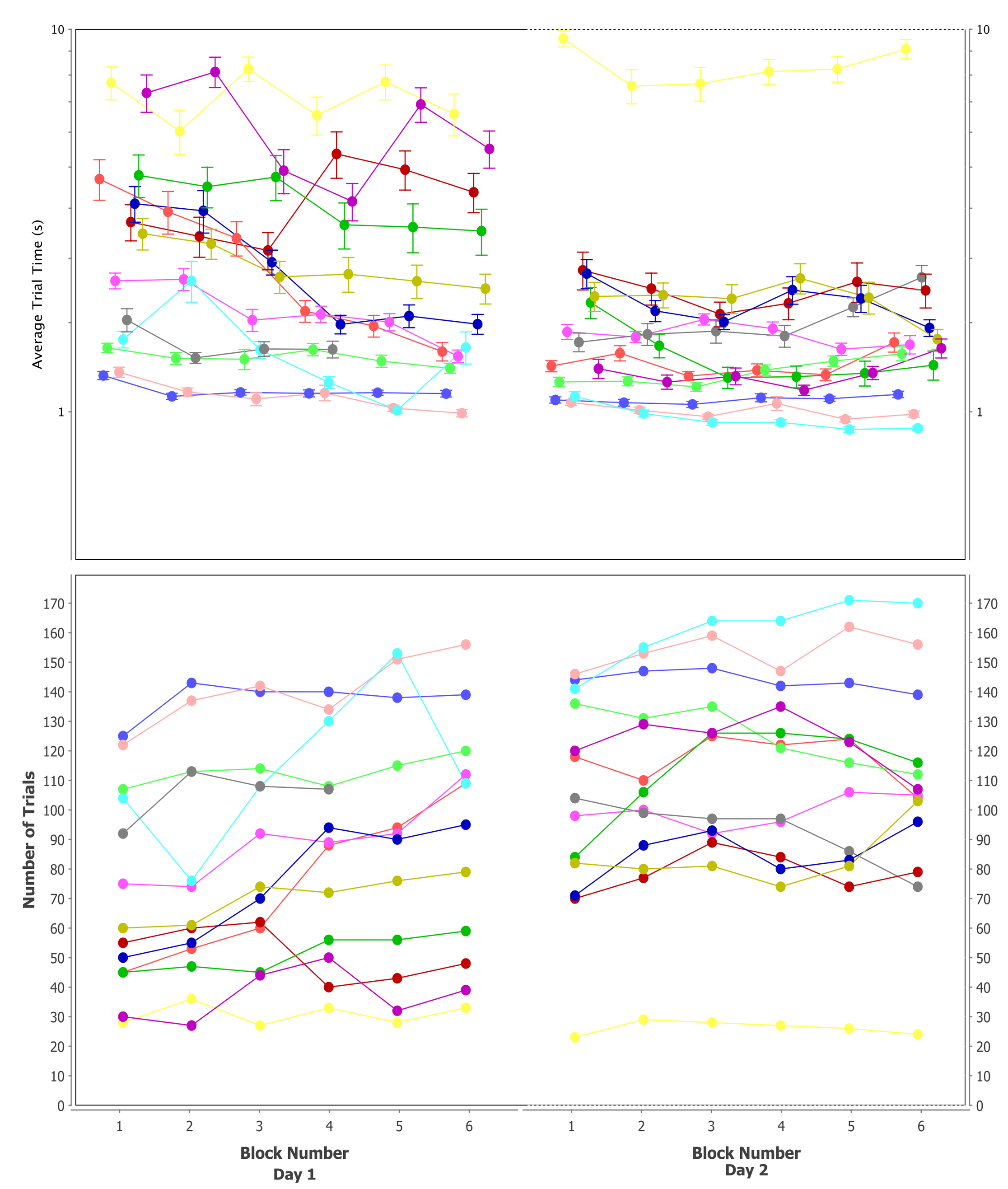
Results

Movements and Haptic Feedback



A) Ideal movement, made by a healthy subject.
B) Movement made by TBI patient, showing difficulties staying on task.
C) Balloon effect, showing breakthrough force when cursor is near target. Note delay in task completion.
D) Pulse effect, showing pulse of force upon loss of movement. Note task completion shortly after nudge.

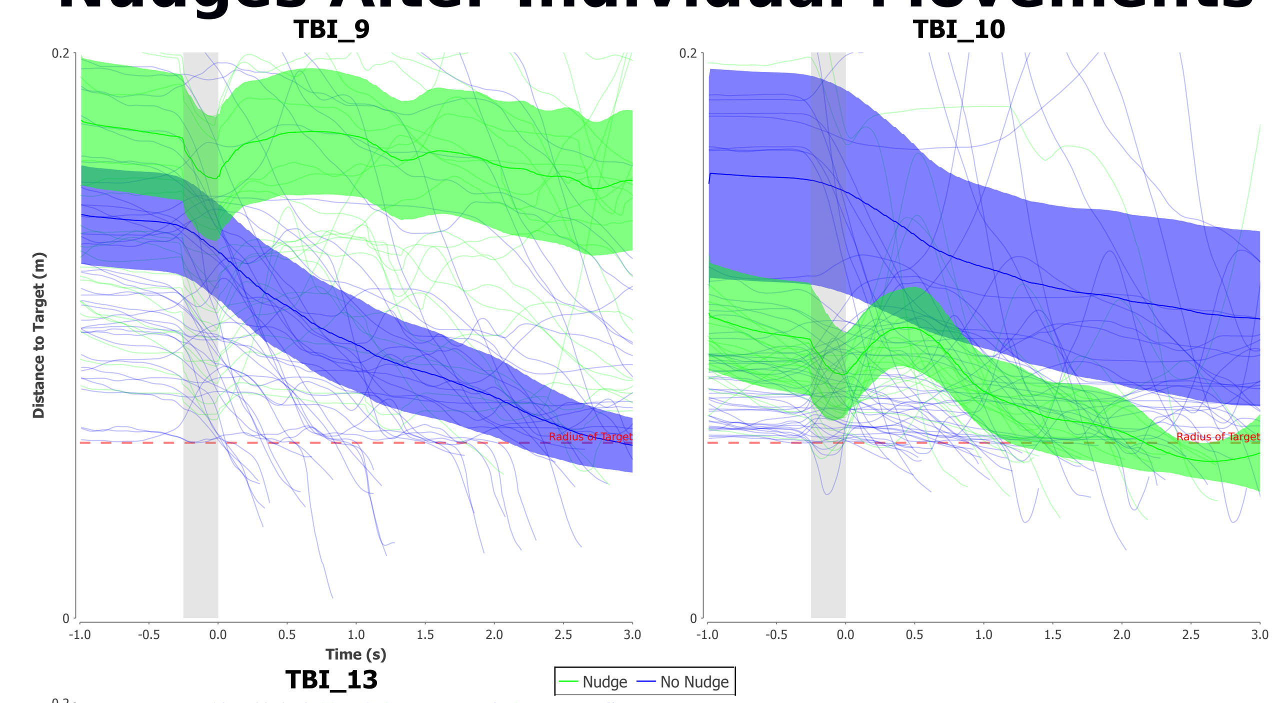
Overall Performance

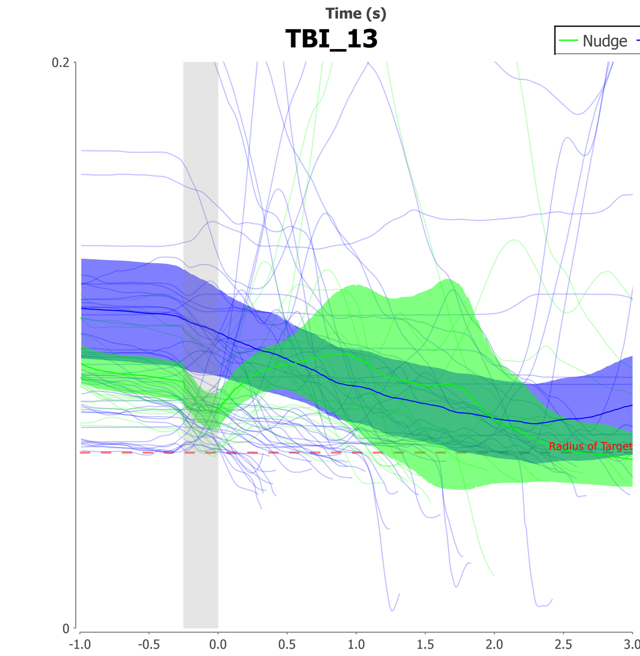


Most patients showed improvement on the first visit and leveled off on the second.

Results

Nudges Alter Individual Movements



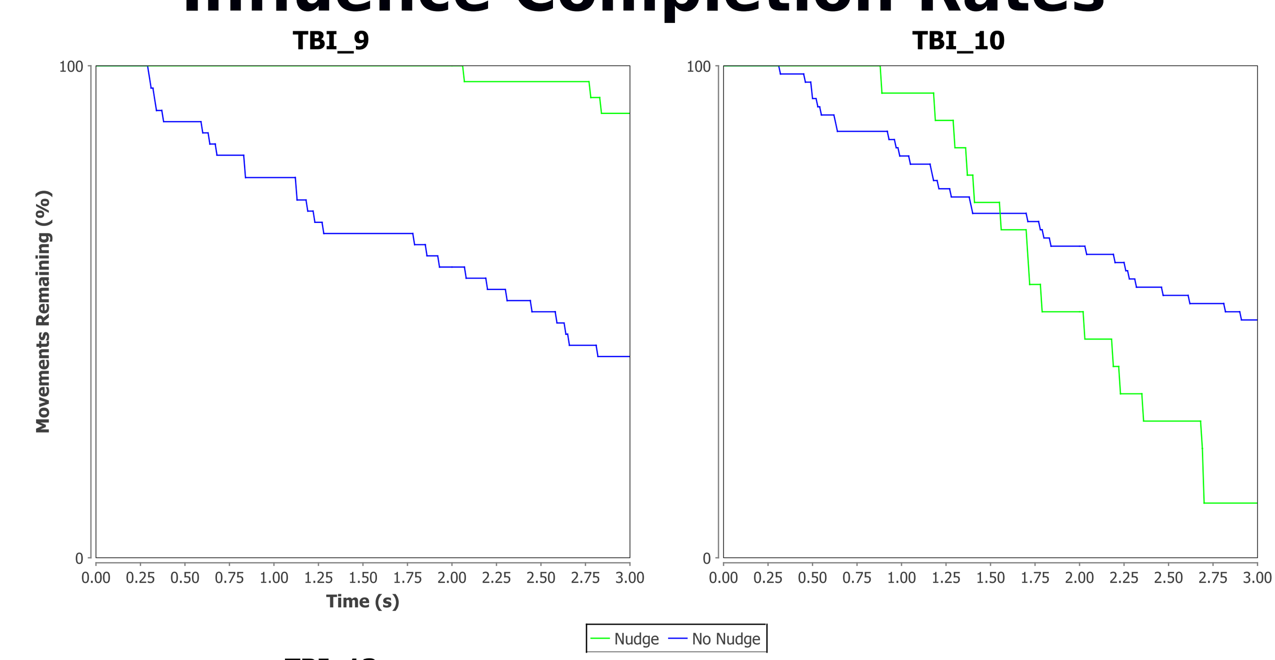


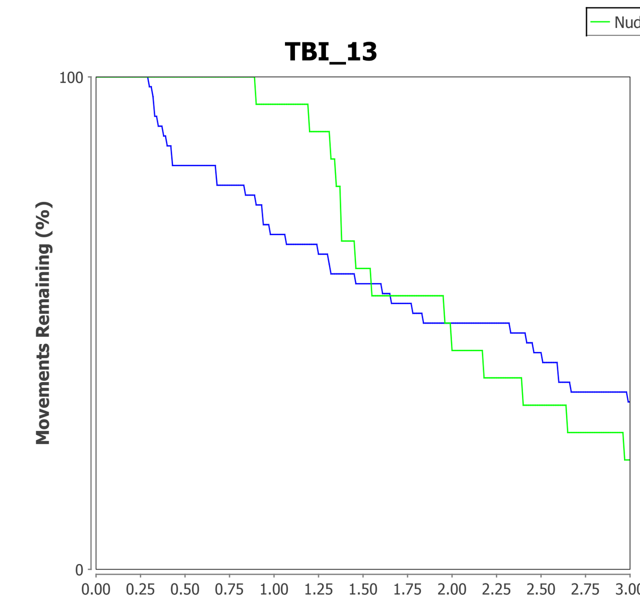
Green: Haptic nudge provided.
Blue: Haptic nudge would have been provided.

Movements normalized to end of nudge, with 95% confidence intervals overlaid.

- All patients show counteraction following end of nudge.
- TBI_9 shows resistance to nudge and inability to complete task,
- TBI_10 shows near immediate return to task and task completion.
- TBI_13 shows some improvement.

Nudges Differentially Influence Completion Rates





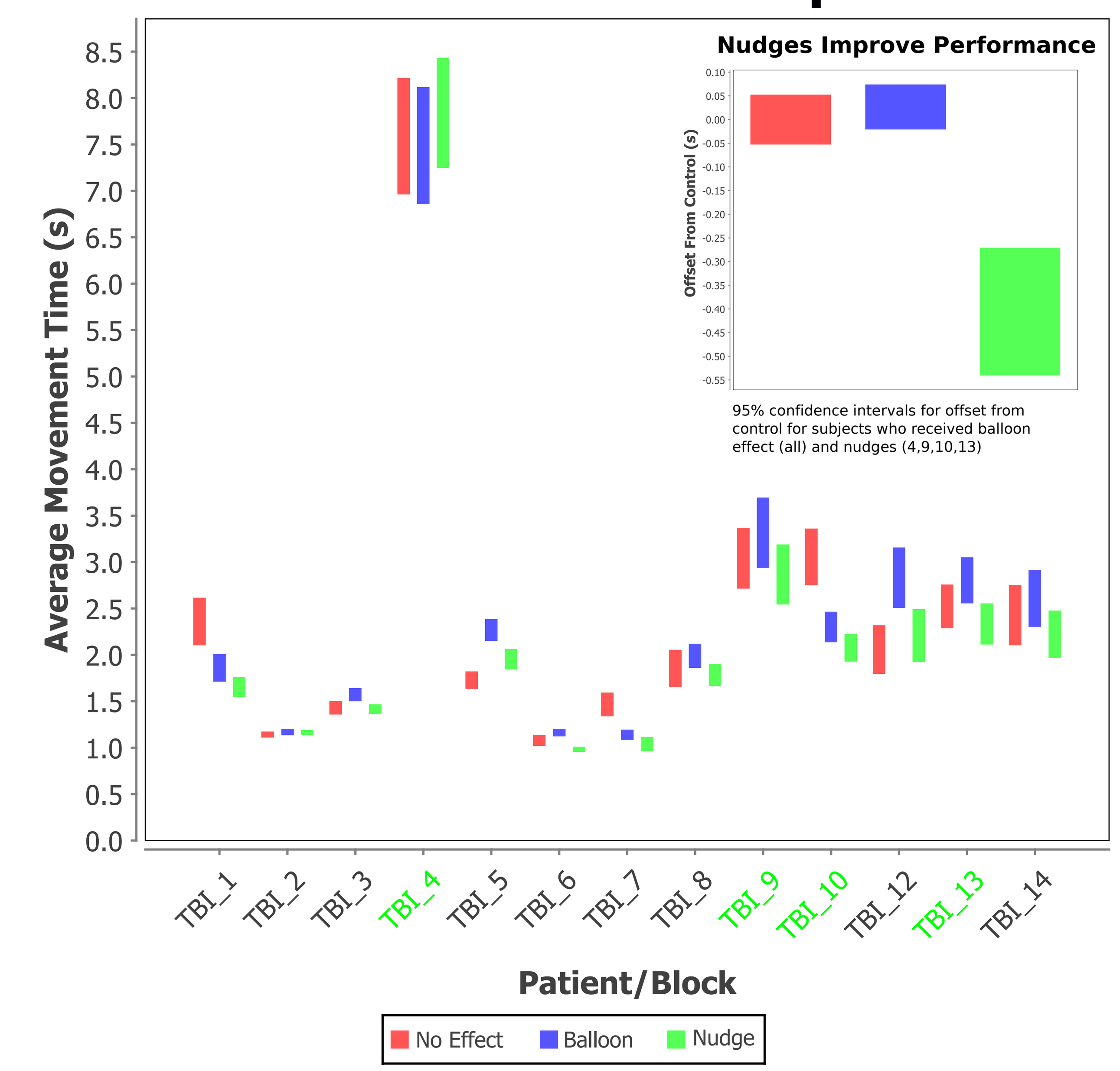
Percentage of movements remaining after a nudge (green) or the point a nudge would have occurred (blue).

All show relatively consistent completion rates without a nudge, as would be expected without any specific feedback.

- TBI_9 shows almost zero completion
- TBI_10 and TBI_13 show improvement.

Results

Overall Effects of Haptics



95% confidence intervals of average movement times by haptic effect.
Highlighted subjects are those that received nudges and lost focus many times.

- Balloon "breakthrough" forces had minimal effect on performance.
- Nudges improved performance in subjects who required attention recapture, though not always significantly.

Conclusions

- Haptic nudges were able to refocus patients' attention.
- In some cases, nudges were able to assist patients in completing the task. One patient resisted the nudge, and this in turn, decreased task performance.
- Overall, nudges improved performance.
- Balloon forces had no significant effects on overall performance.
- Patients improved on Day 1 and in between days, but leveled off on the second.
- More demanding tasks are necessary as patients become more functional.
- The VR system is a powerful and versatile environment for attentional therapy, but requires a longer, more intensive study.

References

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Acknowledgements

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