Automated Deep Brain Stimulation Programming Using Motion Sensors

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Introduction

Deep brain stimulation (DBS) is a well-established treatment for Parkinson's disease (PD). Optimizing DBS settings quickly and in a way that minimizes costs and patient travel burden are important factors for follow-up care, but can be a significant challenge due to the number of variables that must be considered (i.e., severity of multiple symptoms, side effects, and battery life). The goal of this study is to determine if automated and objective assessment of DBS response could improve therapeutic benefit and battery life compared to clinician settings.

Methods

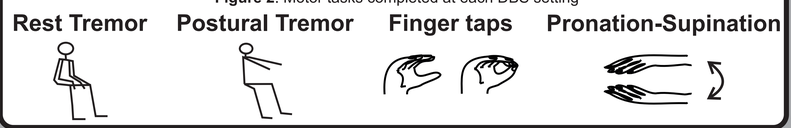
- 9 PD subjects with average OFF medication tremor and/or bradykinesia UPDRS scores ≥ 2 were recruited prior to or just after DBS implant surgery at the University of Minnesota
- Subjects visited the clinic for programming sessions at approximately 1, 2, and 4 months post-surgery, withholding anti-parkinsonian medication overnight
- Subjects wore a motion sensor (Fig 1) on the most distal portion of the first finger of the more affected hand during motor tasks to provide objective measures of tremor and bradykinesia
- Stimulation settings were assessed at various monopolar settings and subjects performed four standardized motor tasks from the UPDRS (Fig 2) following each change in stimulation
- Algorithms were developed offline to select the optimal stimulation contact and voltage combination

Table 1. Subject Demographics

Age	64-76 years
Gender	6 male, 3 female
DBS Target	6 STN, 3 GPI

Figure 1. Wireless finger-worn motion sensor

Figure 2. Motor tasks completed at each DBS setting



Automated DBS Parameter Selection

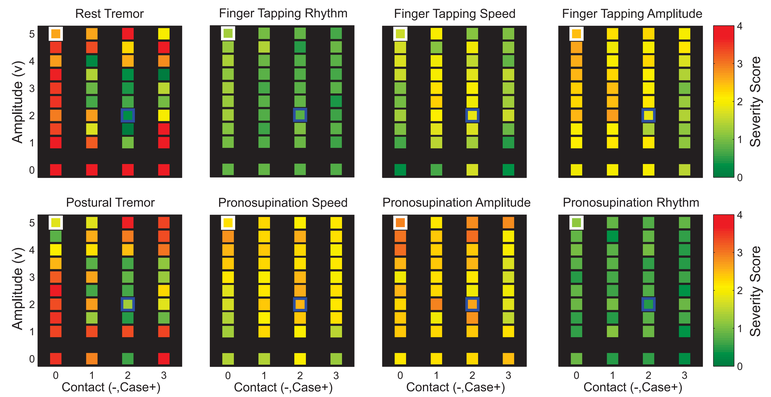
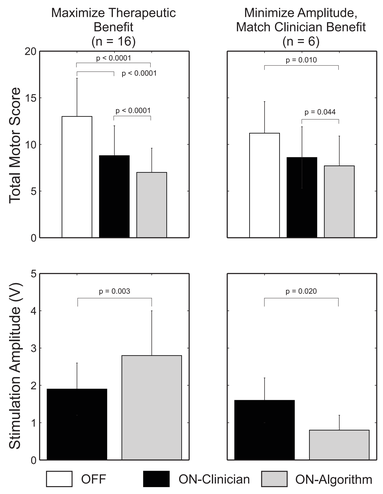


Figure 3. Tuning maps based on objective motion sensor ratings of rest tremor, postural tremor, and bradykinesia for a single subject. The blue box indicates the final DBS settings the clinician selected. The white box indicates the presence of stimulation-induced side effects

- Total motor score, or the sum of the eight symptom severity scores, was utilized as a measure of therapeutic benefit
- Algorithms were developed to:
  1. Maximize therapeutic benefit by identifying the contact and amplitude at which the therapeutic benefit was maximized
  2. Minimize voltage while maintaining at least the therapeutic benefit achieved by the clinician settings



- Clinician DBS settings had a therapeutic effect in 15/16 programming sessions
- When maximizing therapeutic benefit (left), algorithm settings improved relative to clinician in 14/16 programming sessions
  - On average, the clinician settings yielded a 31.7% decrease in total motor score from OFF, while the algorithm settings reduced symptoms by 45.1%
  - Both tremor (n = 10) and bradykinesia (n = 13) typically improved
  - Often came at the expense of an increase in stimulation amplitude
- When optimizing for battery life (right), the algorithm was able to find a setting that maintained therapeutic benefit with an average stimulation amplitude reduction of 50% (6/16 sessions)

Figure 4. Summary of automated algorithms for selecting DBS settings.

Ongoing - Guided DBS Programming

- Developed a prototype system to actively guide a monopolar review of the DBS programming space
- Leverages motion sensor algorithms for motor symptom assessment and allows clinician to manually enter side effects
- Once the functional map is complete, the system identifies stimulation settings which maximize symptomatic improvements while minimizing battery usage and side effects

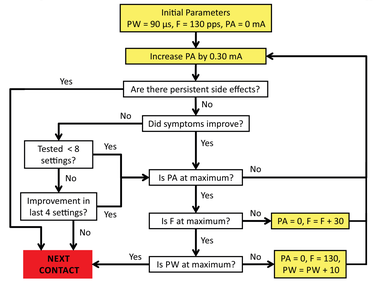


Figure 5. Block diagram of search algorithm

Figure 6. Prototype software guides programmer through monopolar review

- As of June 1, 2014, six subjects have completed the protocol at the University of Cincinnati
- UPDRS being completed with the pulse generator set to three configurations: (1) stimulator off, (2) stimulator on with the optimal settings determined by the clinician, and (3) stimulator on with the settings determined by the prototype system

Conclusions

- Results support the value of automated objective assessment in DBS programming
- Current work is evaluating online automated guidance of DBS programming
- An automated system designed for use by a general practitioner without years of experience in DBS programming could potentially expand the accessibility of DBS for patients not located near specialized centers and increase the efficacy and efficiency of post-operative DBS management

This work was/is supported by NIH/NIA R44AG033520 and NIH/NINDS 1R43NS081902. The content is the sole responsibility of the authors and does not necessarily reflect the views of the NIH, NIA, or NINDS.