# Automated Audio Analysis of Dysarthria in Huntington's disease (Audio-HD)

*Luis Sierra*[1], *Karen Hildebrand*[1], *Clementina Ullman*[1], *Magdaline Mwangi*[1], *Henry O'Connell*[3], *Samuel Frank*[1,2], *Simon Laganiere*[1,2]

[1]*Department of Neurology, Beth Israel Deaconess Medical Center, Boston MA 02215 USA*
[2] *Harvard Medical School, 25 Shattuck St, Boston, MA 02115*
[3]*Canary Speech, Inc,* 3305 N University Ave Suite 200, Provo, UT 84604

Oral presentation: S37.010
Movement Disorders: Phenotyping and Biomarkers; April 26, 2023

Beth Israel Lahey Health

Beth Israel Deaconess Medical Center

HARVARD MEDICAL SCHOOL TEACHING HOSPITAL

# Disclosures



- **Luis Sierra**: has declared that there is no conflict of interest.
- **Karen Hildebrand**: has declared that there is no conflict of interest.
- **Clementina Ullman**: has declared that there is no conflict of interest.
- **Magdaline Mwangi**: has declared that there is no conflict of interest.
- **Henry O'Connell**: Chief Executive Officer and Founder of Canary Speech.
- **Samuel Frank**: has declared that there is no conflict of interest.
- **Simon Laganiere**: has declared that there is no conflict of interest.

**Funding source**: This study was internally funded as reflected on an in-kindness agreement between Canary Speech, Inc and BIDMC.

# Huntington's disease (HD) - Background



- Genetic testing for pathological CAG expansion in HTT
- Slow progressive decline in motor, cognitive and behavioral abilities
  - Pre-motor Manifest → Manifest HD
- Progressive speech/language changes (vast majority of patients)
- Unified Huntington's Disease Rating Scale (UHDRS™) - 124 points
  - Motor Assessment (Item 4): 4 points
    - (0) Normal
    - (1) Unclear, no need to repeat
    - (2) Must repeat to be understood
    - (3) Mostly incomprehensible
    - (4) Anarthria (mute)

# Background and Methods



**Hypotheses:**

- Early speech changes are not evident to clinical examination (UHDRS) (Perez et al., 2018)
- Automated analysis of speech output could detect progressive transition from pre-manifest to manifest HD (Romana et al., 2020)
- Speech changes could serve as clinical or research biomarkers (Tovar et al., 2020; Vogel et al., 2012)

# Background and Methods



**Study cohorts:**

- Patients with genetically-confirmed Huntington's disease
  - Pre-motor manifest HD
  - Manifest HD
- Healthy Controls

**Key Exclusion Criteria:**

- Individuals with any other form of dysarthria (acquired, developmental or trauma-related)

# Audio-HD Methods and Materials



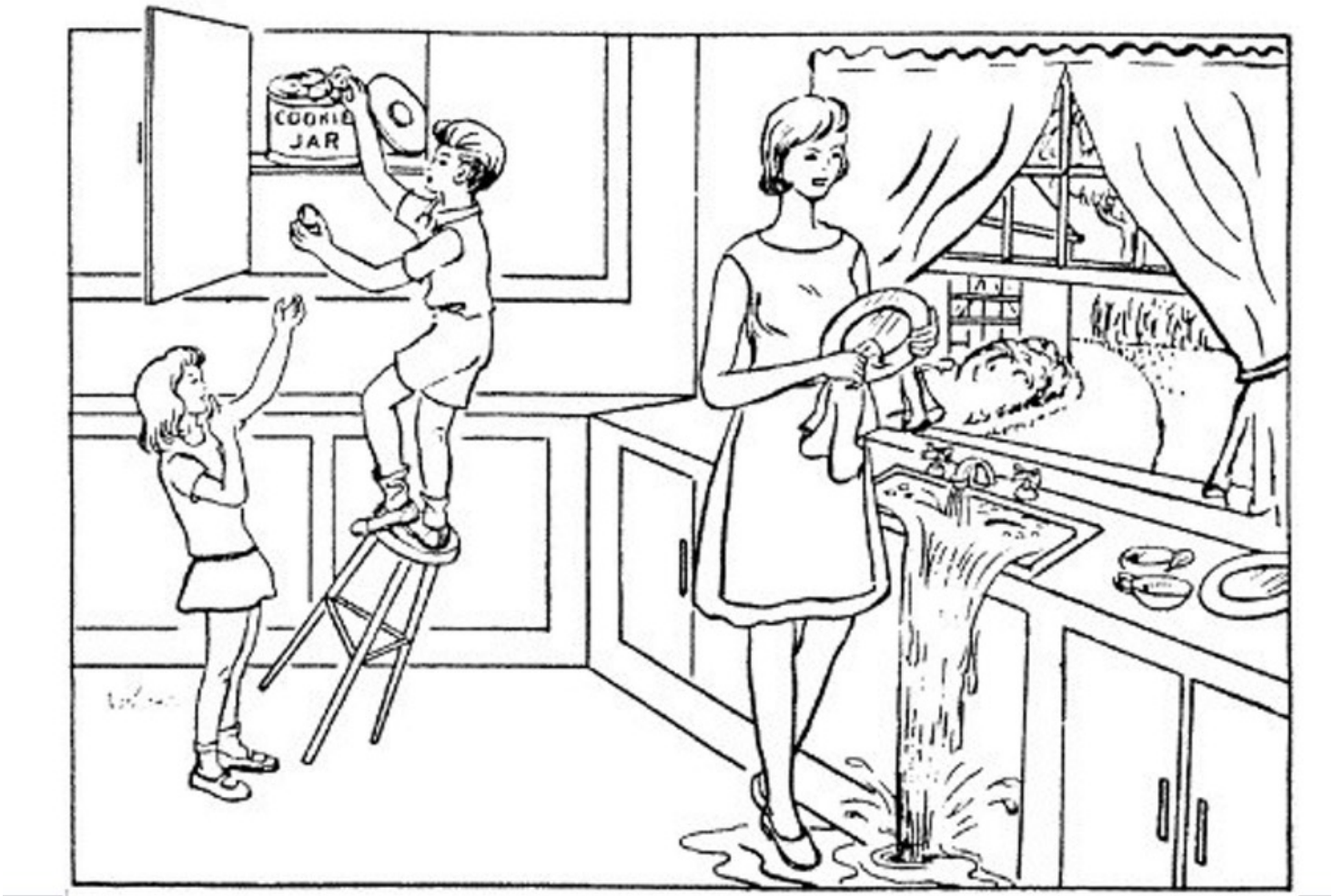
- Automated voice application on a tablet with a stand

- Capture different types of speech:

1. Unconstrained Descriptive Analysis
2. Constrained Reading
3. Procedural Narrative: i.e. Tell me how to make a sandwich.
4. Free Speech: i.e. How are you feeling today?
5. Single Word Reading

# 1. Unconstrained Descriptive Analysis

- **Cookie Theft Picture:** Useful in analysis of Syntax in verbal response.



# 2. Constrained Reading

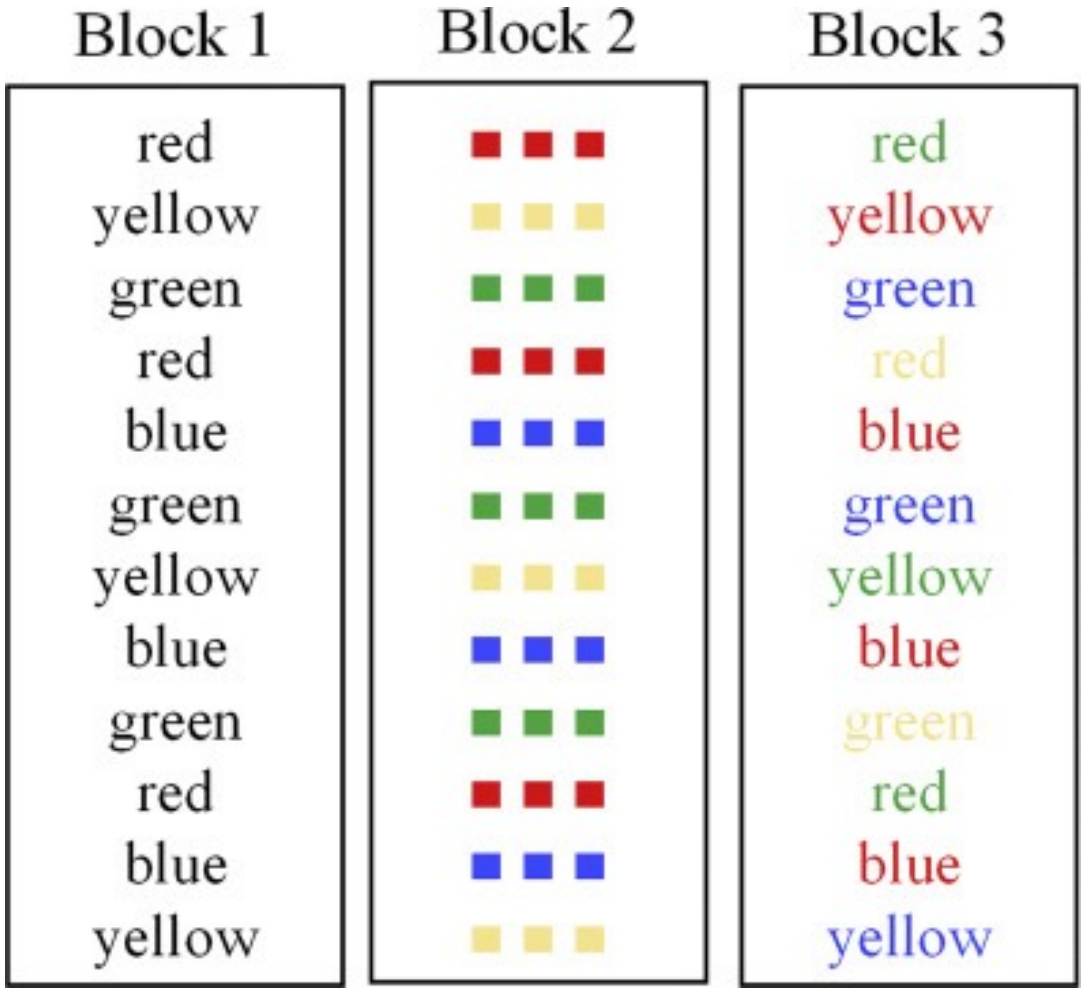


- **Caterpillar Passage**: targeted to inform the assessment of motor speech disorders.

Do you like amusement parks? Well, I sure do. To amuse myself, I went twice last spring. My most MEMORABLE moment was riding on the Caterpillar, which is a gigantic roller coaster high above the ground. When I saw how high the Caterpillar rose into the bright blue sky I knew it was for me. After waiting in line for thirty minutes, I made it to the front where the man measured my height to see if I was tall enough. I gave the man my coins, asked for change, and jumped on the cart. Tick, tick, tick, the Caterpillar climbed slowly up the tracks. It went SO high I could see the parking lot. Boy was I SCARED! I thought to myself, "There's no turning back now." People were so scared they screamed as we swiftly zoomed fast, fast, and faster along the tracks. As quickly as it started, the Caterpillar came to a stop. Unfortunately, it was time to pack the car and drive home. That night I dreamt of the wild ride on the Caterpillar. Taking a trip to the amusement park and riding on the Caterpillar was my MOST memorable moment ever!

# 5. Single Word Reading

## Stroop Color-Word Test



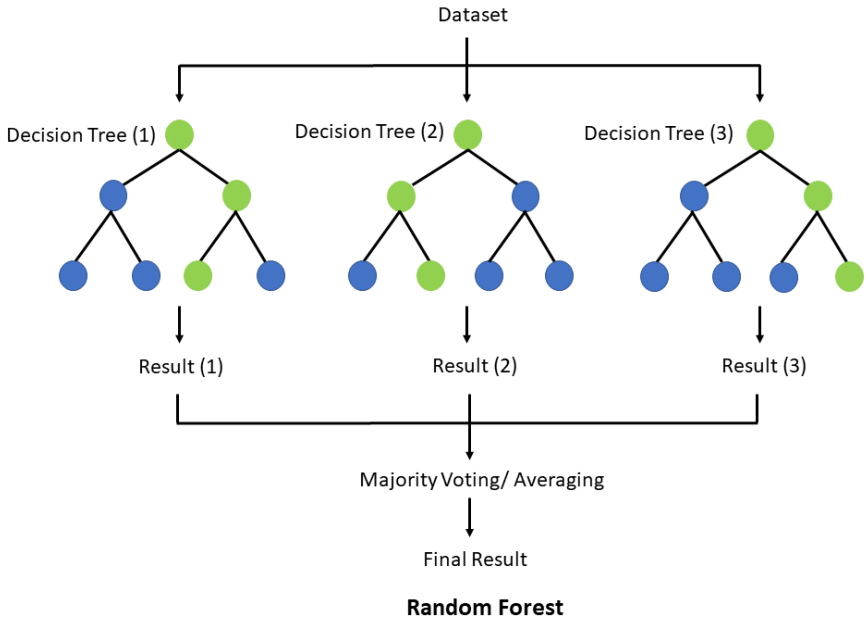
# Analysis

| Features | Abbreviation | Description |
|---|---|---|
| **i-vector** | ivec | Speech embedding based on GMMs |
| **x-vector** | xvec | Speech embedding based on Neural Networks |
| **Language** | lang | Prosodic and linguistic features based on spoken words and their timestamps from ASR (Automatic Speech Recognition) result - pause/filler, speech rate, vowel duration, word popularity for free speech, spoken word error rate for read speech, etc. |
| **Speech** | spc | Speech signal features such as spectral flux, flatness, jitter, shimmer, phonation time, etc. |
| **Prosody** | pros | Prosodic features including f0, energy, speech/silence, pause, breath, etc. |
| **Acoustic statistics** | acou | Statistics (mean, std, slope, quantile, kurtosis, skewness,..) of MFCC, PLP, Pitch per frame |

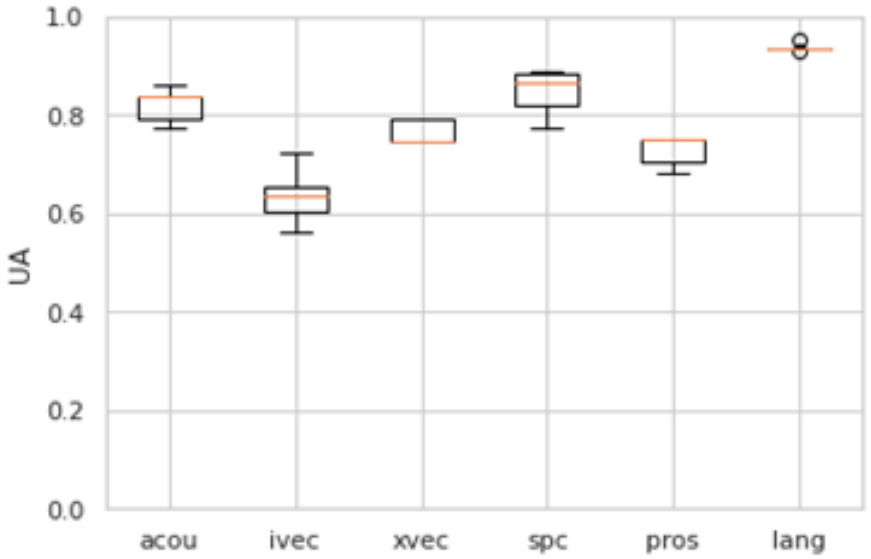
# Methods



Random Forest:




**Random Forest**



# Demographics



| Group | (n = 78) | Total Motor Score | CAG Repeat Length | Age | Education Level | Sex (Female) |
|---|---|---|---|---|---|---|
| HD (±SD) | 46 (23 Pre; 21 Manifest) | 16.1 (15.72) | 43.1 (3.62) | 48.2 (14.0) | 15.1 (2.53) | 50% |
| Controls (±SD) | 32 | --- | --- | 42.7 (17.4) | 16.3 (2.57) | 53% |

- 2 participants were removed from analysis due to inadequate speech samples

# Results Summary



| Label | Feature | N | Accuracy | Sensitivity | Specificity | AUC |
|---|---|---|---|---|---|---|
| Manifest vs. Others | Lang | 76 | 0.96 | 0.91 | 0.98 | 0.98 |
| Manifest vs. Pre-motor manifest | Lang | 44 | **0.95** | **0.95** | **0.95** | **0.97** |

# Confusion matrix



| Confusion Matrix | | Predicted | |
|---|---|---|---|
| | | Pre-Motor | Manifest |
| Actual | Pre-Motor | 20 | 1 |
| | Manifest | 1 | **{22}** |

| Label | Feature | N | Accuracy | Sensitivity | Specificity | AUC |
|---|---|---|---|---|---|---|
| Dysarthria vs. No-Dysarthria | Lang | 44 | 0.82 | 0.67 | 0.90 | 0.85 |

# Conclusions



- 8-minute tablet assessment
- 96% accuracy at distinguishing pre-motor manifest from manifest HD
- High accuracy despite ~41% of manifest HD cohort without clinical dysarthria
- Further training of the model and longitudinal follow up will be critical for determining the overall utility of this approach.

# Potential Limitations



- Random Forest analysis can lead to overfitting
- Can be complex and hard to interpret which specific features are most important
- This tool has not yet been validated with other datasets

# References




- Romana, A., Bandon, J., Carlozzi, N., Roberts, A., & Provost, E. M. (2020, October). Classification of manifest Huntington disease using vowel distortion measures. In *Interspeech* (Vol. 2020, p. 4966). NIH Public Access.
- Perez, M., Jin, W., Le, D., Carlozzi, N., Dayalu, P., Roberts, A., & Provost, E. M. (2018). Classification of huntington disease using acoustic and lexical features. In *Interspeech* (Vol. 2018, p. 1898). NIH Public Access.
- Skodda, S., Schlegel, U., Hoffmann, R., & Saft, C. (2014). Impaired motor speech performance in Huntington's disease. *Journal of Neural Transmission*, *121*, 399-407.
- Tovar, A., Soler, A. G., Ruiz-Idiago, J., Viladrich, C. M., Pomarol-Clotet, E., Rosselló, J., & Hinzen, W. (2020). Language disintegration in spontaneous speech in Huntington's disease: a more fine-grained analysis. *Journal of Communication Disorders*, *83*, 105970.
- Vogel, A. P., Shirbin, C., Churchyard, A. J., & Stout, J. C. (2012). Speech acoustic markers of early stage and prodromal Huntington's disease: a marker of disease onset?. *Neuropsychologia*, *50*(14), 3273-3278.