Effects of Robot Viscous Forces on Arm Movements in Chronic Stroke Survivors: A Randomized Crossover Study

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Abstract

Background

Our previous work showed that speed is linked to the ability to recover in chronic stroke survivors. Patients moving faster on the first day of a three-week study had greater improvements on the Wolf Motor Function Test.

Methods

We examined the effects of three candidate speed-modifying fields in a crossover design: negative viscosity, positive viscosity, and a “breakthrough” force that vanishes after speed exceeds an individualized threshold.

Results

Negative viscosity resulted in a significant speed increase when it was on. No lasting after effects on movement speed were observed from any of these treatments, however, training with negative viscosity led to significant improvements in movement accuracy and smoothness.

Conclusions

Our results suggest that negative viscosity could be used as a treatment to augment the training process while still allowing patients to make their own volitional motions in practice.

Trial registration

This study was approved by the Institutional Review Boards at Northwestern University (STU00206579) and the University of Illinois at Chicago (2018-1251).

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Figures
Figure 1

CONSORT-style diagram for speed crossover. One patient dropped from the study after having a second stroke, which was disqualifying. Data was collected and analyzed for 13 total patients.
Figure 2

Experiment Setup. Patients reached unimanually, alternating between a central home position and randomly to one of eight different target locations. The study was conducted using the Looking Glass virtual reality system and the Barrett Procio robot arm.
Experiment Conditions and Timeline (A) Timeline of the experiment, each “block” of trials lasted for 15 minutes, and there was a short break (30-60 seconds) in after each block. (B) Negative viscosity. Forces were proportional to velocity in all three directions, we drove the forces to zero at higher speeds for safety. (C) Positive viscosity. Similar to negative viscosity but the forces acted opposite to the direction of motion, slowing the participants. (D) Breakthrough. Forces were proportional to velocity until the participants reached 75% of their baseline speed, forces were then removed as a reward for reaching faster speeds.
Figure 4

Effect of experiment conditions on altering patient speed. Error bars represent 95% confidence interval. Negative viscosity had the strongest effect on participant speed, though the aftereffect was opposite to what we hoped to achieve (on average, participants slowed down, though not significantly). There was no significant difference between the effects of positive viscosity and breakthrough, and no significant change from baseline.
Figure 5

Effect of experiment conditions on various movement features. (A) Movement error measured using maximum perpendicular distance. (B) Movement length measured as the magnitude of the distance covered by the subject's arm. (C) Movement smoothness measured as the number of peaks in the speed profile. (D) Pre-movement speed measured as the average speed after target is displayed and before subjects begin moving.