Wearables and Application Solutions for Parkinson’s Disease: An Overview

GREAT LAKES NEUROTECHNOLOGIES

Joseph P. Giuffrida, PhD
President & Principal Investigator

Parkinson’s Disease: Challenges and Opportunities	5 min
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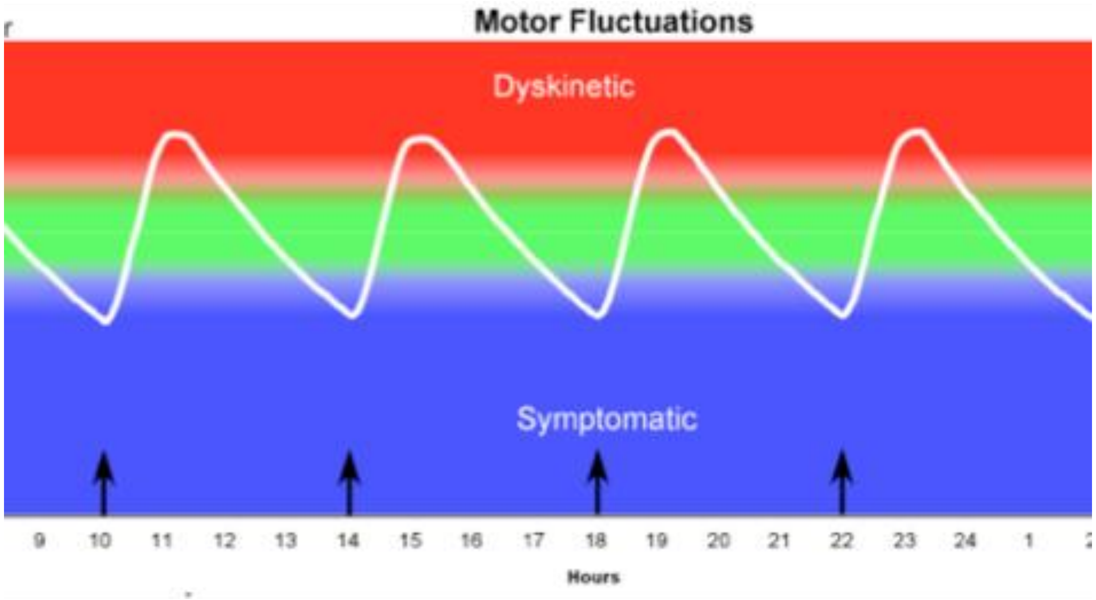
Wearables Road Map	10 min
Clinical Validation of Wearables	
Targeted Applications within Targeted Applications	
Closing the Clinical Workflow	10 min
Closing the Business Case	
Closing the Patient Perspective	
Questions	5 min

Parkinson’s Disease:
Challenges and Opportunities

Parkinson’s is Very Difficult

SYMPTOMS	TREATMENTS	DEMOGRAPHICS
Tremor	Levodopa	Over 60
Dyskinesias	Rasagiline	Growing Incidence
Bradykinesia	Duodopa	Neurodegeneration
Rigidity	DBS	Medicare
Gait	Exercise	VA
Non-Motor et al.	Neuroprotection?	Access to Care

Advanced Parkinson's



Wearable Technology Space & Big Data


Fitbit
Thursday, Jan 24, 2013
Sumner Paine
20,245
of goal 20,000
15
A Wearable Monitor for Movement Disorders in Parkinson's Disease
DELSYS
Statement of Problem
Description of Work to Date
Proposed Solution
Proposed Work
Showing results for "parkinsons"
iPhone Apps
Parkinson's Toolkit
Parkinson's Disease - a Livi...
Parkinson's UK EasyCall
Neurology and Psychiatry...
Parkinsons
PD Life
Neurology (Understanding...
Neurology ipocketcards
iPad Apps
Parkinson's Disease - a Livi...
Neurology and Psychiatry...
Neurology (Understanding...
Neurology ipocketcards
Speech Pacesetter Lite
Assess for DBS
Conversation Paceboard
World Neurology
Europeans developing automatic monitoring for Parkinson's
Tweet 38
Share 20
Share 15
at Lakes Neurotechnologies | Kinesia HomeView | mobile health sensors
arkinson's wearable sensor | REMPARK | Teknon Medical Center |
APDM movement monitoring solutions
COMPANY
WIRELESS INERTIAL SENSORS
GAIT & P
mobility lab
from APDM, Inc.
Sensitive, Valid, and Reliable Outcome Measures
With over 100 universities and hospitals using this system worldwide, Mobility Lab™ is the most trusted sensor-based gait and balance system on the market.
Mobility Lab™ makes it easy for you to collect, analyze, and store outcome measures. Simply strap sensors on to your subject, instruct them to preform a standardized test, and when they are finished a report is automatically generated to compare against normative values. Beginning to end takes less than 5 minutes.
Postural Sway
• Sway Area
• Sway Speed
• Sway Distance
• Sway Path
• Center of Mass Motion
Upper Limb
• Arm Swing Speed
• Arm Range of Motion
• Arm Swing Variability
• Arm Swing Asymmetry
• Trunk Range of Motion
Postural Transitions
• Turn Duration
• Turn Speed
Lower Limb
• Gait Speed
• Stride Length
Adaptive auditory cueing system
Tremor inertial sensor (wrist):
- Sends tremor data to smartphone
FES actuator
- Haptic cueing
- Step initiation
s and provides cues to help
pebble
shimmer
DISCOVERY IN MOTION
RSS
About
Conta
Home
Technology
Applications
Solutions
Products
Purchase
Technology
• Key Features
• Hardware
• Expansion Modules
• Firmware
• Software Development
• LabVIEW
• MATLAB
• Android
• C#
• Software Applications
• 9DoF Calibration
• ShimmerConnect
• PAMSys – Physical Activity Monitoring
• Capabilities
Newsletter:
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Technology
Shimmer – Wearable Wireless Sensor Platform
Shimmer is a wireless sensor platform that allows you to capture and communicate a wide range of sensed data in real-time.
Shimmer is the main component (often referred to as the main-board) required to set up a wireless sensing application, and provides a range of functions including basic motion sensing, data capture, processing, and the wireless transmission of sensed data.
A full range of sensor modules (or daughter-cards) can then be connected to Shimmer, to allow for applications in complex motion sensing, vital signs and biophysical sensing, environmental and ambient sensing.
Shimmer System Overview (example uses ECG module)
Hardware
Firmware
Software
Sensor module (ECG) is combined with Shimmer platform
Assembled Shimmer ECG
Wireless transfer of data to computing devices in real-time

Intel, Michael J. Fox and Big Data: Fighting Parkinson's Disease

By Virginia Backaitis | Aug 13, 2014 Follow 908 followers

You've been there. In the doctor's office that is. You're not feeling well and you want to tell the doc all about it, but he wants to ask you questions like: How would you rate the pain on a scale of 1 to 10? When did this start? How long does it last? How would you rate your sleep 1 to 10?

You answer the questions with what is, at best, a guess. And the doctor makes assessments based upon your answers. But is what he calls an "8" the same thing you call an 8? And what does "sleeping well" actually mean? (And, yes, we know there's information like heart rate, blood pressure, lab work data to consider, but we're putting that aside for the moment.)

Now forget about yourself and think of a Parkinson's patient. Michael J. Fox or Intel's Andy Grove may be the ones we "know" best, unless there's someone in our personal lives who has been affected. Their doctors probably include some

Apple ResearchKit Turns iPhones Into Medical Diagnostic Devices

Posted Mar 9, 2015 by Josh Constine (@joshconstine)

3,737 SHARES

Medical research is plagued by small sample sizes and inconsistent dat

Parkinson mPower study app

View More by This Developer

By Sage Bionetworks, a Not-For-Profit Research Organization

Open iTunes to buy and download apps.

View in iTunes

Free

Category: Medical
Released: Mar 09, 2015
Version: 1.0
Size: 69.6 MB
Language: English
Seller: Sage Bionetworks, a Not-For-Profit Research Organization
© 2015, Sage Bionetworks
You must be at least 17 years old to download this app.
Infrequent/Mild Alcohol, Tobacco, or Drug Use or References
Frequent/Intense Medical/Treatment Information

Description

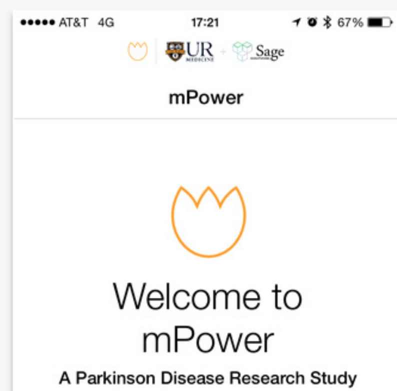
How can we together better manage the symptoms of Parkinson disease?

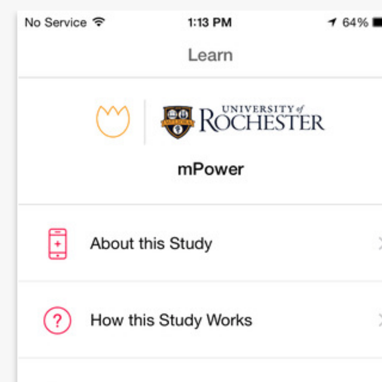
Living with Parkinson disease means coping with symptoms that change daily. Yet these daily changes are not

...More

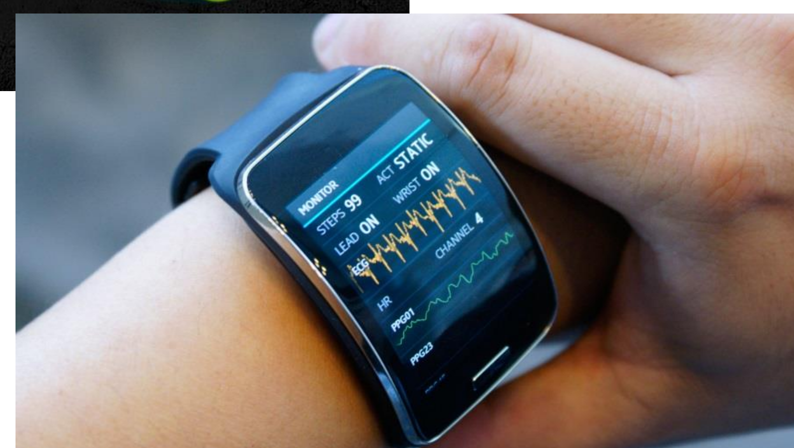
Sage Bionetworks, a Not-For-Profit Research Organization Web Site ▸ Parkinson mPower study app Support ▸

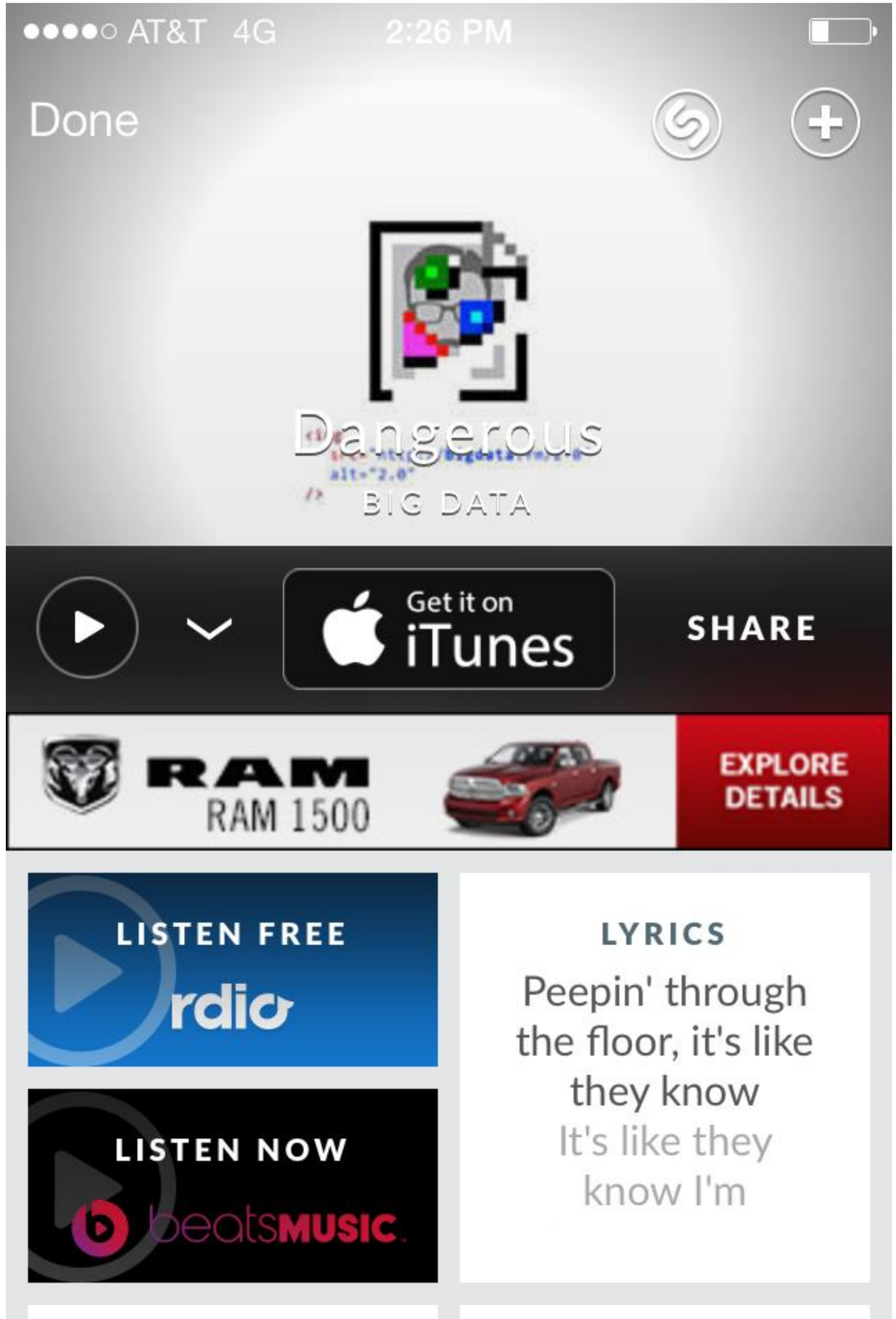
iPhone Screenshot






TURNS OUT,
YOU CAN
MEASURE
DESIRE.
NOW IT'S ON.


MONITOR
STEPS 99
ACT STATIC
LEAD ON
WRIST ON
ECG
CHANNEL 4
HR
PPG01
PPG23


AT&T 4G 2:26 PM
Done
Dangerous
BIG DATA
Get it on
iTunes
SHARE
RAM
RAM 1500
EXPLORE DETAILS
LISTEN FREE
rdio
LISTEN NOW
beatsMUSIC
LYRICS
Peepin' through the floor, it's like they know
It's like they know I'm

Can Parkinson's Wearables Learn from MS?

Biogen idec explores use of wearables to track MS patient activity

March 10, 2015 8:29 pm by Stephanie Baum | 10 Comments

Like 9 Tweet 86 Share 50 Share 27

As part of an effort by Biogen idec to explore ways to use wearables with MS patients to help physicians quantify patient activity, it recently completed a study of 250 patients in collaboration with PatientsLikeMe, Naomi Fried, vice president of medial information and innovation at Biogen, referenced the study as part of a keynote presentation on digital health at the MidAmerica Healthcare Venture Forum in Chicago this week.

This is the problem that Biogen idec wants to solve. Impaired mobility affects more than 90 percent of people with MS, but the quantified assessment of their walking ability tends to be limited to clinical settings. Sensors could give physicians a more accurate assessment of the level of activity of these patients if they were willing to wear activity trackers between appointments.

The study of 250 people with MS sought an answer to the questions: Would patients actually use wearables as part of their daily lives and be willing to share that information with physicians?

The initial takeaway from the study is that it needs to use devices with more sophisticated sensors to quantify movement accurately and consistently. "Current technology is not built to provide consistent and validated data in MS. We are early in the process, but hope to have progress in the coming months," according to an emailed statement about the study from Biogen. It also noted that it was encouraged by the "overwhelming positive participation" from MS patients. It took the response as a sign of encouragement as it explores using wearables in the future.

Big Enough Data

Agile Development: Systems, Algorithms, and Applications

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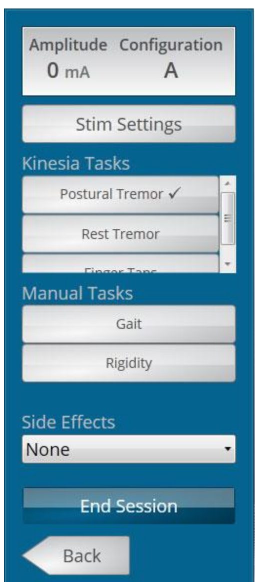
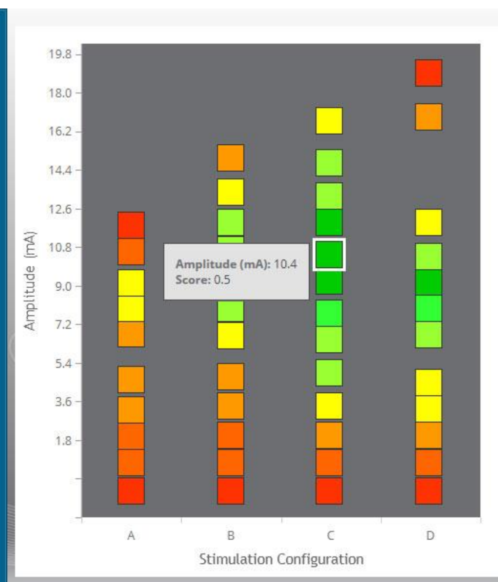
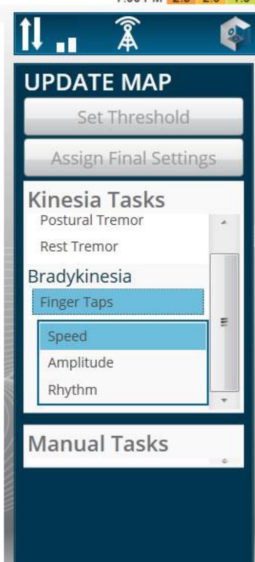






Time	Rest Tremor	Postural Tremor	Finger Taps Speed	Finger Taps Amplitude	Finger Taps Rhythm	Dyskinesia
7:01 AM	4.0	3.5	2.5	2.4	2.2	0.0
7:02 AM	SINEMET (100mg)					
7:32 AM	3.4	3.3	1.7	1.4	1.0	0.0
8:01 AM	3.0	3.0	1.8	1.8	1.2	0.0
8:34 AM	2.9	2.8	1.3	1.2	1.0	0.0
9:00 AM	2.8	2.4	1.2	1.1	1.2	0.0
9:23 AM	2.8	2.6	1.0	1.0	1.0	0.0
10:00 AM	2.6	2.8	1.0	1.0	1.0	0.0
10:33 AM	3.2	3.3	1.5	1.9	1.5	0.0
11:01 AM	3.5	3.5	2.3	2.2	2.0	0.0
11:30 AM	3.7	3.8	2.0	2.0	1.8	0.0
12:00 PM	SINEMET (100mg)					
12:01 PM	3.3	3.8	2.6	2.7	2.0	0.0
12:32 PM	3.2	3.4	1.8	1.9	2.0	0.0
1:08 PM	2.6	3.1	2.0	1.4	1.8	0.0
1:28 PM	2.6	2.9	1.5	1.2	1.7	0.0
2:00 PM	2.7	2.7	1.3	1.0	1.5	0.0
2:32 PM	2.9	2.6	1.0	1.2	1.7	0.0
3:00 PM	3.0	2.9	1.1	1.5	1.3	0.0
3:29 PM	3.3	3.1	1.4	1.7	1.7	0.0
4:02 PM	3.8	3.6	1.6	1.8	1.8	0.0
4:30 PM	3.9	3.8	1.9	1.9	2.0	0.0
5:01 PM	3.9	3.9	2.5	2.4	2.0	0.0
5:15 PM	SINEMET (100mg)					
5:29 PM	3.5	3.6	2.1	2.2	2.0	0.0
6:02 PM	3.3	3.5	2.0	2.1	1.6	0.0
6:30 PM	3.0	2.9	1.9	2.0	1.5	0.0
7:00 PM	2.8	2.5	1.5	1.8	1.3	0.0
				1.5	1.1	0.0
				1.4	0.9	0.0
				1.5	1.1	0.0
				1.6	1.4	0.0
				1.8	1.8	0.0
				1.9	2.1	0.0
				1.7	1.6	0.0
				0.4	0.4	0.0

Increase dose by 200mg, Dose interval unchanged

Time	Rest Tremor	Postural Tremor	Finger Taps Speed	Finger Taps Amplitude	Finger Taps Rhythm	Dyskinesia
6:55 AM	3.9	3.4	2.6	2.5	2.3	0.0
6:57 AM	SINEMET (300mg)					
7:28 AM	2.5	3.0	1.7	1.4	1.0	0.0
7:59 AM	0.5	1.9	1.8	1.5	1.2	1.3
8:30 AM	0.3	0.9	0.3	0.5	1.0	2.9
9:05 AM	0.1	0.5	0.2	0.2	1.2	3.5
9:33 AM	0.3	0.4	0.0	0.0	1.0	3.8
10:02 AM	0.5	0.1	0.5	0.3	1.0	3.7
10:31 AM	1.5	2.0	1.0	0.5	1.5	2.9
10:58 AM	3.0	3.1	2.3	2.2	2.0	0.0
11:35 AM	3.5	3.4	2.0	2.0	1.8	0.0
11:50 PM	SINEMET (300mg)					
11:56 PM	1.1	2.7	2.3	2.2	2.0	0.0
12:30 PM	0.2	2.0	1.8	1.9	2.0	3.0
1:04 PM	0.1	1.4	2.0	1.4	1.8	3.3
1:38 PM	0.0	1.1	0.8	0.9	1.7	3.5
2:02 PM	0.0	1.0	0.6	1.0	1.5	3.6
2:30 PM	0.2	1.0	1.0	1.2	1.7	2.4
3:07 PM	0.4	0.7	1.1	1.5	1.3	1.1
3:33 PM	0.5	1.3	1.4	1.7	1.7	0.0
4:03 PM	2.6	1.5	1.6	1.8	1.8	0.0
4:28 PM	3.5	2.0	1.9	1.9	2.0	0.0
5:00 PM	3.8	2.2	2.1	2.1	2.0	0.0
5:05 PM	SINEMET (300mg)					
5:39 PM	3.5	2.2	2.1	2.2	2.0	0.0
6:03 PM	2.3	2.0	2.0	2.1	1.6	0.0
6:29 PM	1.7	1.3	1.9	2.0	1.5	0.5
7:05 PM	0.8	1.1	1.5	1.8	1.3	1.0
7:36 PM	0.6	0.8	1.2	1.5	1.1	2.3
8:01 PM	0.3	0.6	1.0	1.4	0.9	3.8
8:28 PM	0.2	1.0	1.2	1.5	1.1	3.7
9:00 PM	0.3	1.1	1.3	1.6	1.4	1.3
9:34 PM	0.3	2.0	1.6	1.8	1.8	0.5
9:59 PM	2.8	2.3	2.0	1.9	2.1	0.0
Mean	1.3	1.6	1.4	1.5	1.6	1.6
Fluctuation	1.3	0.9	0.7	0.6	0.4	1.5

Decrease dose by 100mg, Decrease dose interval by 2 hours

Time	Rest Tremor	Postural Tremor	Finger Taps Speed	Finger Taps Amplitude	Finger Taps Rhythm	Dyskinesia
7:00 AM	3.5	3.2	2.7	2.5	2.4	0.0
7:01 AM	SINEMET (200mg)					
7:31 AM	2.0	2.1	1.9	2.1	2.2	0.0
8:00 AM	0.6	0.7	0.3	0.5	1.0	0.0
8:33 AM	0.3	0.5	0.2	0.2	1.2	0.0
8:59 AM	0.2	0.2	0.0	0.0	1.0	0.0
9:22 AM	0.2	0.0	0.5	0.3	1.0	0.0
9:59 AM	1.1	1.5	1.0	0.5	1.5	0.0
10:32 AM	SINEMET (200mg)					
11:00 AM	1.2	1.3	1.5	1.4	1.5	0.0
11:29 AM	0.3	0.3	0.5	0.6	2.1	0.0
11:59 PM	0.2	0.2	0.3	0.3	1.0	0.0
12:00 PM	0.1	0.0	0.4	0.1	2.3	0.0
12:31 PM	0.2	0.6	0.6	0.1	2.1	0.0
1:07 PM	1.2	1.6	1.7	1.6	1.7	0.0
1:27 PM	SINEMET (200mg)					
1:59 PM	1.0	0.8	1.0	0.9	1.0	0.0
2:31 PM	0.3	0.7	0.3	0.8	0.9	0.0
2:59 PM	0.2	0.5	0.2	0.5	0.9	0.0
3:28 PM	0.0	0.3	0.2	0.8	0.9	0.0
4:01 PM	0.5	0.8	0.9	1.6	1.7	0.0
4:29 PM	1.3	1.7	1.6	2.1	2.1	0.0
5:00 PM	SINEMET (200mg)					
5:14 PM	1.0	1.5	1.0	0.9	1.0	0.0
5:28 PM	0.3	0.6	0.3	0.8	2.4	0.0
6:01 PM	0.2	0.3	0.2	0.5	2.0	0.0
6:29 PM	0.0	0.0	0.2	0.8	1.7	0.0
6:59 PM	0.5	0.2	0.9	1.6	1.2	0.0
7:32 PM	1.3	0.9	1.6	2.1	1.0	0.0
8:03 PM	SINEMET (200mg)					
8:29 PM	0.8	0.6	0.5	0.7	0.5	0.0
9:01 PM	0.0	0.2	0.2	1.1	0.9	0.0
9:32 PM	0.0	0.1	0.9	1.6	1.3	0.0
9:55 PM	0.5	0.6	1.9	2.0	1.9	0.0
Mean	0.7	0.8	0.8	1.0	1.5	0.0
Fluctuation	0.7	0.7	0.7	0.7	0.5	0.0

Clinical Validation and Publications

NIH Funding

Over $25 Million in SBIR Funding

- National Institute of Health, US
- State of Ohio Commercialization Programs

Collaborators

Over 30 Collaborating Institutions

- Clinical Testing
- Research Collaboration
- Commercialization Partners
- Controlled Database with over 1,000 Patients

Publications

Over 75 Peer-Reviewed & Presentations

- Tremor, Bradykinesia & Dyskinesia Assessment
- Parkinson's Telemedicine
- Deep Brain Stimulation Programming
- Clinical Trials

Quality and Regulatory

FDA Clearance to Market

- 510k Clearance to Market
  - Intended Use
    - Kinesia is intended to monitor physical motion and muscle activity to quantify kinematics of movement disorder symptoms such as tremor and assess activity in any instance where quantifiable analysis of motion and muscle activity is desired.

ISO, CE Mark, Health Canada, and TGA

- ISO 13485:2003
- European Medical Device Directive 93/42/EEC
- Canadian Medical Device Conformity Assessment System
- EMERGO EUROPE: Authorized Agent

Standards and Testing

- Tested to IEC 60601 Standards
- Complies with FCC Part 15 Rules
- HIPAA Compliant

Wearables Roadmap

Context

Environment

Hello My Name Is…

Would I Use Wearables?

I Want My Doctor to See…

A Road Map for Parkinson's Wearables

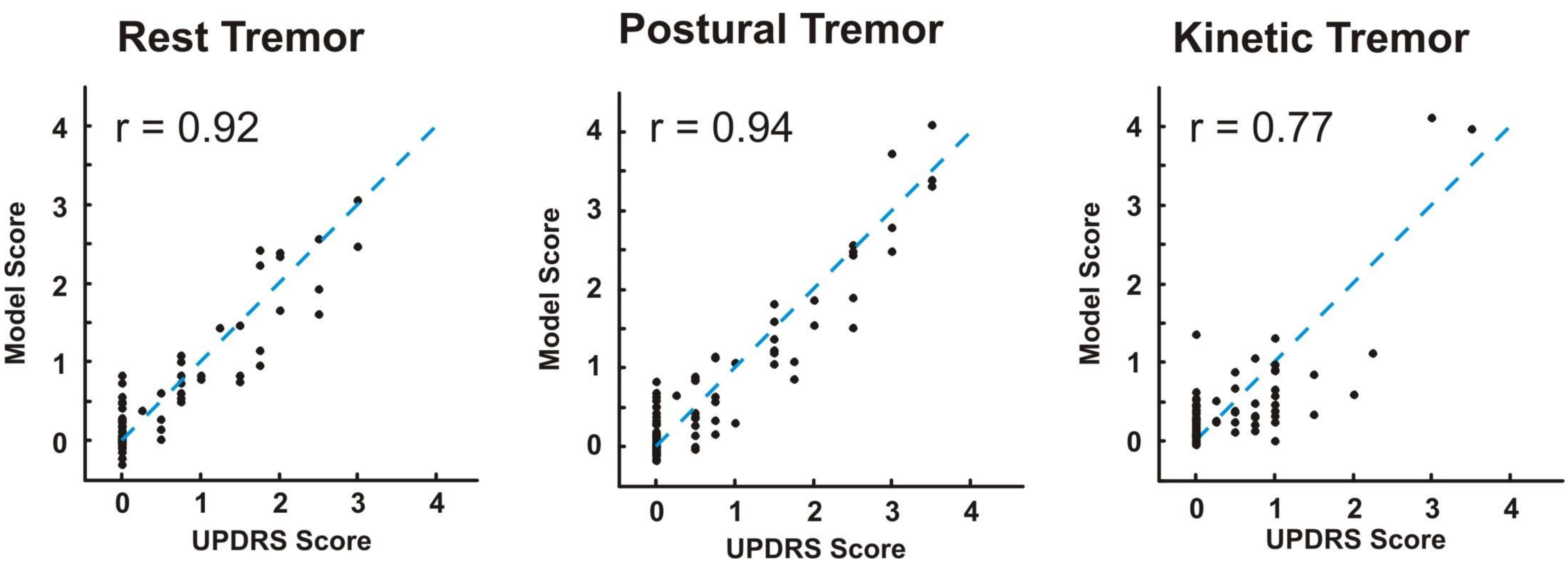
- What Symptoms are You Trying to Measure?
- Detection or Severity?
- Are Symptoms Voluntary or Involuntary?
- Context of Daily Life?
- Patient Environment and Confounding Factors?

Clinical Validation of Wearables

Clinical Validation Workflow

1. Start with Controlled Environment
2. Include Broad Range of Severities
3. Compare Versus Traditional Gold Standard (Video)
4. Demonstrate Correlations, Sensitivity, and Test-Retest Reliability
5. Move to Unconstrained Environment and Tasks That Mask or Mimic Symptoms

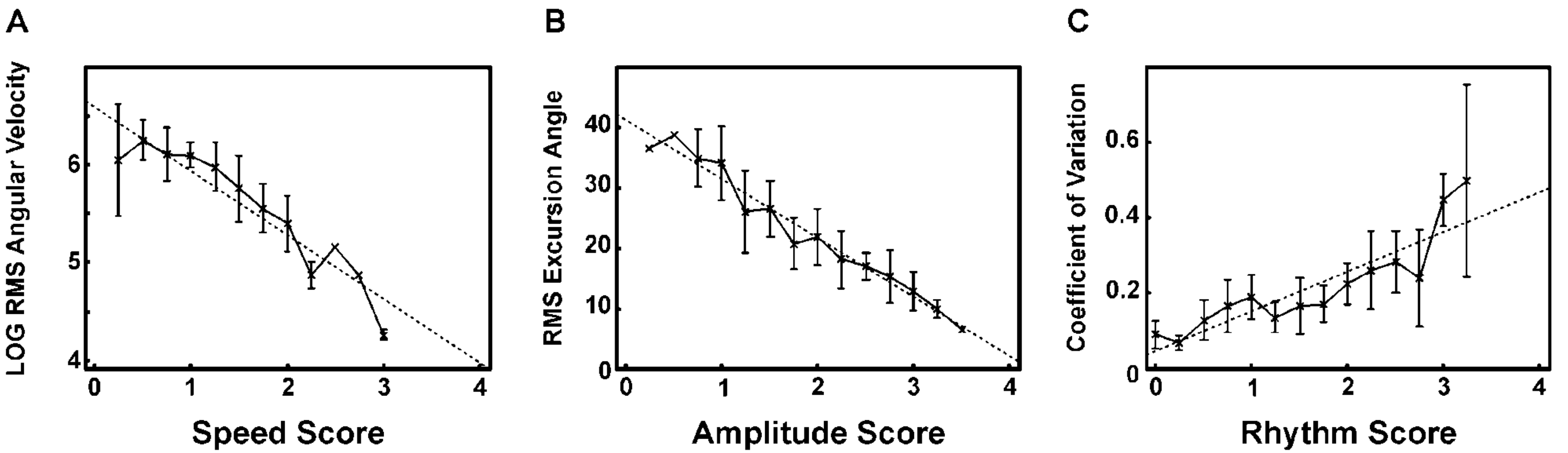
Discrete Tremor Assessment



Published

Giuffrida, J. P., Riley, D, Maddux, B, and Heldman, D.A. Clinically deployable Kinesia technology for automated tremor assessment. *Movement Disorders* 24 (5): 723-730, 2009.

Discrete Bradykinesia Assessment



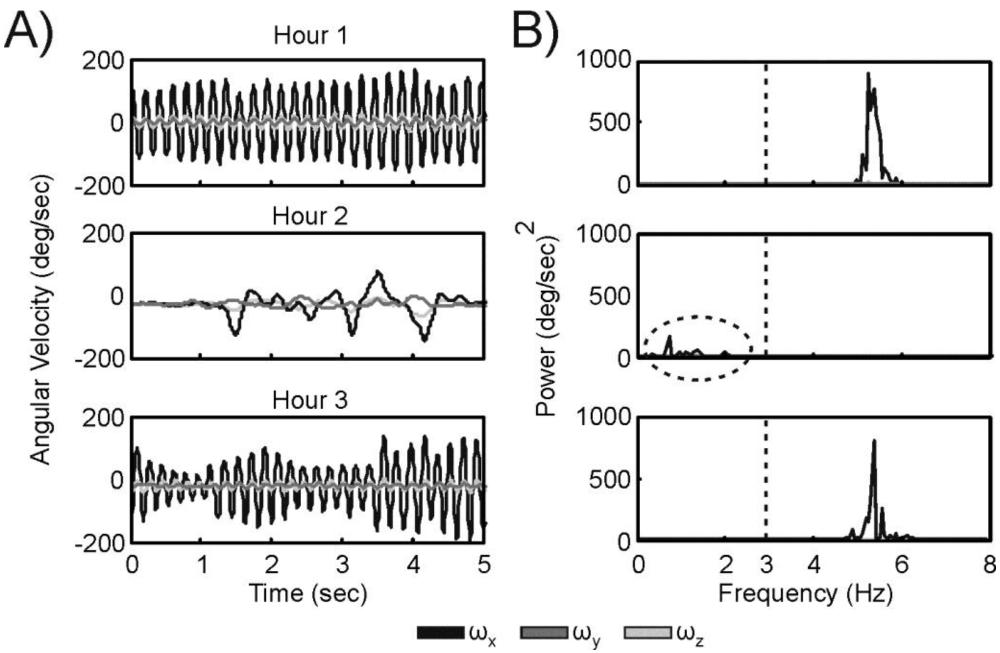
Objective Quantification

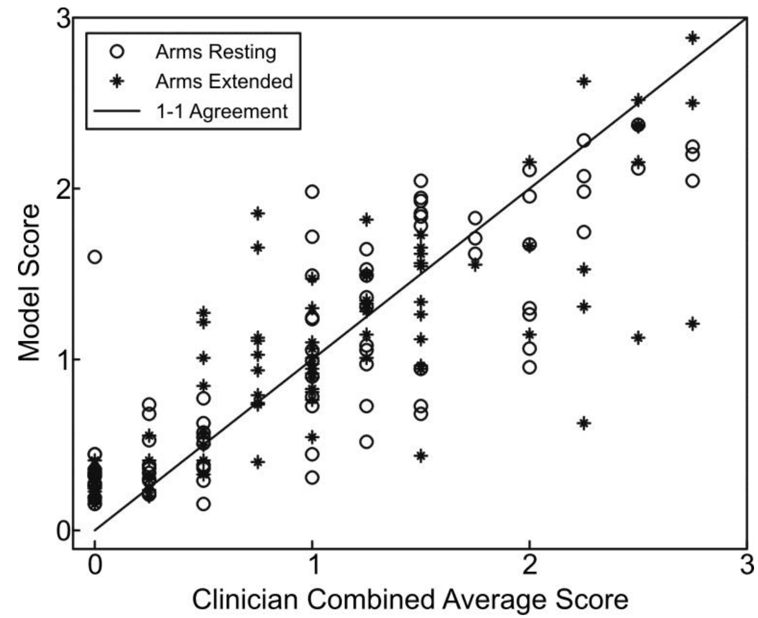
Kinematic features are highly correlated to clinician MBRS scores

Published

Heldman, DA; Giuffrida, JP; Chen, R; Payne, M; Mazzella, F; Duker, AP; Sahay, A; Kim, SJ; Revilla, FJ; Espay, AJ. The Modified Bradykinesia Rating Scale for Parkinson’s disease: Reliability and Comparison with Kinematic Measures. *Movement Disorders*. 2011.

Discrete Dyskinesia Assessment

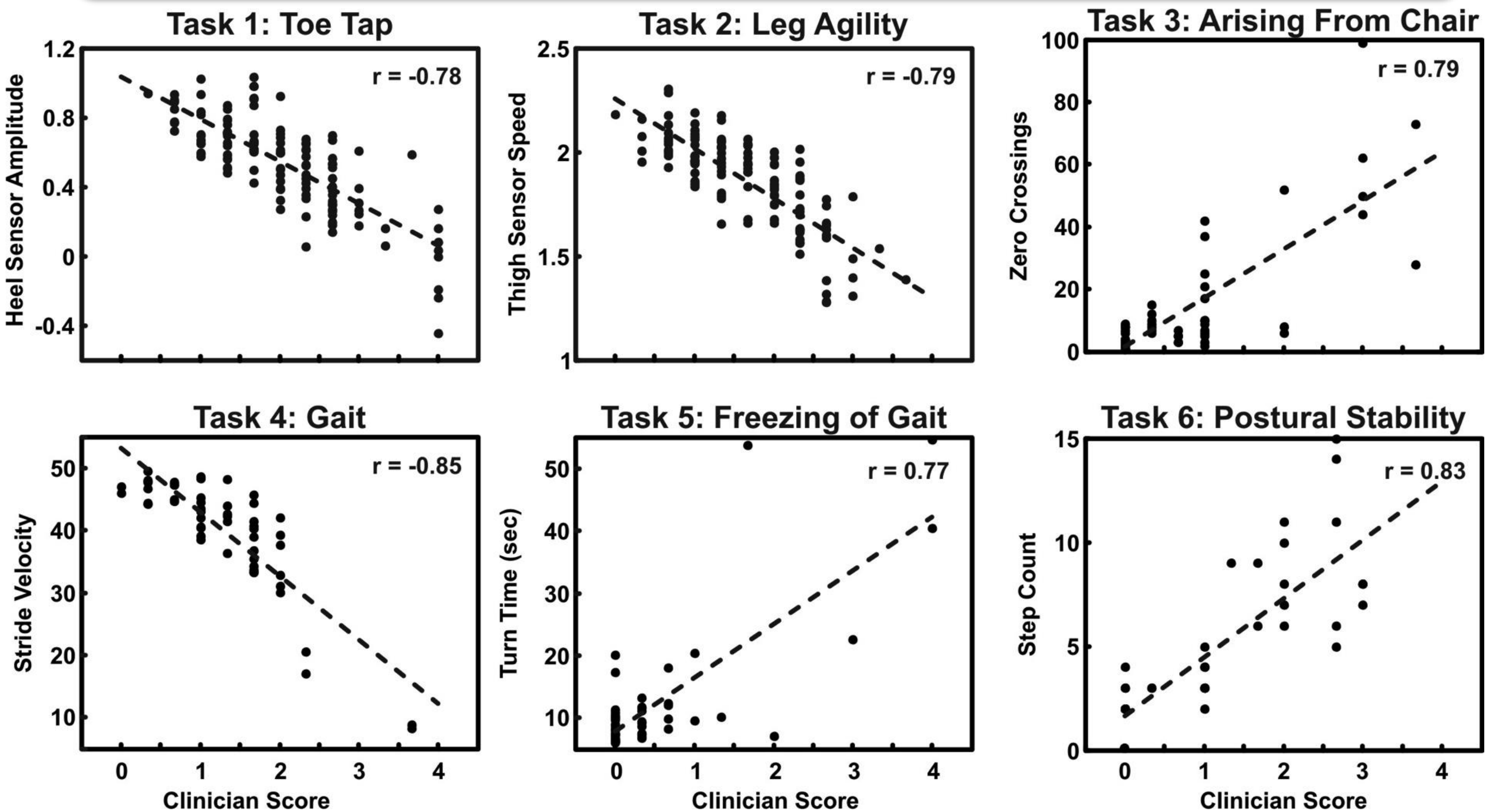




Published

Mera, TO, Burack, MA, and Giuffrida, JP. “Quantitative Assessment of Levodopa Induced Dyskinesia Using Automated Motion Sensing Technology”, IEEE-EMBS Proceedings 2012.

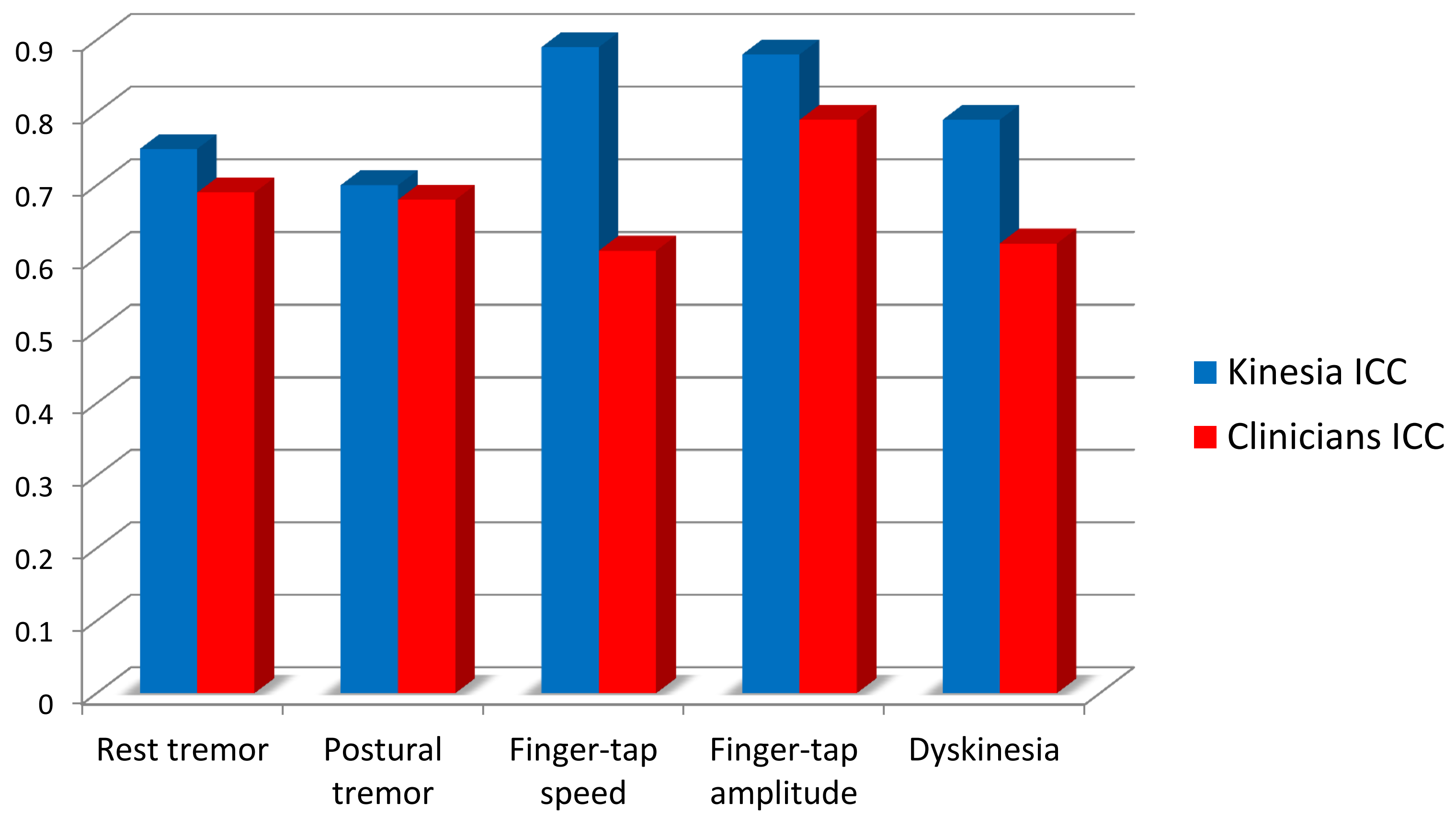
Discrete Gait and Balance Assessment



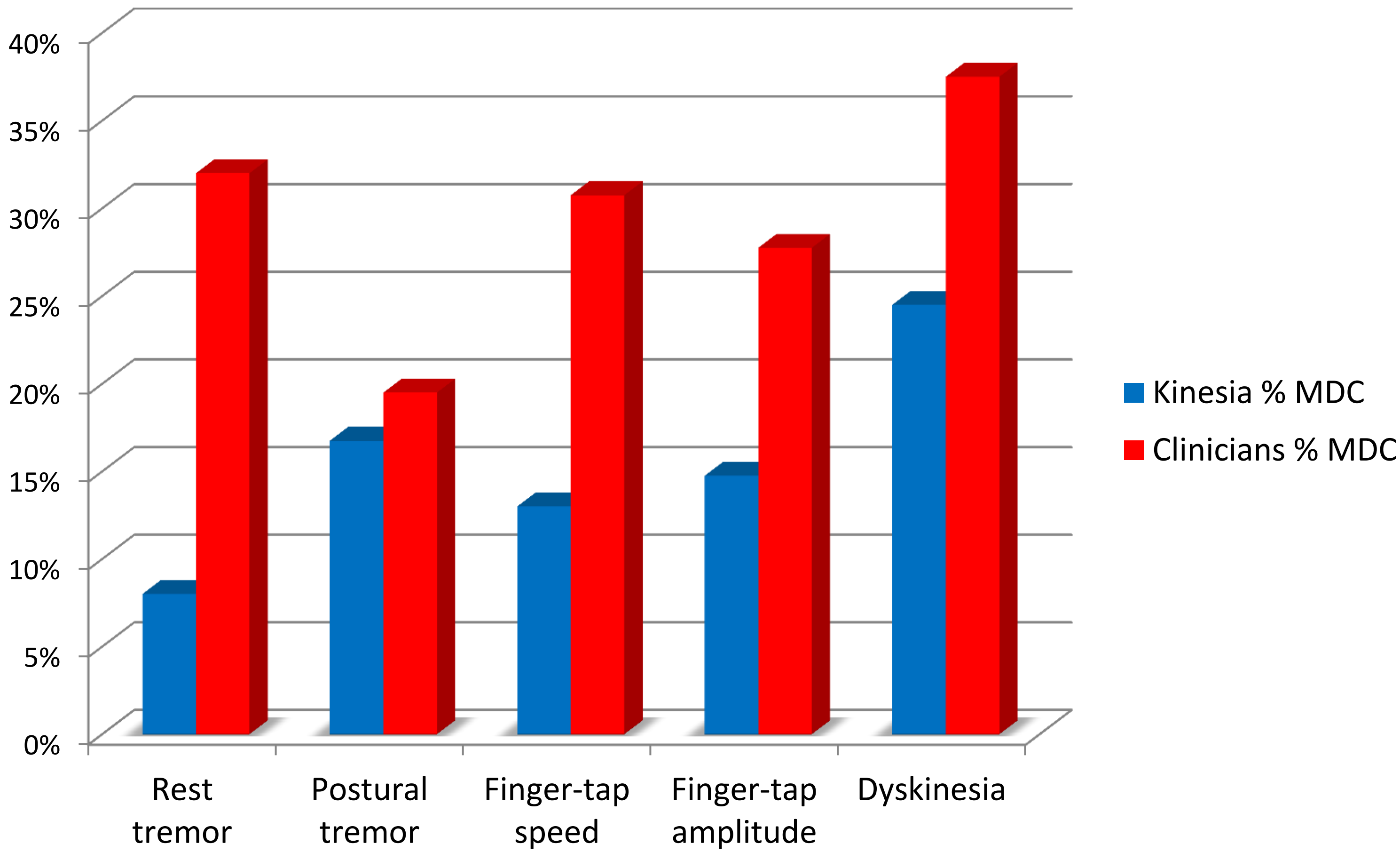
Recently Published

TO. Mera, DE. Filipkowski, DE. Riley, Christina M. Whitney, Benjamin L. Walter, Steven A. Gunzler, Joseph P. Giuffrida, "Quantitative analysis of gait and balance response to deep brain stimulation in Parkinson's disease " Gait & Posture - 07 December 2012

Test-Retest Reliability: Intra Class Correlations



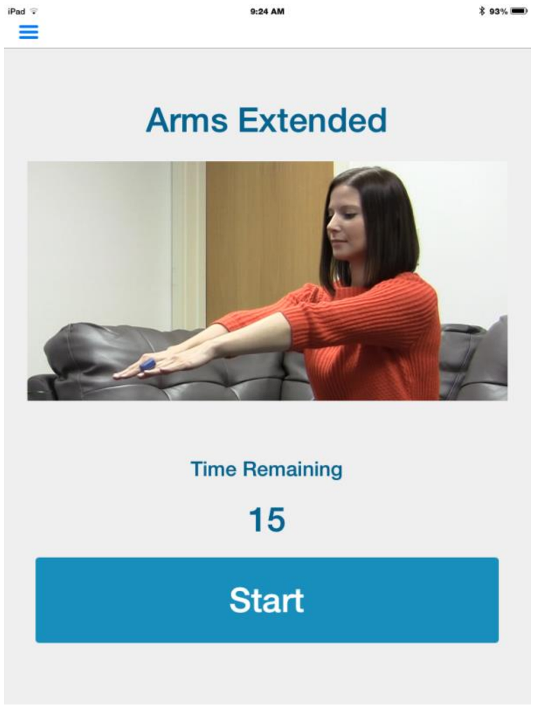
Sensitivity: Minimum Detectable Changes, % of Full Scale




Targeted Applications
Targeted Applications

Objective Sensor

Mobile App



Web Portal and Reports

Time	Rest Tremor	Postural Tremor	Finger Taps Speed	Finger Taps Amplitude	Finger Taps Rhythm	Dyskinesia
6:55 AM	3.9	3.4	2.6	2.5	2.3	0.0
6:57 AM	SINEMET (300mg)					
7:28 AM	2.5	3.0	1.7	1.4	1.0	0.0
7:59 AM	0.5	1.9	1.8	1.5	1.2	1.3
8:30 AM	0.3	0.9	0.3	0.5	1.0	2.9
9:05 AM	0.1	0.5	0.2	0.2	1.2	3.5
9:33 AM	0.3	0.4	0.0	0.0	1.0	3.8
10:02 AM	0.5	0.1	0.5	0.3	1.0	3.7
10:31 AM	1.5	2.0	1.0	0.5	1.5	2.9
10:58 AM	3.0	3.1	2.3	2.2	2.0	0.0
11:35 AM	3.5	3.4	2.0	2.0	1.8	0.0
11:50 PM	SINEMET (300mg)					
11:56 PM	1.1	2.7	2.3	2.2	2.0	0.0
12:30 PM	0.2	2.0	1.8	1.9	2.0	3.0
1:04 PM	0.1	1.4	2.0	1.4	1.8	3.3
1:38 PM	0.0	1.1	0.8	0.9	1.7	3.5
2:02 PM	0.0	1.0	0.6	1.0	1.5	3.6
2:30 PM	0.2	1.0	1.0	1.2	1.7	2.4
3:07 PM	0.4	0.7	1.1	1.5	1.3	1.1
3:33 PM	0.5	1.3	1.4	1.7	1.7	0.0
4:03 PM	2.6	1.5	1.6	1.8	1.8	0.0
4:28 PM	3.5	2.0	1.9	1.9	2.0	0.0
5:00 PM	3.8	2.2	2.1	2.1	2.0	0.0

Kinesia™ one

Task-Based Motor Assessments

Time	Rest Tremor	Postural Tremor	Finger Taps Speed	Finger Taps Amplitude	Finger Taps Rhythm	Dyskinesia
7:01 AM	4.0	3.5	2.5	2.4	2.2	0.0
7:02 AM	SINEMET (100mg)					
7:32 AM	3.4	3.3	1.7	1.4	1.0	0.0
8:01 AM	3.0	3.0	1.8	1.8	1.2	0.0
8:34 AM	2.9	2.8	1.3	1.2	1.0	0.0
9:00 AM	2.8	2.4	1.2	1.1	1.2	0.0
9:23 AM	2.8	2.6	1.0	1.0	1.0	0.0
10:00 AM	2.6	2.8	1.0	1.0	1.0	0.0
10:33 AM	3.2	3.3	1.5	1.9	1.5	0.0
11:01 AM	3.5	3.5	2.3	2.2	2.0	0.0
11:30 AM	3.7	3.8	2.0	2.0	1.8	0.0
12:00 PM	SINEMET (100mg)					
12:01 PM	3.3	3.8	2.6	2.7	2.0	0.0
12:32 PM	3.2	3.4	1.8	1.9	2.0	0.0
1:08 PM	2.6	3.1	2.0	1.4	1.8	0.0
1:28 PM	2.6	2.9	1.5	1.2	1.7	0.0
2:00 PM	2.7	2.7	1.3	1.0	1.5	0.0
2:32 PM	2.9	2.6	1.0	1.2	1.7	0.0
3:00 PM	3.0	2.9	1.1	1.5	1.3	0.0
3:29 PM	3.3	3.1	1.4	1.7	1.7	0.0
4:02 PM	3.8	3.6	1.6	1.8	1.8	0.0
4:30 PM	3.9	3.8	1.9	1.9	2.0	0.0
5:01 PM	3.9	3.9	2.5	2.4	2.0	0.0
5:15 PM	SINEMET (100mg)					
5:29 PM	3.5	3.6	2.1	2.2	2.0	0.0
6:02 PM	3.3	3.5	2.0	2.1	1.6	0.0
6:30 PM	3.0	2.9	1.9	2.0	1.5	0.0
7:00 PM	2.8	2.5	1.5	1.8	1.3	0.0
7:33 PM	2.6	2.6	1.2	1.5	1.1	0.0
8:04 PM	2.6	2.6	1.0	1.4	0.9	0.0
8:30 PM	2.9	2.8	1.2	1.5	1.1	0.0
9:02 PM	3.3	3.2	1.3	1.6	1.4	0.0
9:33 PM	3.5	3.6	1.6	1.8	1.8	0.0
10:00 PM	3.8	3.9	2.0	1.9	2.1	0.0
Mean	3.2	3.2	1.6	1.7	1.6	0.0
Fluctuation	0.4	0.5	0.5	0.4	0.4	0.0

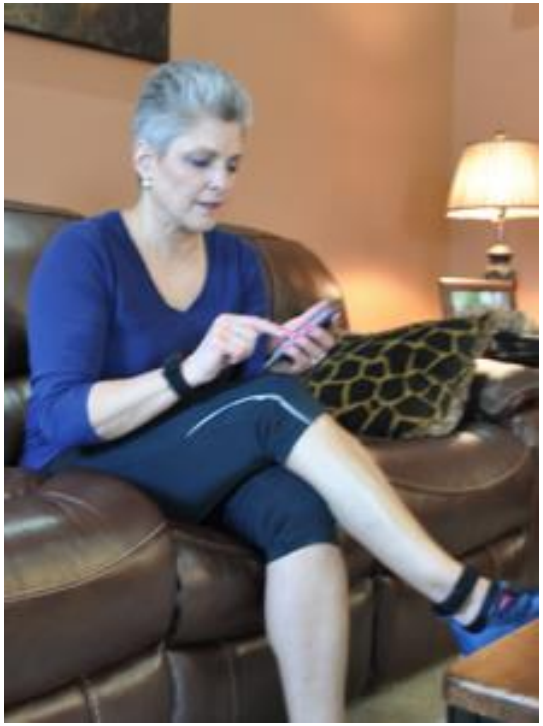
Increase dose by 200mg, Dose interval unchanged

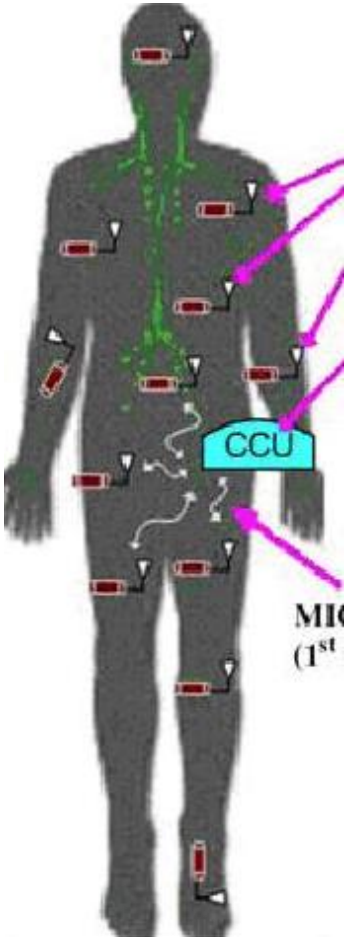
Time	Rest Tremor	Postural Tremor	Finger Taps Speed	Finger Taps Amplitude	Finger Taps Rhythm	Dyskinesia
6:55 AM	3.9	3.4	2.6	2.5	2.3	0.0
6:57 AM	SINEMET (300mg)					
7:28 AM	2.5	3.0	1.7	1.4	1.0	0.0
7:59 AM	0.5	1.9	1.8	1.5	1.2	1.3
8:30 AM	0.3	0.9	0.3	0.5	1.0	2.9
9:05 AM	0.1	0.5	0.2	0.2	1.2	3.5
9:33 AM	0.3	0.4	0.0	0.0	1.0	3.8
10:02 AM	0.5	0.1	0.5	0.3	1.0	3.7
10:31 AM	1.5	2.0	1.0	0.5	1.5	2.9
10:58 AM	3.0	3.1	2.3	2.2	2.0	0.0
11:35 AM	3.5	3.4	2.0	2.0	1.8	0.0
11:50 PM	SINEMET (300mg)					
11:56 PM	1.1	2.7	2.3	2.2	2.0	0.0
12:30 PM	0.2	2.0	1.8	1.9	2.0	3.0
1:04 PM	0.1	1.4	2.0	1.4	1.8	3.3
1:38 PM	0.0	1.1	0.8	0.9	1.7	3.5
2:02 PM	0.0	1.0	0.6	1.0	1.5	3.6
2:30 PM	0.2	1.0	1.0	1.2	1.7	2.4
3:07 PM	0.4	0.7	1.1	1.5	1.3	1.1
3:33 PM	0.5	1.3	1.4	1.7	1.7	0.0
4:03 PM	2.6	1.5	1.6	1.8	1.8	0.0
4:28 PM	3.5	2.0	1.9	1.9	2.0	0.0
5:00 PM	3.8	2.2	2.1	2.1	2.0	0.0
5:05 PM	SINEMET (300mg)					
5:39 PM	3.5	2.2	2.1	2.2	2.0	0.0
6:03 PM	2.3	2.0	2.0	2.1	1.6	0.0
6:29 PM	1.7	1.3	1.9	2.0	1.5	0.5
7:05 PM	0.8	1.1	1.5	1.8	1.3	1.0
7:36 PM	0.6	0.8	1.2	1.5	1.1	2.3
8:01 PM	0.3	0.6	1.0	1.4	0.9	3.8
8:28 PM	0.2	1.0	1.2	1.5	1.1	3.7
9:00 PM	0.3	1.1	1.3	1.6	1.4	1.3
9:34 PM	0.3	2.0	1.6	1.8	1.8	0.5
9:59 PM	2.8	2.3	2.0	1.9	2.1	0.0
Mean	1.3	1.6	1.4	1.5	1.6	1.6
Fluctuation	1.3	0.9	0.7	0.6	0.4	1.5

Decrease dose by 100mg, Decrease dose interval by 2 hours

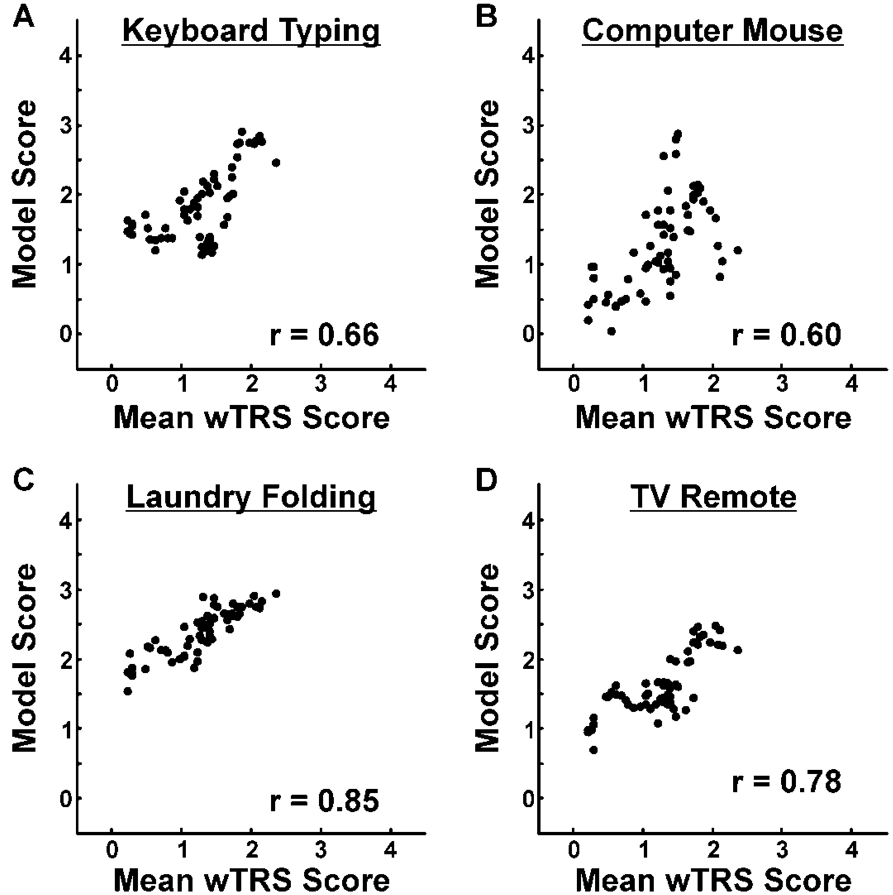
Time	Rest Tremor	Postural Tremor	Finger Taps Speed	Finger Taps Amplitude	Finger Taps Rhythm	Dyskinesia
7:00 AM	3.5	3.2	2.7	2.5	2.4	0.0
7:01 AM	SINEMET (200mg)					
7:31 AM	2.0	2.1	1.9	2.1	2.2	0.0
8:00 AM	0.6	0.7	0.3	0.5	1.0	0.0
8:33 AM	0.3	0.5	0.2	0.2	1.2	0.0
8:59 AM	0.2	0.2	0.0	0.0	1.0	0.0
9:22 AM	0.2	0.0	0.5	0.3	1.0	0.0
9:59 AM	1.1	1.5	1.0	0.5	1.5	0.0
10:32 AM	SINEMET (200mg)					
11:00 AM	1.2	1.3	1.5	1.4	1.5	0.0
11:29 AM	0.3	0.3	0.5	0.6	2.1	0.0
11:59 PM	0.2	0.2	0.3	0.3	1.0	0.0
12:00 PM	0.1	0.0	0.4	0.1	2.3	0.0
12:31 PM	0.2	0.6	0.6	0.1	2.1	0.0
1:07 PM	1.2	1.6	1.7	1.6	1.7	0.0
1:27 PM	SINEMET (200mg)					
1:59 PM	1.0	0.8	1.0	0.9	1.0	0.0
2:31 PM	0.3	0.7	0.3	0.8	0.9	0.0
2:59 PM	0.2	0.5	0.2	0.5	0.9	0.0
3:28 PM	0.0	0.3	0.2	0.8	0.9	0.0
4:01 PM	0.5	0.8	0.9	1.6	1.7	0.0
4:29 PM	1.3	1.7	1.6	2.1	2.1	0.0
5:00 PM	SINEMET (200mg)					
5:14 PM	1.0	1.5	1.0	0.9	1.0	0.0
5:28 PM	0.3	0.6	0.3	0.8	2.4	0.0
6:01 PM	0.2	0.3	0.2	0.5	2.0	0.0
6:29 PM	0.0	0.0	0.2	0.8	1.7	0.0
6:59 PM	0.5	0.2	0.9	1.6	1.2	0.0
7:32 PM	1.3	0.9	1.6	2.1	1.0	0.0
8:03 PM	SINEMET (200mg)					
8:29 PM	0.8	0.6	0.5	0.7	0.5	0.0
9:01 PM	0.0	0.2	0.2	1.1	0.9	0.0
9:32 PM	0.0	0.1	0.9	1.6	1.3	0.0
9:55 PM	0.5	0.6	1.9	2.0	1.9	0.0
Mean	0.7	0.8	0.8	1.0	1.5	0.0
Fluctuation	0.7	0.7	0.7	0.7	0.5	0.0

Sensitivity of Data Versus Patient Burden





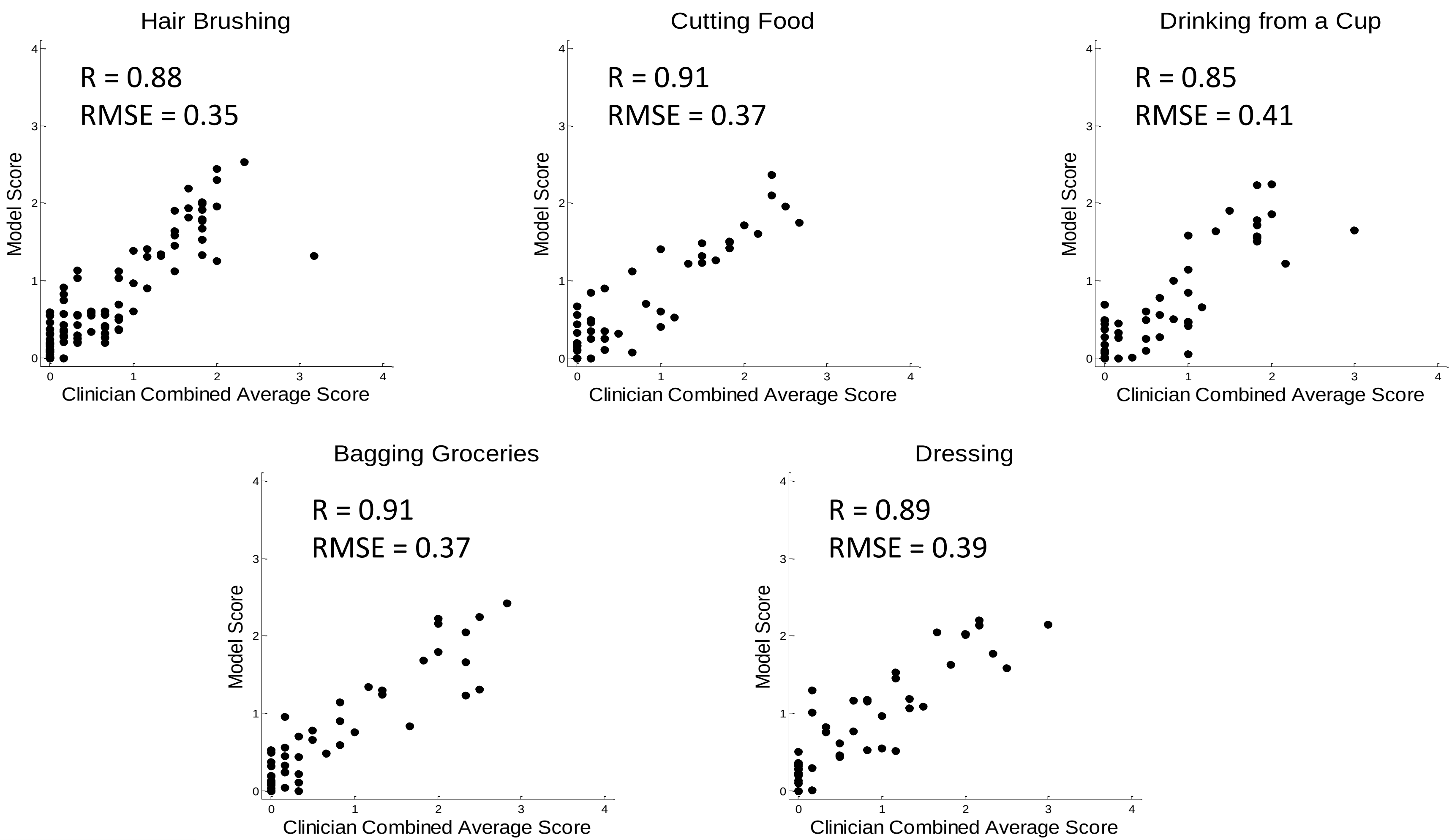
Continuous Tremor Assessment



Published

D. A. Heldman, J. Jankovic, D. E. Vaillancourt, J. Prodoehl, R. J. Elble, and J. P. Giuffrida. Essential tremor quantification during activities of daily living. *Parkinsonism & Related Disorders*, 2011.

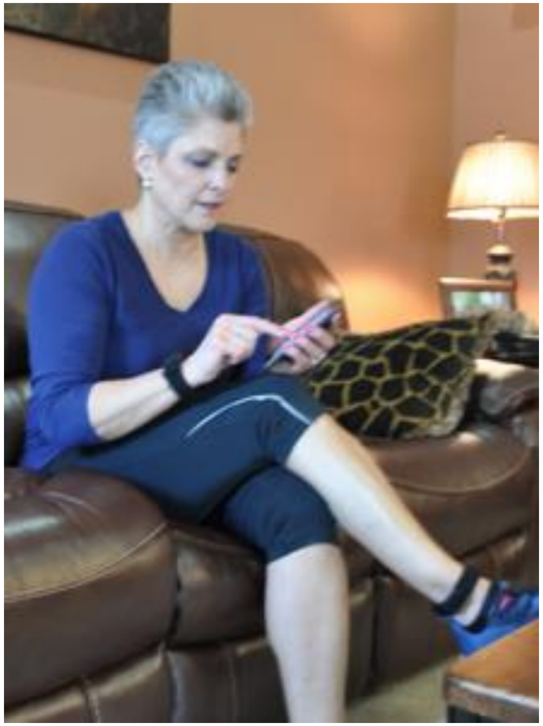
Continuous Dyskinesia Assessment



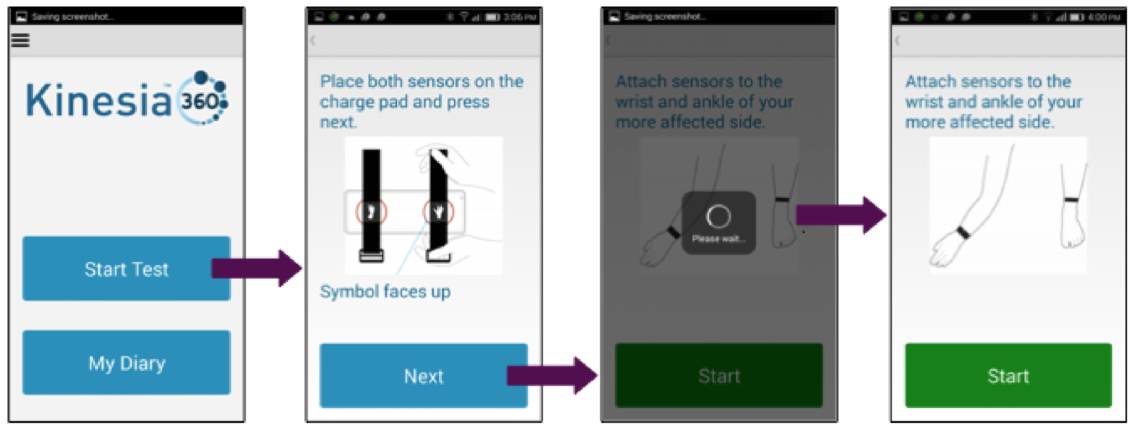
Published

Christopher L. Pulliam, Michelle A. Burack, Dustin A. Heldman, Joseph P. Giuffrida and Thomas O. Mera. Motion Sensor Dyskinesia Assessment During Activities of Daily Living. *Journal of Parkinson's Disease 2014*.

Wearable Sensors



Mobile App



Start Test to begin

Sensor bands on charge pad, press Next

Tablet establishing connection

Sensors connected. Press Start

Kinesia 360

Continuous Parkinson's Monitoring

Summary Data

Total Wear Time: 9:52 HR

Tremor Summary Data

	Time	Percent Wear Time
Total Time TremorDetect=0	2:46	28
Total Time TremorDetect=1	7:06	72
Time Rnd (TremorScore) = 0	2:46	28
Time Rnd (TremorScore) = 1	1:42	17.2
Time Rnd (TremorScore) = 2	5:24	54.7
Time Rnd (TremorScore) = 3	0:00	0
Time Rnd (TremorScore) = 4	0:00	0
Average (Tremor Score)	0.88	
Standard Dev (Tremor Score)	0.69	

Dyskinesia Data Summary

	Time	Percent Wear Time
Total Time DysDetect=0	8:20	84.5
Total Time DysDetect=1	1:32	15.5
Time Rnd (DysProb) = 0	7:42	78
Time Rnd (DysProb) = .5	0:38	6.4
Time Rnd (DysProb) = 1	1:32	15.5

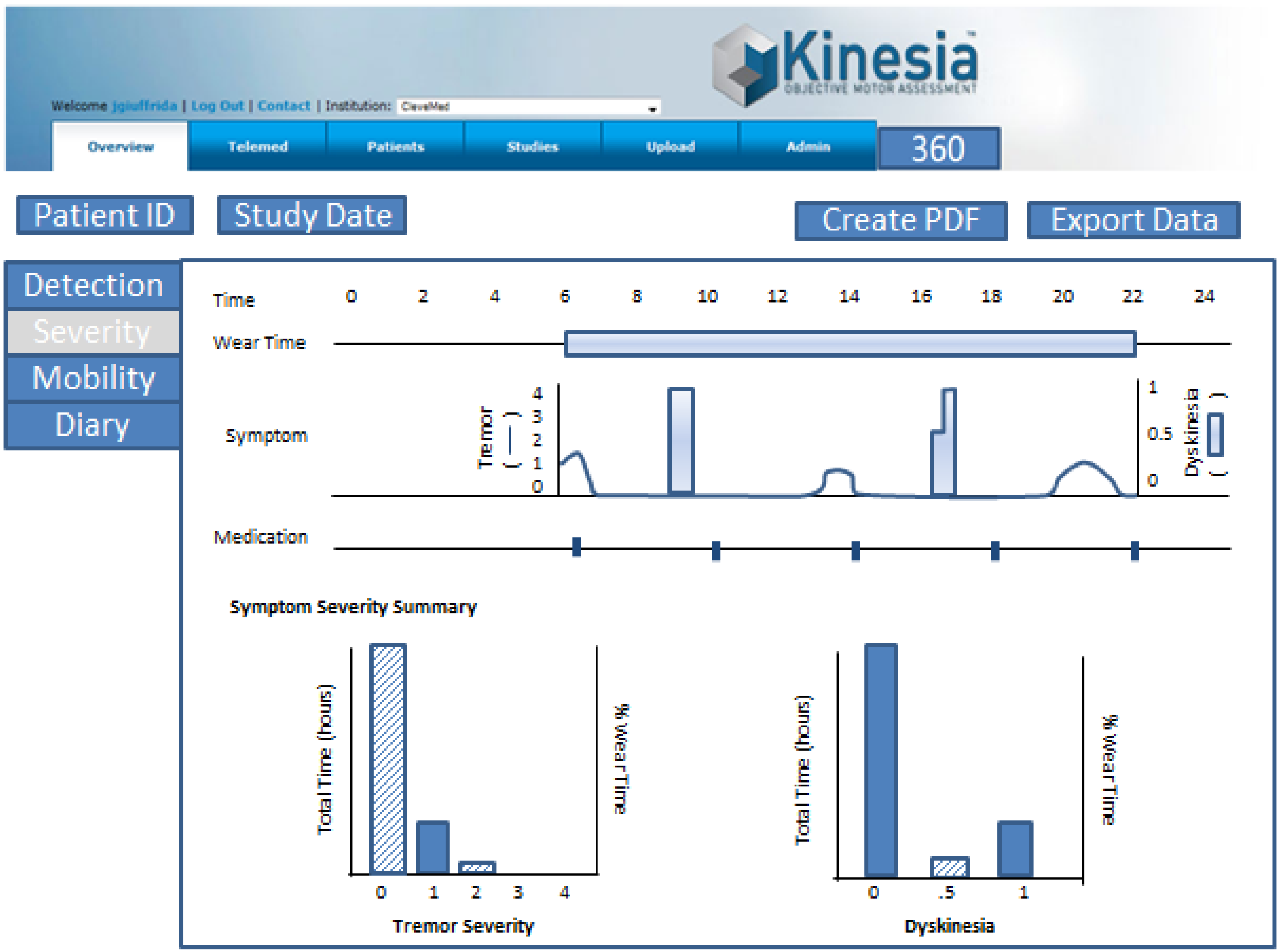
Mobility Data Summary

	Time	Percent Wear Time
Total Time Rest	0:25	4.3
Total Time Active (Non-Gait)	2:14	22.7
Total Time Gait	7:12	73
Total Active Time	9:26	95.7
Wear Time Steps	549	
% Arm Swing During Gait	92.1	

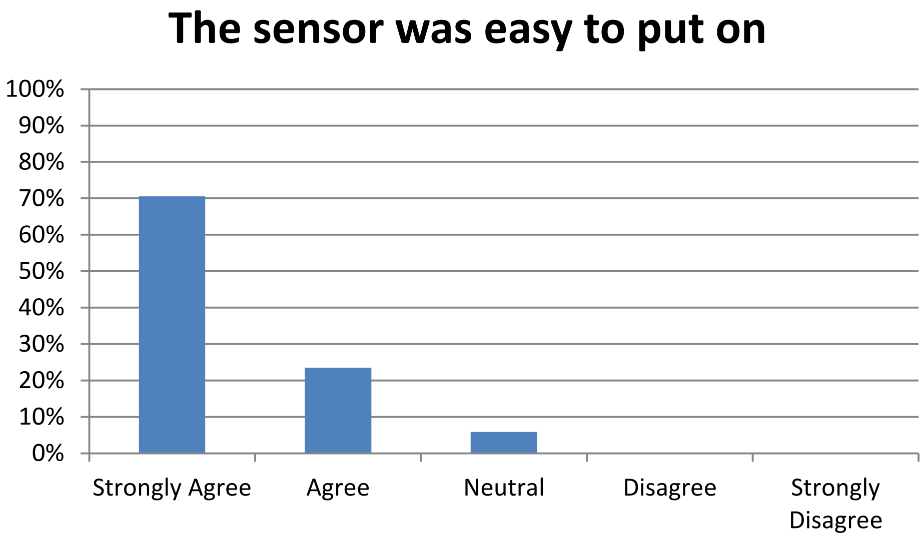
Subject Reported Diary

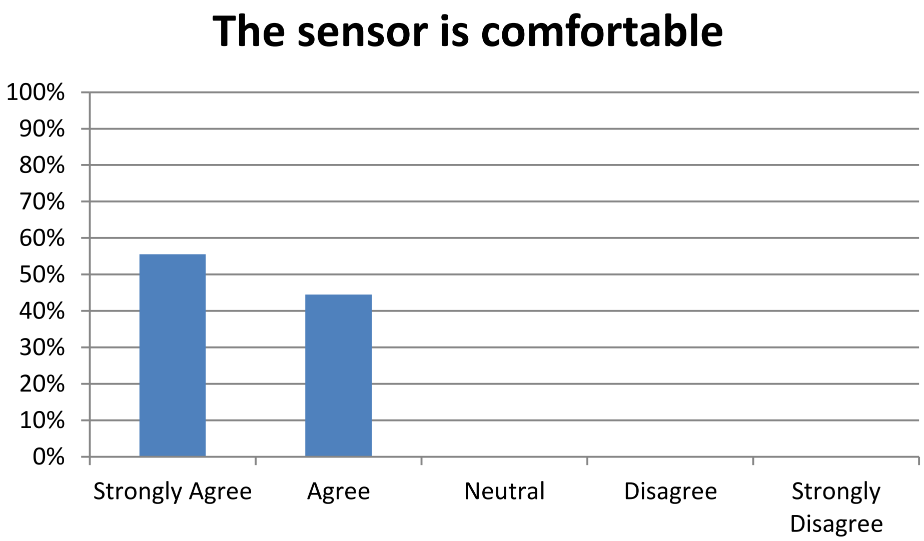
	Time	Percent Day	Percent Waking Day
Sleeping	9:30	39.6	
OFF	8:30	35.4	58.6
ON	1:30	6.3	10.3
ON with Non-Troublesome Dys	2:00	8.3	13.8
ON with Troublesome Dys	2:30	10.4	17.2

Continuous Parkinson's Monitoring

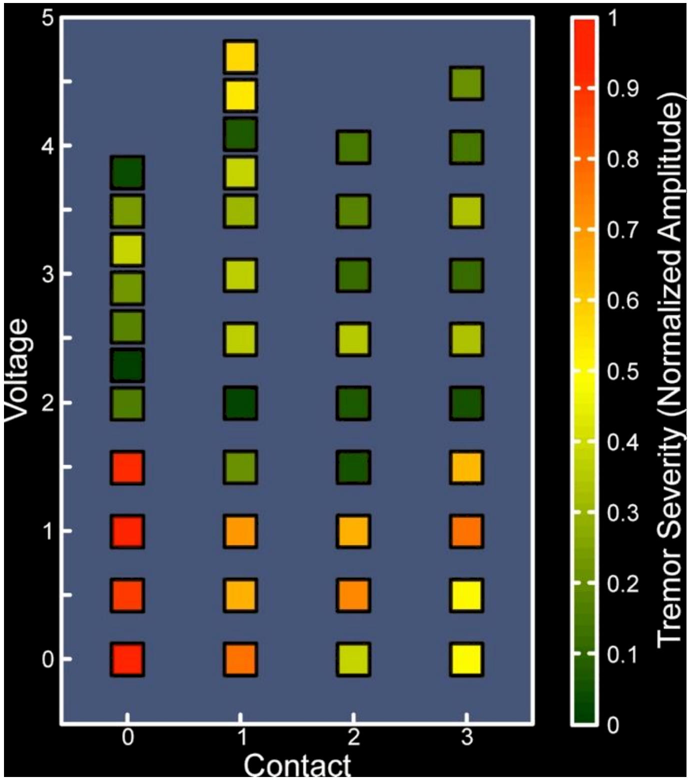


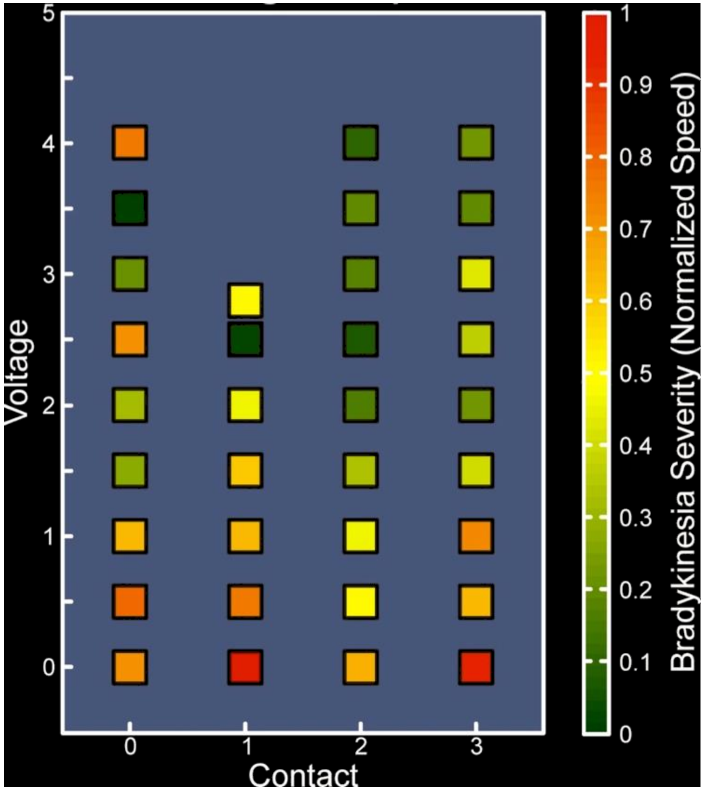
Patient Perspective





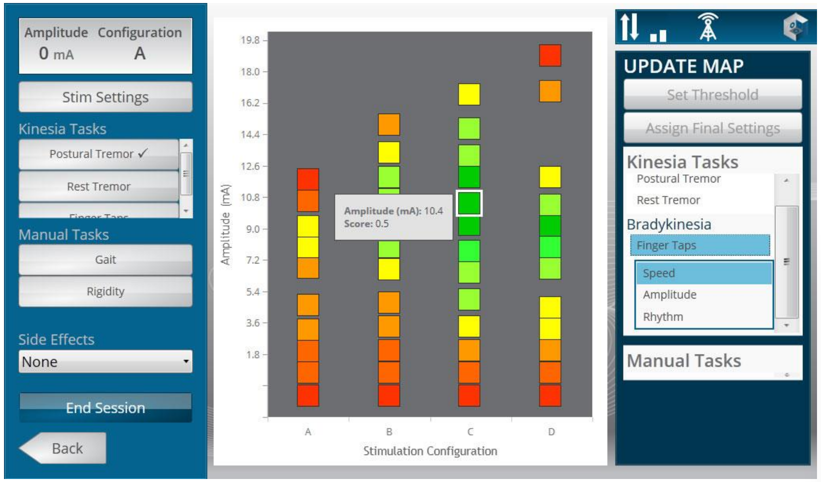
Deep Brain Stimulation: Outpatient Programming





Objective Sensor

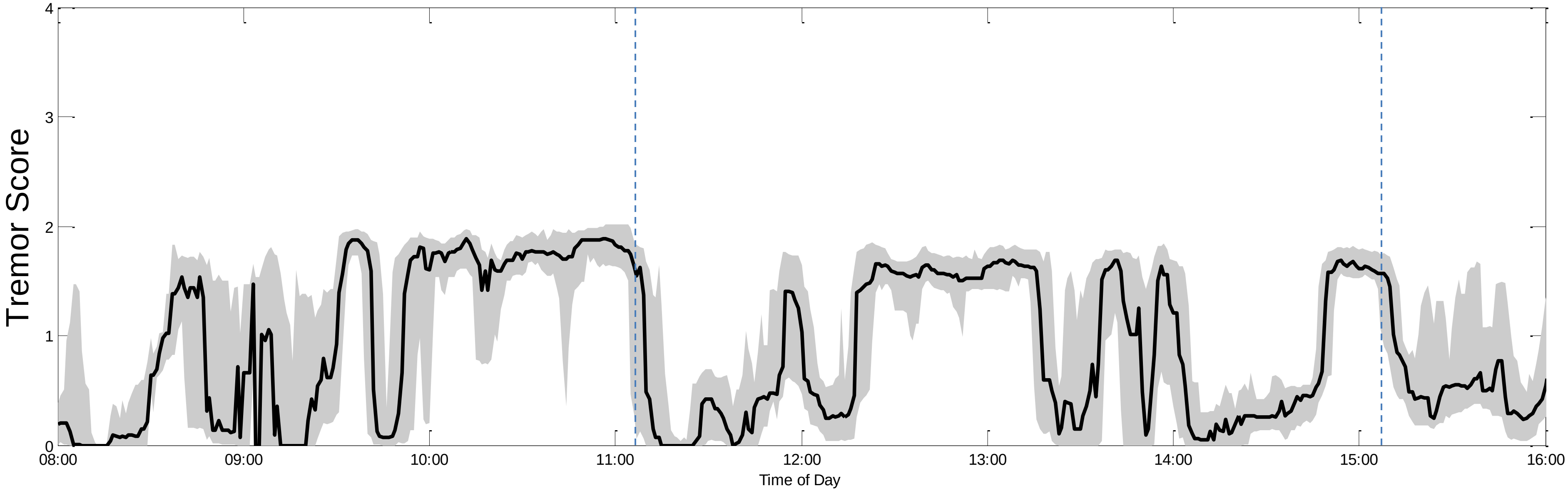
DBS Programming Map

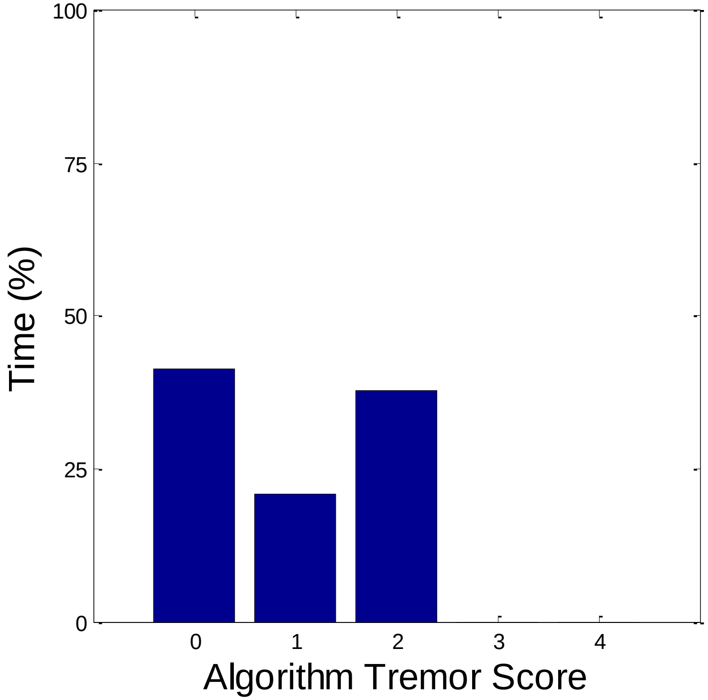


Web Portal

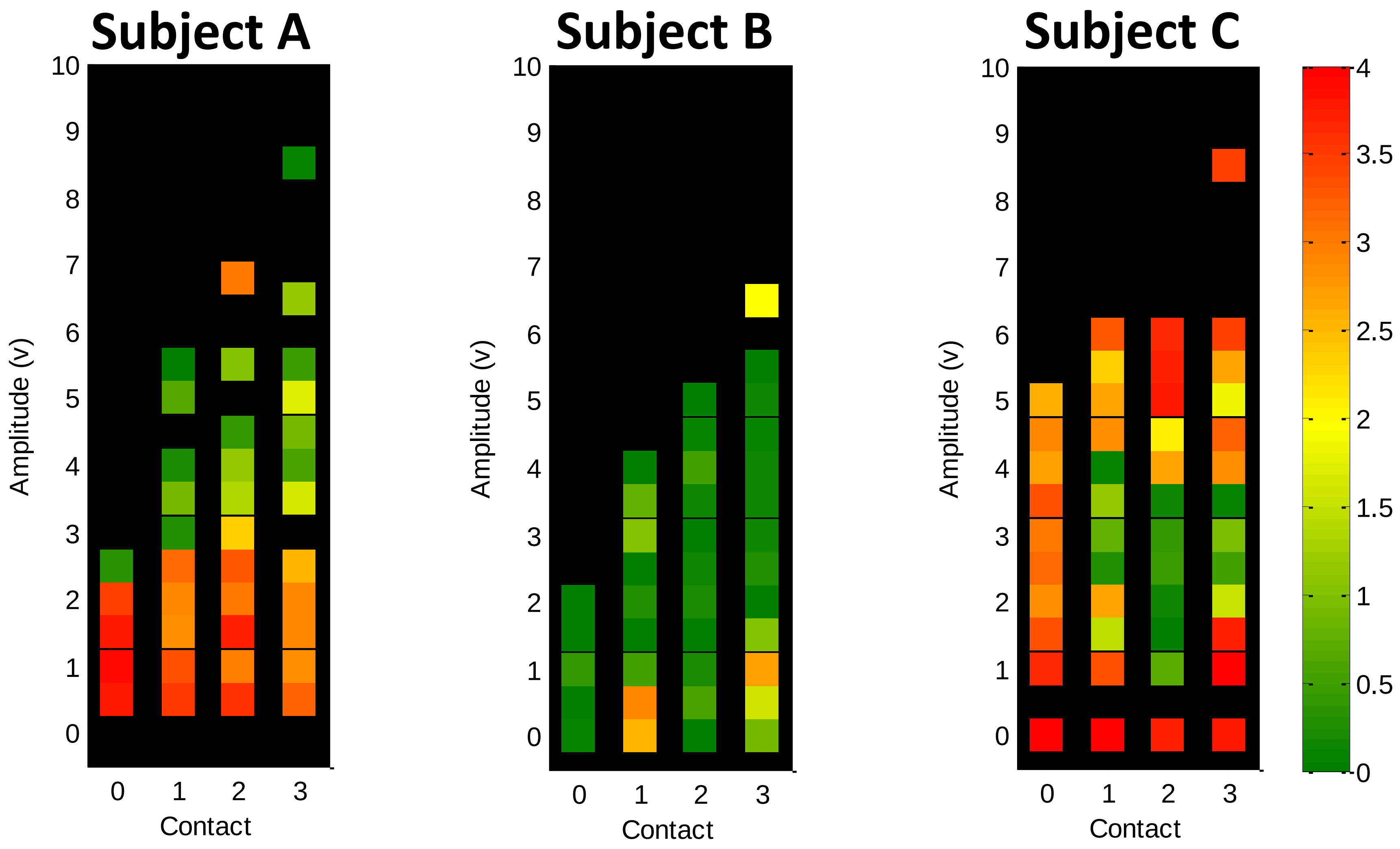
Kinesia ProView™

Closing The Clinical Workflow

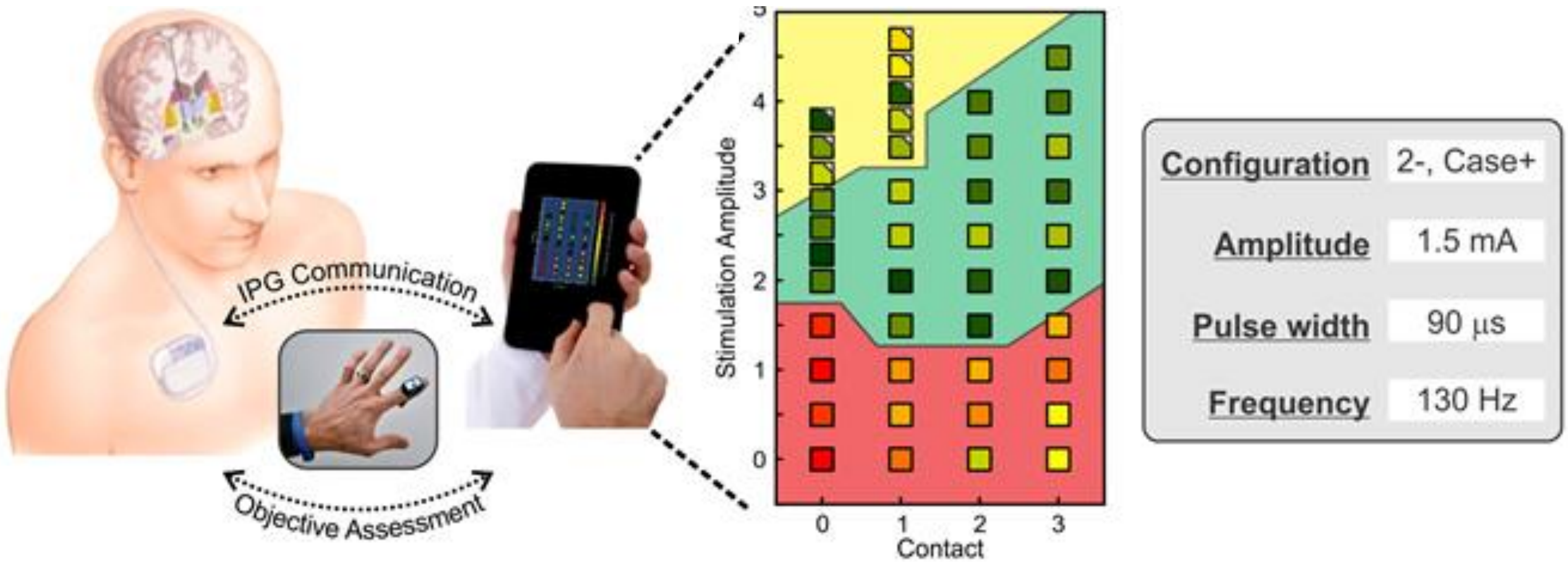

Tremor Score
4
3
2
1
0
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time of Day


Time (%)
100
75
50
25
0
0
1
2
3
4
Algorithm Tremor Score

Rest Tremor DBS Tuning Maps



Potential Solution for DBS Programming

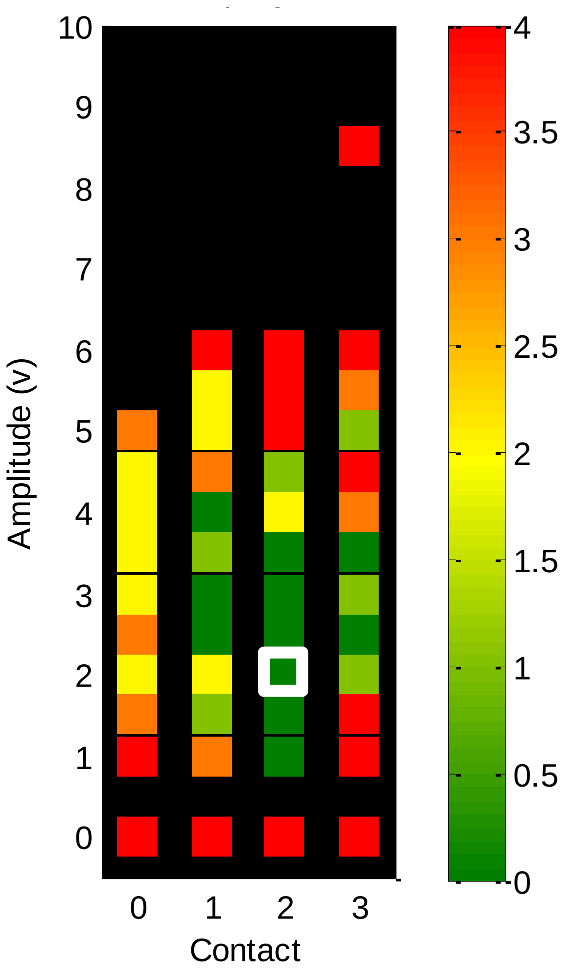


Can a Computerized Sensing System...

1. Find DBS Settings that Improve Motor Outcomes Compared to Clinicians?
2. Find DBS Settings that Provide Similar Motor Outcomes at Lower Amplitude?
3. Automatically Guide a Programming Session to Improve Motor Outcomes?

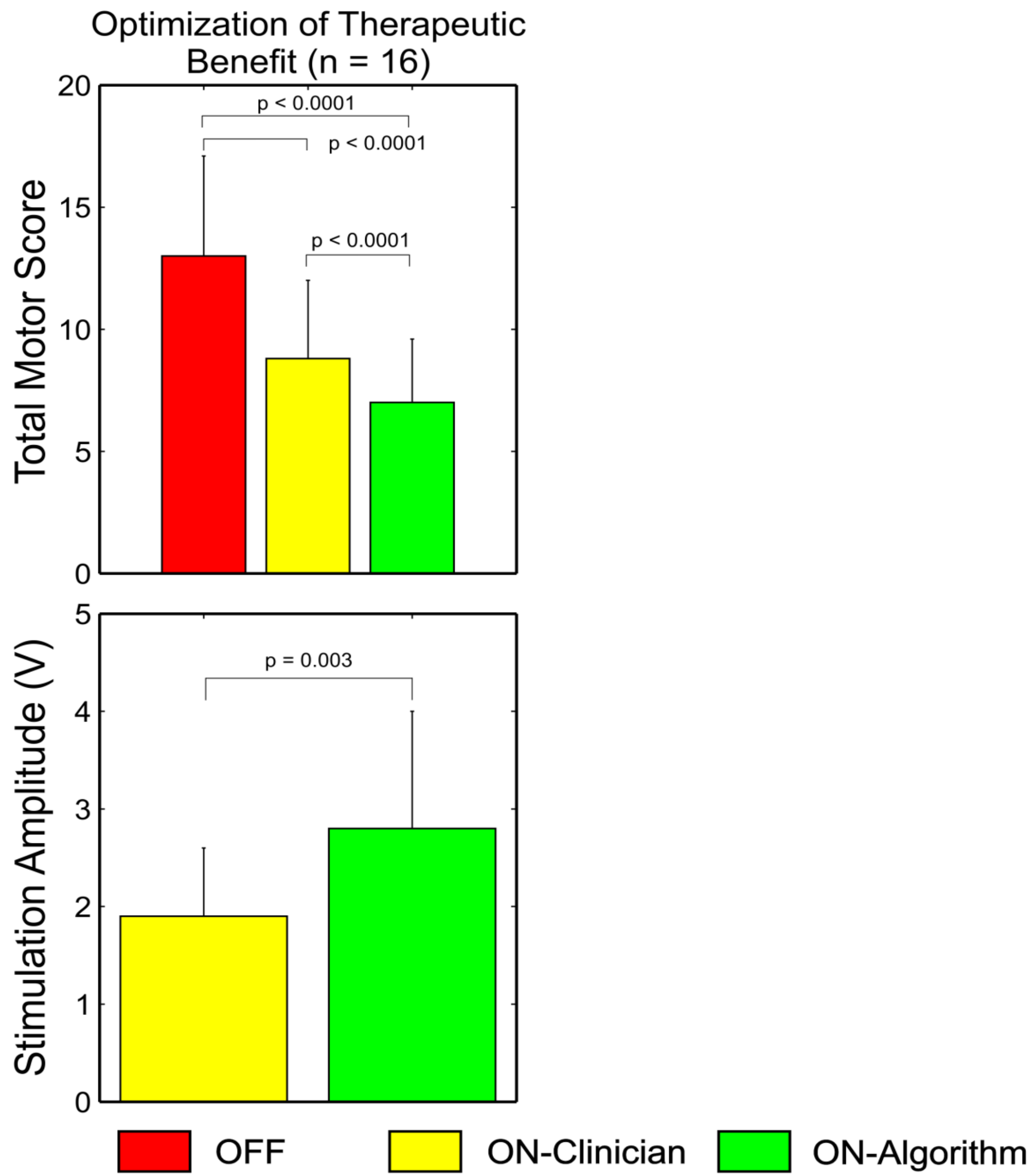
Post Hoc Comparisons to Clinicians

DBS Parameter Selection



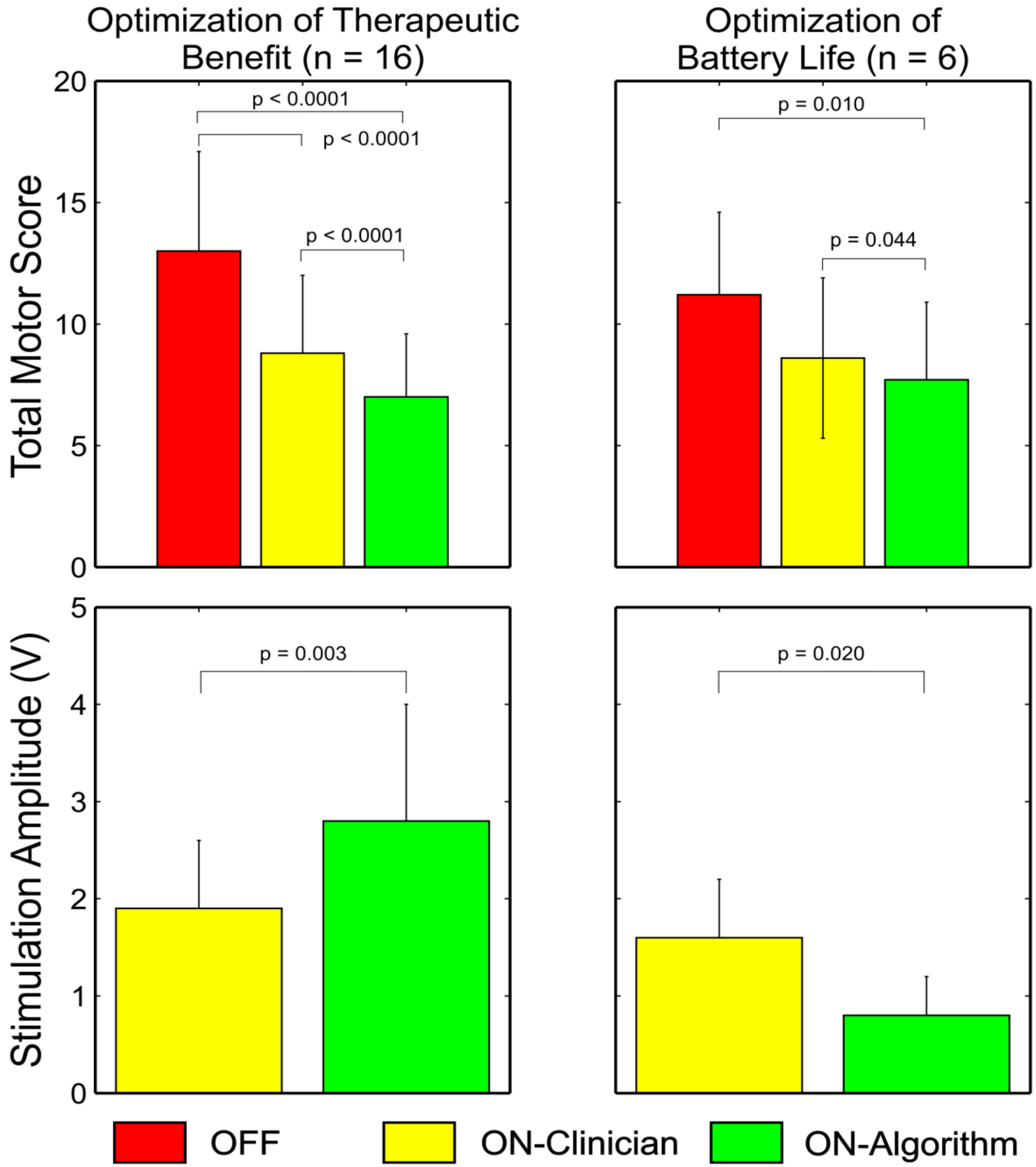
Post Hoc Comparisons to Clinicians

Optimization Algorithms for Tremor & Bradykinesia



Post Hoc Comparisons to Clinicians

Optimization Algorithms for Tremor & Bradykinesia



Real-Time Computer Guided Programming

Algorithm Settings

Subject	Contact / Polarity	Amplitude	Pulse Width (µs)	Frequency (Hz)	Kinesia Score Off	Kinesia Score On After Functional Mapping	Percent Improvement
1	0-/C+	1.8 mA	90	130	0.5	0.4	14.5%
2	1-/C+	0.5 mA	90	130	0.9	0.5	47.9%
3	0-/C+	1.2 mA	90	130	1.8	1.5	13.7%
4	2-/C+	3.9 mA	90	130	2.8	2.0	29.6%
6	1-/C+	1.5 mA	90	130	1.5	0.9	38.1%
7	1-/C+	2.4 mA	90	130	2.8	0.5	82.7%
Average					**1.7**	**1.0**	**37.8%***

*$p = 0.01$

Closing The Business Case

Reimbursement

Reimbursement

Delivery Models

Reimbursement

Delivery Models

Business Models

Reimbursement

Delivery Models

Business Models

EHR Integration

"All this talk about EMRs and EHRs is just a fad - like the Internet thing."

Closing The Patient Perspective

I, Myself, Want to See…

Wearables are Important Because...

Wearables Roadmap
For the Future?

Acknowledgements: Clinical Collaborators

Site	Location	Collaborator(s)	Research Area
Baylor College of Medicine	Houston, TX	Dr. Joseph Jankovic	Tremor Assessment, Telemedicine
Cleveland Clinic	Cleveland, OH	Dr. Hubert Fernandez;	Bradykinesia Assessment
Henry Ford Health System	Detroit, MI	Dr. Peter LeWitt	Quantitative PD Assessment, Neuroprotection
Kent State University	Kent, OH	Angie Ridgel, PhD	PD Exercise Therapy
Johns Hopkins University	Baltimore, MD	Dr. Zoltan Mari	Quantitative PD Assessment
University of Rochester	Rochester, NY	Dr. Ray Dorsey	Telemedicine
NIH NINDS	Bethesda, MD	Dr. Mark Hallett	tDCS for Parkinson's
Rush University	Chicago, IL	Dr. Christopher Goetz	Patient Home Evaluations, Telemedicine
Southern Illinois University School of Medicine	Springfield, IL	Dr. Rodger Elble	Tremor Assessment
Greenville Neuromodulation Center	Greenville, PA	Dr. Erwin Montgomery	DBS, Rigidity, Telemedicine
University of Cincinnati College of Medicine	Cincinnati, OH	Dr. Espay, Dr. Revilla, and Dr. Duker	Quantitative Assessments, Home Monitoring, Deep Brain Stimulation
University Hospitals Case Medical Center	Cleveland, OH	Dr. David Riley and Dr. Ben Walter	Tremor, Bradykinesia, Gait, Balance, and DBS
University of Florida	Gainesville, FL	David Vallaincourt, PhD	Tremor
University of Minnesota	Minneapolis, MN	Dr. Jerrold Vitek	Deep Brain Stimulation
University of Rochester	Rochester, NY	Dr. Michelle Burack	Dyskinesias
University of Florida	Gainesville, FL	Dr. Michael Okun	Patient Home Evaluations
Hospital Universitario de Burgos	B urgos, Spain	Dr. Esther Cubo	Telemedicine

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National Institute of Neurological Disorders and Stroke

National Institute on Aging

National Institute on Minority Health and Health Disparities

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R44AG034708
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R43NS074627
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R44MD004049
R44NS043816

Questions?

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