Collecting remote voice and movement data from people with Parkinson's disease (PD) using multimodal conversational AI: Lessons learned from a national study

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Disclosures

- Financial Disclosures
  - Modality.AI, Inc., Salary & Shares
    - Vikram Ramanarayanan – Chief Scientific Officer
    - David Pautler – Founder, Chief Technology Officer
    - Hardik Kothare – Research Scientist
    - Jackson Liscombe – Research Scientist
    - Oliver Roesler – Research Scientist
    - William Burke – Director
    - Michael Neumann – Research Scientist
    - David Suendermann-Oeft – Founder, Chief Executive Officer

- Purdue University, Salary
  - Andrew Exner – doctoral student, trainee on NIH T32 grant
  - Sandy Snyder – Research Associate
  - Shreya Sridhar – undergraduate student; owns shares from Modality.AI
  - Jessica Huber – Professor, Principal Investigator (NIH grants)
- SpeechVive, Inc., Shares
  - Sandy Snyder
  - Jessica Huber – Inventor
- Non-Financial Disclosures
  - Purdue University
    - Jessica Huber – medical advisory board for Rock Steady Boxing

Rationale

- Needs
  - Accessibility of care by people with PD
  - Need for monitoring of dynamic symptoms
  - Burden of technical assessment and measurement
- Solution
  - Conversational artificial intelligence agent
  - Automatic computation and delivery of relevant patient data
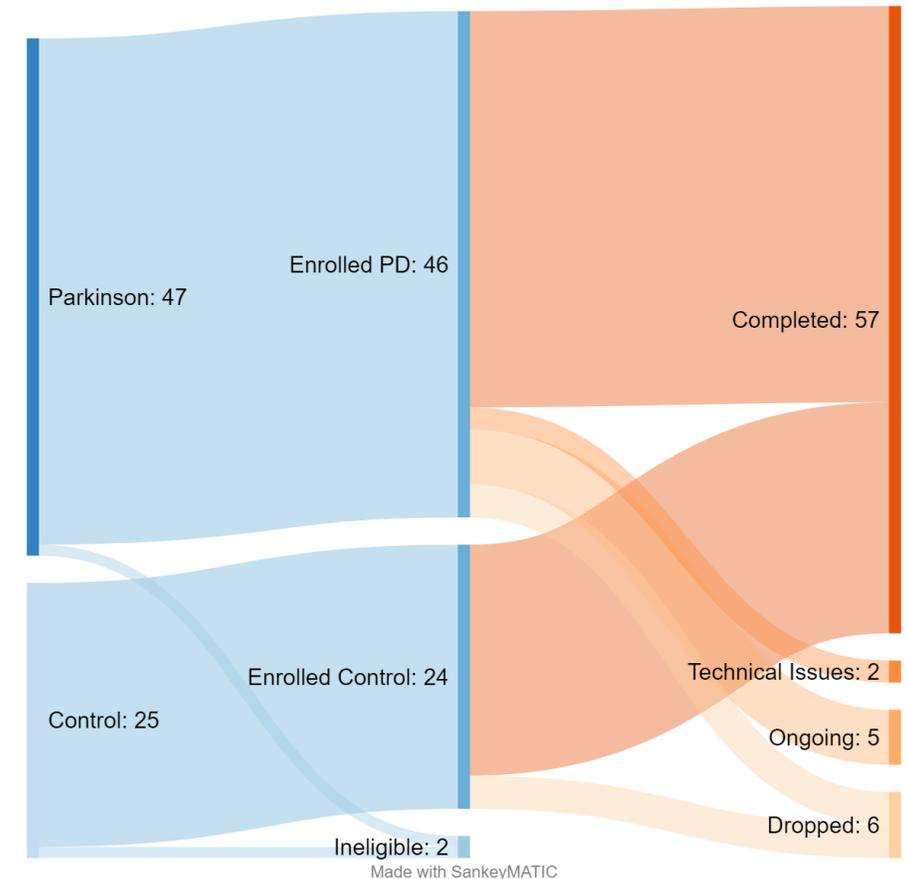
- Features
  - Automated, customizable assessment
  - Convenient time
  - Home environment
  - Minimal technological requirements
  - Automatic computation of speech acoustic metrics, facial kinematic metrics, and limb motor function
  - User-friendly dashboard for healthcare providers

CPIB-S score	PDQ-39 score	NASA-TLX-R score	Phonation of 'Ah' with Timer Mean F0 (Hz)	Phonation of 'Ah' for complete breath Mean F0 (Hz)	Pitch glide of 'Ee' upwards Max F0 (Hz)	Prosody Max F0 (Hz)	Pitch glide of 'Ee' downwards Min F0 (Hz)	Prosody Min F0 (Hz)	Phonation of 'Ah' with Timer Cepstral Peak Prominence (dB)	Phonation of 'Ah' for complete breath Cepstral Peak Prominence (dB)	Pitch glide of 'Ee' upwards Cepstral Peak Prominence (dB)	Pitch glide of 'Ee' downwards Cepstral Peak Prominence (dB)	SIT Speech duration (seconds)	Rainbow Passage Speech duration (seconds)
17/30 =	56/152 ↓	9/12 =	203.79 ↓		633.12 =	399.86 ↓	74.76 =	135.73 ↑	30.66 ↑		27.91 ↓	23.86 ↑	2.92 =	31.10 ↓
17/30 ↑	58/152 ↑	9/12 ↓	211.75 ↑		634.73 =	435.57 ↓	76.41 =	127.02 ↑	20.14 ↓		28.80 ↓	20.65 ↓	3.45 =	34.74 ↑
14/30 ↓	55/152 ↑	10/12 ↑	197.73 ↓		632.16 =	463.06 ↑	74.54 ↓	120.14 ↓	27.57 ↓		30.46 ↑	23.70 ↑	2.90 =	28.64 =
17/30	53/152	9/12	289.55 ↑		633.36 =	435.88 ↓	82.41 ↑	146.88 =	33.41 ↑		26.44 ↓	23.17 ↓	2.98 =	30.68 =

Methods: Participants

- *n* = 46 people with PD; 24 age- and sex-matched controls enrolled
  - Successful completion of at least one data collection session: *n* = 40 people w/ PD, 23 controls
  - Approximately 12.5% attrition across both groups
  - Recruitment is ongoing

- Inclusion criteria:
  - Age 30-85
  - Dx idiopathic PD
  - Internet access
  - Device w/ microphone & camera
  - Self-reported adequate hearing and vision
  - Fluency in English

- Exclusion criteria:
  - Dx neurological disease other than PD
  - Hx HNC cancer or surgery
  - Hx voice disorder or pulmonary disease
  - Recent Hx smoking (<5 years)
  - More than moderate cognitive impairment <10 on MoCA)

Parkinson: 47 — Enrolled PD: 46 — Completed: 57 — Technical Issues: 2 — Ongoing: 5 — Dropped: 6 — Control: 25 — Enrolled Control: 24 — Ineligible: 2

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Methods: Initial Visit

- WebEx meeting with lab staff member
  - Discuss Study
  - Obtain Consent
  - Obtain Medical History
  - Complete Montreal Cognitive Assessment
  - Orientation to System Access
  - Receive individualized link to complete online assessments

Methods: Conversations with Tina

- Number of Assessments: 4
- Frequency of Assessments: 1/week
  - Median 8 days, Mean 10 days
- Timing: When convenient for participants, on-state of PD medication
- All tasks completed each session
- Total Duration: 15-20 minutes

- Speech Tasks
  - Sustained vowels
  - Reading 1 paragraph of Rainbow Passage
  - Short narrative
  - Intonational prosody
  - Monologue
- Non-Speech Tasks
  - Finger tapping
  - Abbreviated oral mechanism exam
- Surveys
  - Parkinson Disease Questionnaire (PDQ-39)
  - Communication Participation Bank, Short (CPIB-S)
 - Task Load Index (TLX)

Results: Internet Issues

- Anticipated
- Impact: Mild
- Observed Problems
  - Loss of signal
  - Premature session termination and loss of tasks
  - Problems detected in ~1.3% of files
- Solution
  - Discard affected samples
  - Offline technical support by lab and Modality staff
    - E.g. Environmental changes to reduce bandwidth use and improve strength of home internet connection
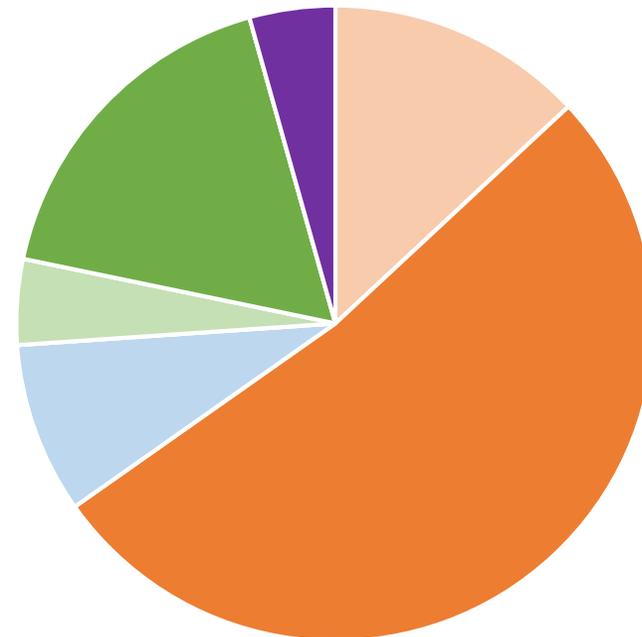 - Change in bandwidth expectations
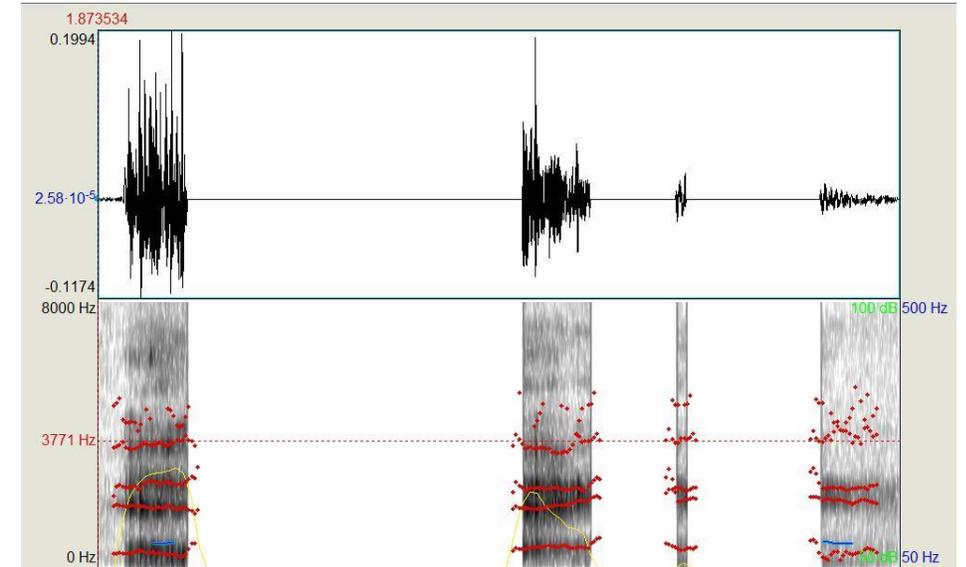
Geographic Distribution of Participants
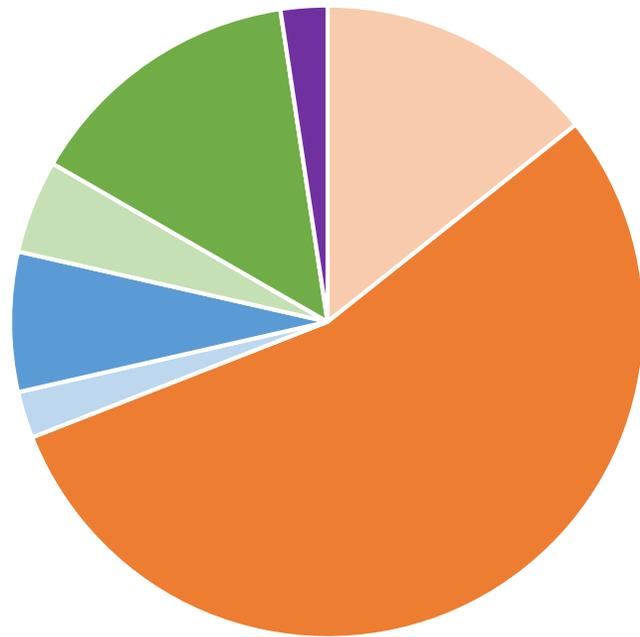
Results: Voice Activity Detection

- Unanticipated
- Impact: Moderate
- Observed Problems
  - Premature task termination, especially of monologue
- Cause
  - Low vocal intensity
  - Long pauses
  - Signal attenuation
  - Throat clears, lip smacks, background noise, etc.
- Solution
  - Adjust pause tolerance criteria
  - Re-prompting to achieve minimum task duration
  - Adjust minimally-accepted task parameters (i.e. duration)

Results: Cognitive Impairment

- Anticipated

- Impact: Mild-Moderate

- Observed Problems
  - Difficulty executing session independently
  - Instruction confusion (primarily with monologue collection)

- Solution
  - Discard affected samples
  - Monitor participant course and provide offline follow-up
  - Opportunity to provide feedback at the end of the session

MoCA Scores of Participants
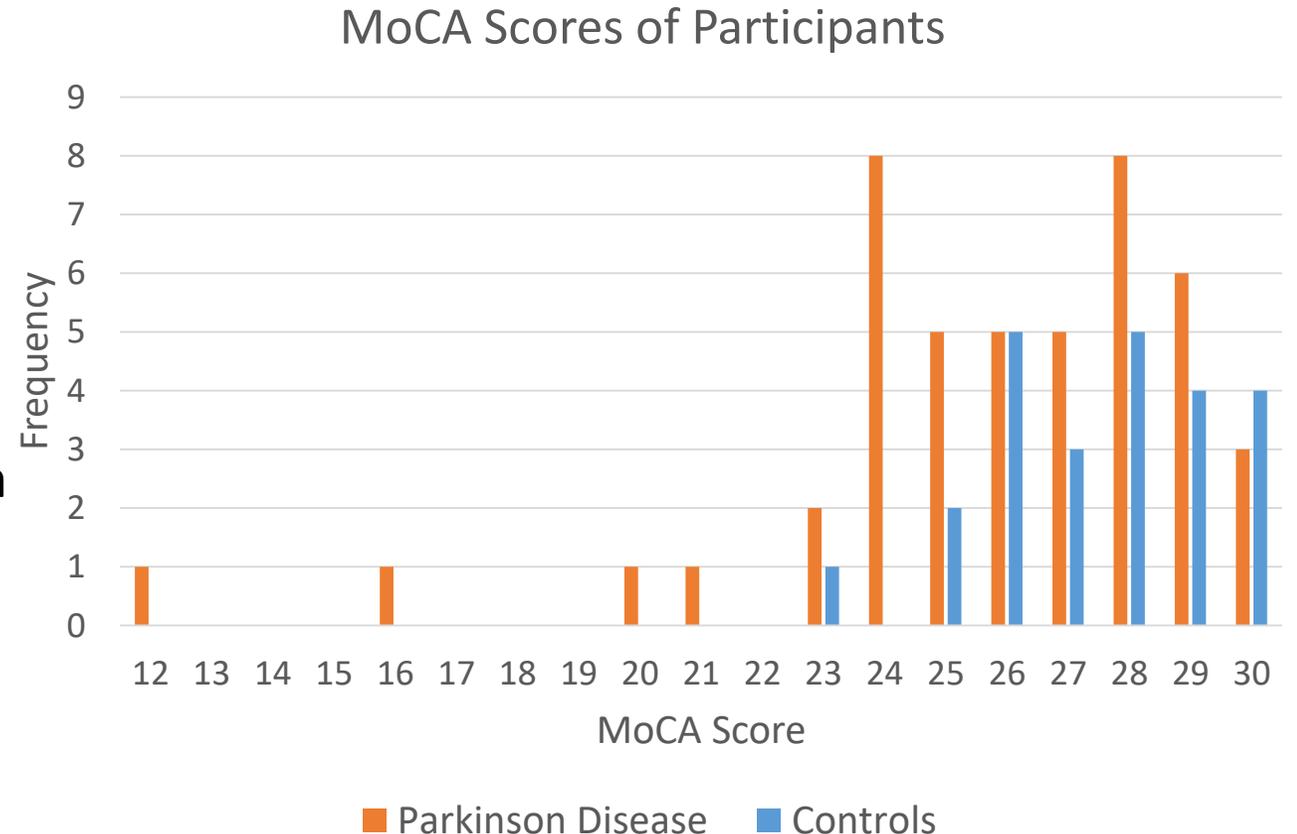
Results: Caregiver Interactions

- Unanticipated
- Impact: Moderate
- Caregiver Role
  - Help participants connect to the system
  - Assist with assessment as needed
- Observed Problems
  - Visual artifacts of caregiver presence
  - Acoustic artifacts of caregiver speech
  - Tasks not completed as directed due to caregiver interference
- Solution
  - Manual correction/exclusion of samples by human measurers
  - Flag outliers based on overall system distribution of metrics
- Remaining Need
  - Protocol for system to flag aberrant samples for automatic measures

Discussion

- The Modality.AI system is feasible for both speech and motor assessments
- When conducting telemedicine studies & clinical assessments, practitioners & researchers need to consider
  - Bandwidth
  - Cognition
  - Caregiver interactions
  - Task design
  - Technical specifications (e.g. task duration, anticipated pause duration, etc.)
- Future Research
  - Validity and reliability of automatic measurements

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