Robot-Based Measures of Upper Limb Cognitive-Motor Interference Across the HIV-Stroke Spectrum

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Takeaway: Our preliminary results show that we are able to concurrently measure motor and cognitive performance on a robot-based dual-task. CMI can be a possible assessment metric for subtler cognitive and motor deficits in a variety of populations dealing with neurological injuries.

INTRODUCTION

- With over half of the HIV population projected to be over 50 years old by 2020, HIV-associated comorbidities such as HIV-associated neurocognitive disorders (HAND) and stroke pose an increasing risk (Heaton 2004).
- Cerebrovascular events have an incidence rate of 3.87 per 1000 years lived and occur at an average age of 48 years old in the HIV population, 1.5 times higher and 22 years younger than the general population, respectively (Vinikoor 2013).
- Cognitive-motor interference (CMI) is defined as the decrease in performance in one or both tasks involved in a dual-task compared to the tasks performed in isolation, and is a metric used to measure fall risk and mild cognitive impairment in aging and stroke populations (Plummer 2013).
- We explore robot-based measures of CMI in stroke and HIV-stroke subjects as a possible way to detect subtle functional decline.

METHODS

- **Subject Population:** Eight subjects participated in this study — five healthy subjects, one stroke subject, and two HIV-stroke subjects.
- **Clinical Assessment:** The following clinical tests were administered to the stroke and HIV-stroke groups: Montreal Cognitive Assessment (MoCA), Beck's Depression Inventory (BDI), Upper Extremity Fugl-Meyer test (UE-FM), grip strength test, Box and Block test, Modified Ashworth Scale, Color Trails 1 and 2, Grooved Pegboard Test, Digital Symbol Coding Test, and the International HIV Dementia Scale. The clinical scores are included in Table 1.
- **Robotic Assessment:** The Haptic TheraDrive (Fig. 1) is a one degree-of-freedom robot designed in our lab for upper limb stroke rehabilitation. Each subject performed a set of three different tasks on the TheraDrive — a motor task (trajectory tracking), a cognitive task (n-back working memory test), and a combined cognitive-motor task (spatial span visuospatial working memory task).
- **Dual-Task Effect (DTE):** To quantify the DTE in the motor domain between the spatial span task and trajectory tracking task, we looked at spectral arc length. For the cognitive domain DTE, we looked at the total score between the spatial span task and n-back. A z-score for each robot-based metric was first calculated from the subject's scores and the mean and standard deviation of the healthy group. Once converted into a z-score, a dual-task effect equation was applied (Equation 1). This produced a positive or negative value that indicated improved or decreased performance in the dual-task relative to the single task performance, respectively.

$$(Equation\ 1) \quad DTE(\%) = \frac{metric_{dual} - metric_{single}}{metric_{single}} * 100\%$$

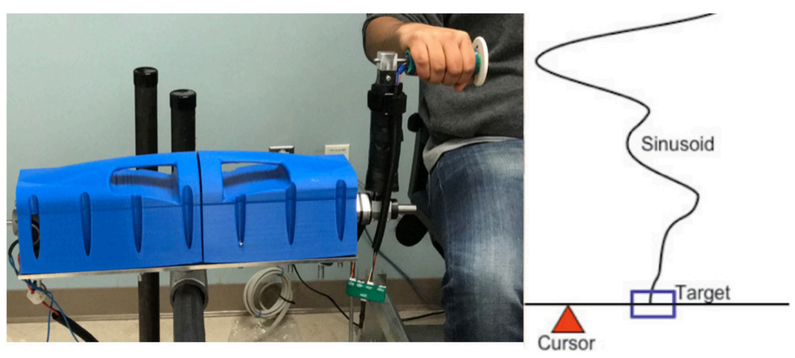
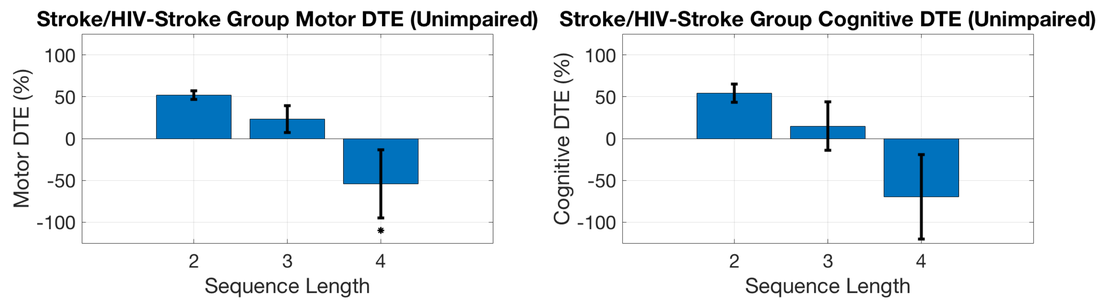
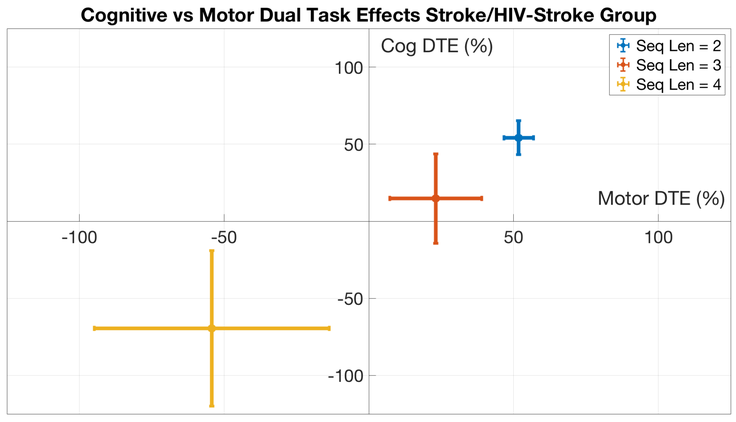


Fig 1. Haptic TheraDrive (left) and screenshot of the tracking task (right).

RESULTS



- **Fig 2, left.** The smoothness DTE is significantly worse for a sequence length of four than it is for a sequence length of two ($p < 0.05$).
- **Fig 2, right.** The difference between the percent correct response DTE for a sequence length of two and a sequence length of four in the unimpaired limb of the stroke/HIV-stroke group approached significance, but did not meet the alpha cutoff level of 0.05 ($p = 0.058$).



- **Fig 3.** Both the motor and cognitive DTEs are shown together on the same plot across the different sequence lengths, with the horizontal and vertical error bars representing the standard error of the motor and cognitive DTE, respectively.

DISCUSSION AND CONCLUSIONS

- These preliminary results show that we are able to concurrently measure motor and cognitive performance on the spatial span task.
- We are able to observe differences within the task based on sequence length, performance between limbs, and performance between groups in the smoothness and correct response rate metrics in the spatial span task.
- There is an increase in both cognitive and motor DTE as the sequence length increases, indicating that the stroke/HIV-stroke group is performing worse compared to the healthy population in both domains as the task becomes more difficult.
- Subjects demonstrated a pattern of only the smoothness being affected as the task difficulty increases or decreased performance in both cognitive and motor domains, consistent with the two kinds of CMI found in stroke patients.
- Going forward, being able to identify the kind of CMI based on these metrics can potentially be used as a way to identify subtler decline in activities of daily living.

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