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On the Effects of Deep Brain Stimulation on Motor Performance of the Affected Side of a Hemidystonic Child During a Continuous Motor Task

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Introduction

- **Dystonia** is a movement disorder involving involuntary muscle contractions causing abnormal movements and postures[1].
- A subset of dystonic movements are **hyperkinetic;** they are excess unwanted movements that are superimposed on voluntary movement[1].
- Deep Brain Stimulation (DBS) is a neuro-modulatory intervention that has profound impact on treatment of children with movement disorders such as dystonia [2].
- We showed previously that **cyclic task-related frequency content is seen** in kinematics and muscle activity during motor task performance by a hemidystonic child [3].

Objective

Our goal is to study and compare how stimulating at different targets in basal ganglia and thalamus can affect task performance in both left (affected) and right (unaffected) sides of a left hemidystonic patient.

Materials and Methods

Patients: We used kinematics and electromyography (EMG) data from a 16 years old male pediatric patient, diagnosed with **left hemidystonia**, who underwent DBS surgery. Permanent leads implanted in right Vo, bilateral GPi, and left VPLa.

Pre-Existing Leads	New Lead Targets
R GPi, R VPL, R VO	L GPi, L VPL, L VO, L VIM

Experimental Setup: The subject was asked to perform a cyclic movement task, that is drawing figure-eights on an iPad, using both right and left hands. Each task consists of 3 trials of 9 repetitions for each hand for different stimulation targets:

	Test 1	Test 2	Test 3	Test 4	Test 5
LH	R: Clinical Stim L: Off Stim	R: Clinical Stim L: GPi Stim	R: Clinical Stim L: VIM Stim	R: Clinical Stim L: VO Stim	Not Performed
RH	R: Clinical Stim L: Off Stim	R: Clinical Stim L: GPi Stim	R: Clinical Stim L: VIM Stim	R: Clinical Stim L: VO Stim	R: Clinical Stim L: VPLa Stim

Data: **Kinematics** were recorded from the task iPad, and **EMG** signals for each hand were recorded from eight muscles of the upper limb.

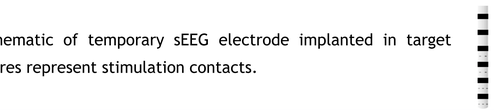

Figure 1. The schematic of temporary sEEG electrode implanted in target regions. Black squares represent stimulation contacts.

Results

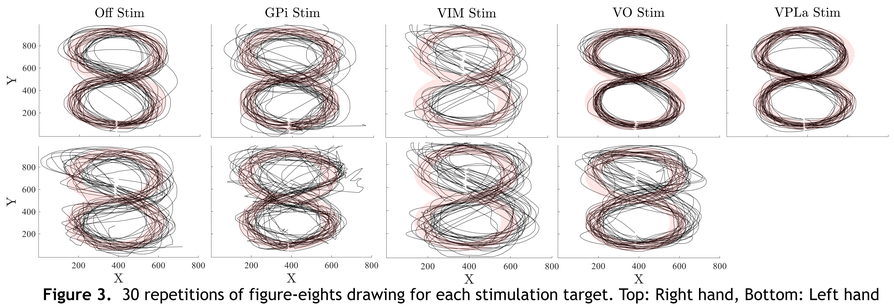

Figure 3. 30 repetitions of figure-eights drawing for each stimulation target. Top: Right hand, Bottom: Left hand

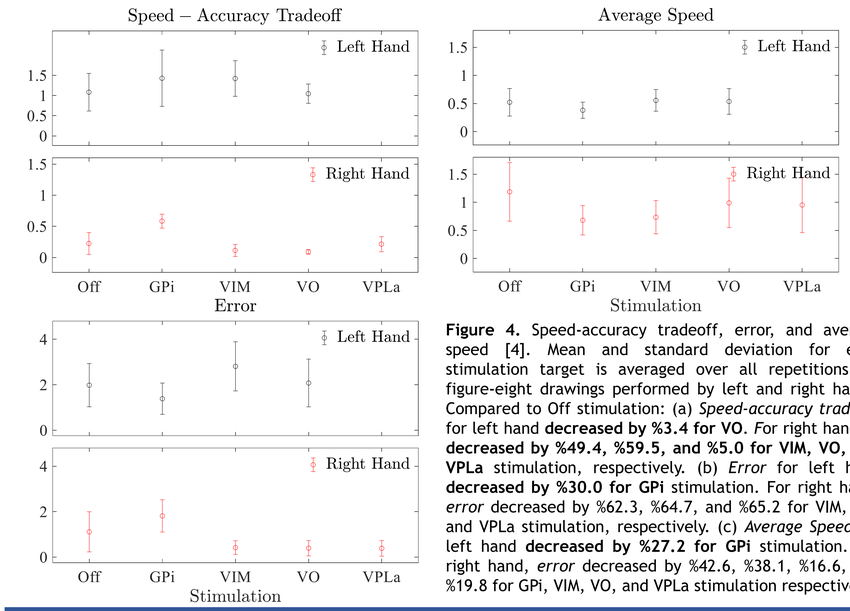

Figure 4. Speed-accuracy tradeoff, error, and average speed [4]. Mean and standard deviation for each stimulation target is averaged over all repetitions for figure-eight drawings performed by left and right hands. Compared to Off stimulation: (a) *Speed-accuracy tradeoff* for left hand **decreased by %3.4 for VO**. For right hand, it **decreased by %49.4, %59.5, and %5.0 for VIM, VO, and VPLa** stimulation, respectively. (b) *Error* for left hand **decreased by %30.0 for GPi** stimulation. For right hand, *error* decreased by %62.3, %64.7, and %65.2 for VIM, VO, and VPLa stimulation, respectively. (c) *Average Speed* for left hand **decreased by %27.2 for GPi** stimulation. For right hand, *error* decreased by %42.6, %38.1, %16.6, and %19.8 for GPi, VIM, VO, and VPLa stimulation respectively.

Previous Work [3]

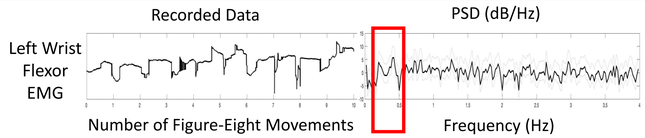

Fig 2. EMG Spectral Analysis.
Left Flexor EMG. Raw traces of Bayesian nonlinear filtered EMG[5] (Left). PSD from 0-4Hz (Right). While drawing figure-eights, the subject will traverse the y direction once, and the x direction twice. This gives peaks at **task-related frequencies**.
Red Box: Task-related frequency content.

Results

Left Hand								
Stim.	**Task-correlation Index**							
	L Bi.	**L Tri.**	**L WF**	**L WE**	**L AD**	**L LD**	**L PD**	**L Sup.**
Off	0.088	0.088	0.047	0.105	0.113	0.048	0.063	0.072
GPi	0.083	0.041	0.042	0.074	0.057	0.088	0.090	0.062
VIM	0.016	0.084	0.077	0.052	0.052	0.028	0.054	0.065
VO	0.102	0.029	0.073	0.063	0.132	0.110	0.160	0.091
Right Hand								
Stim	**Task-correlation Index**							
	R Bi.	**R Tri.**	**R WF**	**R WE**	**R AD**	**R LD**	**R PD**	**R Sup.**
Off	0.081	0.112	0.028	0.032	0.069	0.130	0.048	0.113
GPi	0.097	0.068	0.032	0.073	0.097	0.047	0.067	0.041
VIM	0.114	0.108	0.098	0.108	0.090	0.100	0.053	0.047
VO	0.048	0.075	0.045	0.044	0.114	0.066	0.112	0.057
VPLa	0.031	0.032	0.050	0.067	0.074	0.081	0.066	0.083

Table 1. Task-correlation index (TCI). Left hand: TCI for VO stim. (i.e., %9.7) is higher than that of Off stim. (i.e., %8.0). Right hand: TCI for VIM stim. (i.e., %10) is higher than that of Off stim. (i.e., %7.5).

Conclusion

- Results from this study suggest that stimulating GPi, VO, VIM, and VPLa on left hemisphere have contributed to improvement **in ipsilateral/contralateral task performance**.
- Our results suggest that **DBS can increase correlation of muscle activity with task**.
- Our results suggest that performance metrics have the potential to be used as a quantitative tool **to improve decision making** for DBS permanent lead implantation.

Future Work

- Developing better **quantitative tools that could improve decision making** during DBS procedure.

Limitations

- Presence of pre-existing leads with clinical stimulation limited our ability to precisely study the effects of our stimulation settings on ipsilateral/contralateral task performance.
- A population study to evaluate task performance in DBS on-DBS off conditions can give us better insight on how quantitative tools can help with decision making during DBS procedure.

Acknowledgments

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