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MEDICINE

Natural Language Processing and Machine Learning in Language Disorders

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Primary Progressive Aphasia

- **Non fluent PPA variant (nfvPPA)**
  - impaired speech articulation or agrammatic speech
  - impaired comprehension of syntactically complex sentences
  - diminished production of verbs and fewer syntactically complex sentences

- **Semantic PPA variant (svPPA)**
  - difficulties in confrontation naming and single word comprehension
  - impaired semantic memory of familiar objects
  - ʽempty speechʼ in verbal production

- **Logopenic PPA variant (lvPPA)**
  - difficulties in word retrieval
  - difficulties in repetition of long words and phrases
  - phonological errors in speech production

Mild Cognitive Impairment

- **Patients with mild cognitive impairment (MCI)** portray noticeably incipient memory difficulty in remembering events and situations along with problems in decision making, planning, and finding their way in familiar environments, detailed neuropsychological assessments also indicate deficits in language performance.
- As the MCI progresses, MCI individuals face a higher risk of developing Alzheimer's Disease (AD).
- To this day, there is no cure for dementia but early-stage treatment can delay the progression of MCI; thus, the development of valid tools for identifying early cognitive changes is of great importance.

Problem

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- Diagnosis, prognosis, and evaluation of patients' condition requires substantial effort and Manual analysis of speech communication is **time-consuming** and **requires substantial expertise**:
  - Speech transcription
  - Annotation of the linguistic characteristic
  - Measurements
  - Scoring
- **Manual analysis lacks standardization:** FoqusAphasia (Stark et al., 2020).
- **Data elicitation and types of communication**
  - Free style conversation
  - Map Tasks
  - Picture Description tasks
- Perceptual identification of speech characteristics (just by listening) is **subjective**, and varies on how clinicians process, interpret, and judge acoustic, grammatical, etc. properties of speech and language.

Stark Brielle, C., Dutta, M., Murray Laura, L., Bryant, L., Fromm, D., MacWhinney, B., Ramage Amy, E., Roberts, A., den Ouden Dirk, B., Brock, K., McKinney-Bock, K., Paek Eun, J., Harmon Tyson, G., Yoon Si, O.,Themistocleous, Charalambos, Yoo, H., Aveni, K., Gutierrez, S., & Sharma, S. Standardizing Assessment of Spoken Discourse in Aphasia: A Working Group With Deliverables. *American Journal of Speech-Language Pathology.*https://doi.org/10.1044/2020_AJSLP-19-00093

Aims

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Aim 1 To provide easy, quick, and automated diagnosis, prognosis, and ultimately improve therapy decisions using NLP and ML.

Aim 2 To assist medical providers by identifying subgroups of patients by subtyping patients into variants.

Aim 3 To evaluate the effectiveness of treatment methods by quantifying their effects on speech and language.

Aim 4 To augment current treatment and evaluation batteries for speech and language pathology using NLP and ML.

Identification of patients with MCI vs. HC

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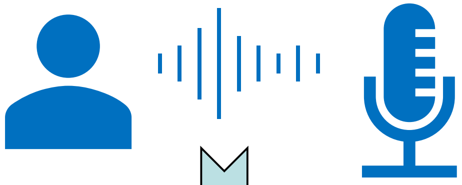
30 HCs
25 pat. with MCI
(55 and 79 years old)



Automatic Transcription &Segmentation

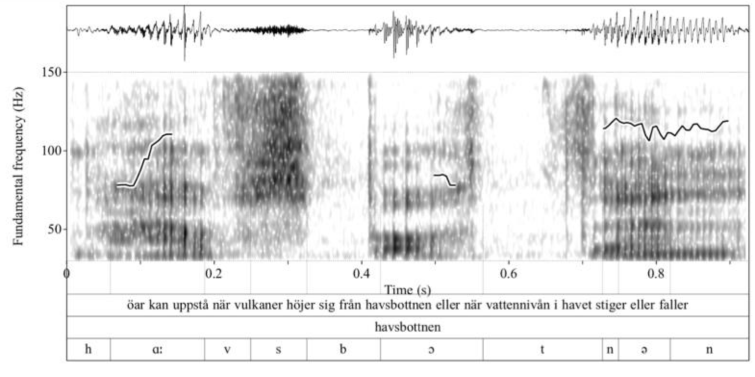


FIGURE 1 | Waveform, spectrogram, and *F0* contour—superimposed on the spectrogram—of an example utterance (upper tier). Shown in the plot is the segmentation of the word *havsbottnen* "seabed" (middle tier); the individual sounds are shown in the lowest tier. Sound boundaries are indicated with thin vertical lines. The ordinate shows the *F0* values whereas the abscissa shows the time in second.

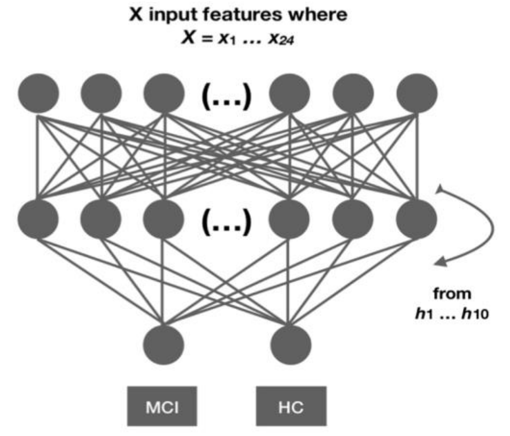


FIGURE 2 | Network architecture. We developed 10 different networks with 21 predictors each. The networks differed in the number of hidden layers ranging from 1 . . . 10. Each network architecture was evaluated twice using cross-validation and evaluation split. Model comparison measures are reported for each evaluation separately.

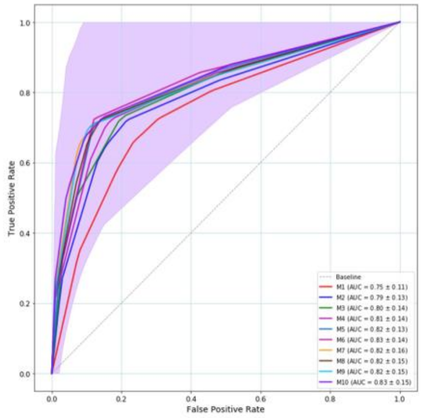


FIGURE 3 | Mean ROC curve and AUC of the 5-fold crossvalidation. Model—*M1 . . . M10*— are represented by solid line with a different color. The baseline is represented by a dashed gray line. All models provided ROC curves that were over the baseline. The best model is the model whose ROC curve approaches the left upper corner. The shaded area indicates the M10's *SD* that is the outperforming model both in terms of ROC/AUC (83%) and validation accuracy (83%).

1.Vowel Formants (i.e., *F*1, *F*2, *F*3, *F*4, *F*5) at the 15%, 50%, and 75% of the vowels' total duration: i.e., *F*1 15%,*F*1 50%,*F*1 75%...*F*5 15%,*F*5 50%, and *F*5 75%.
2.Fundamental frequency (*F*0): *mean F*0, *min F*0, and *max F*0.
3.Vowel duration
4.Gender.
5.Age

Themistocleous Charalambos, Eckerström Marie, and Dimitrios Kokkinakis (2018). Identification of Mild Cognitive Impairment from Speech in Swedish using Deep Sequential Neural Networks. Frontiers in Neurology.

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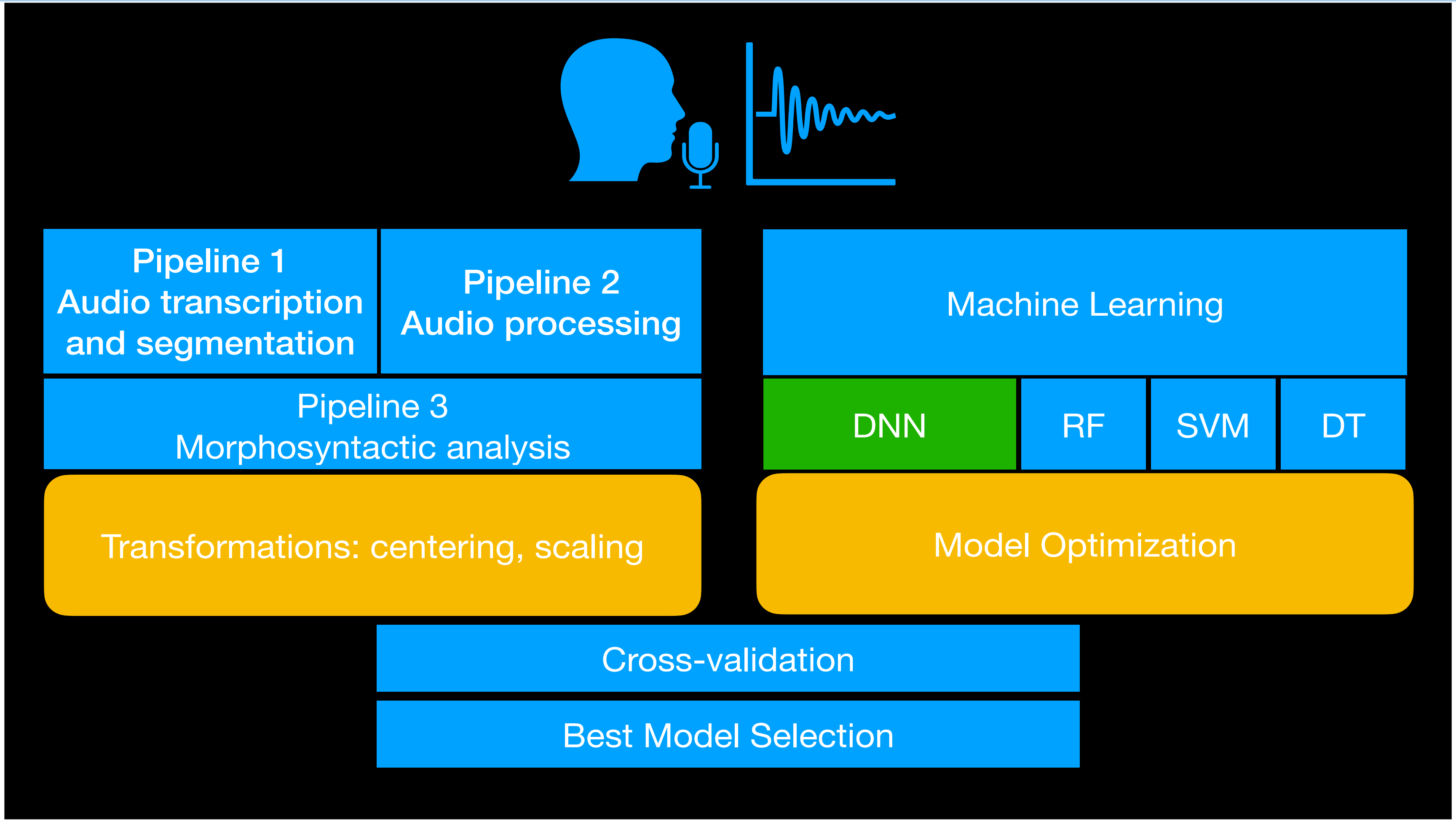
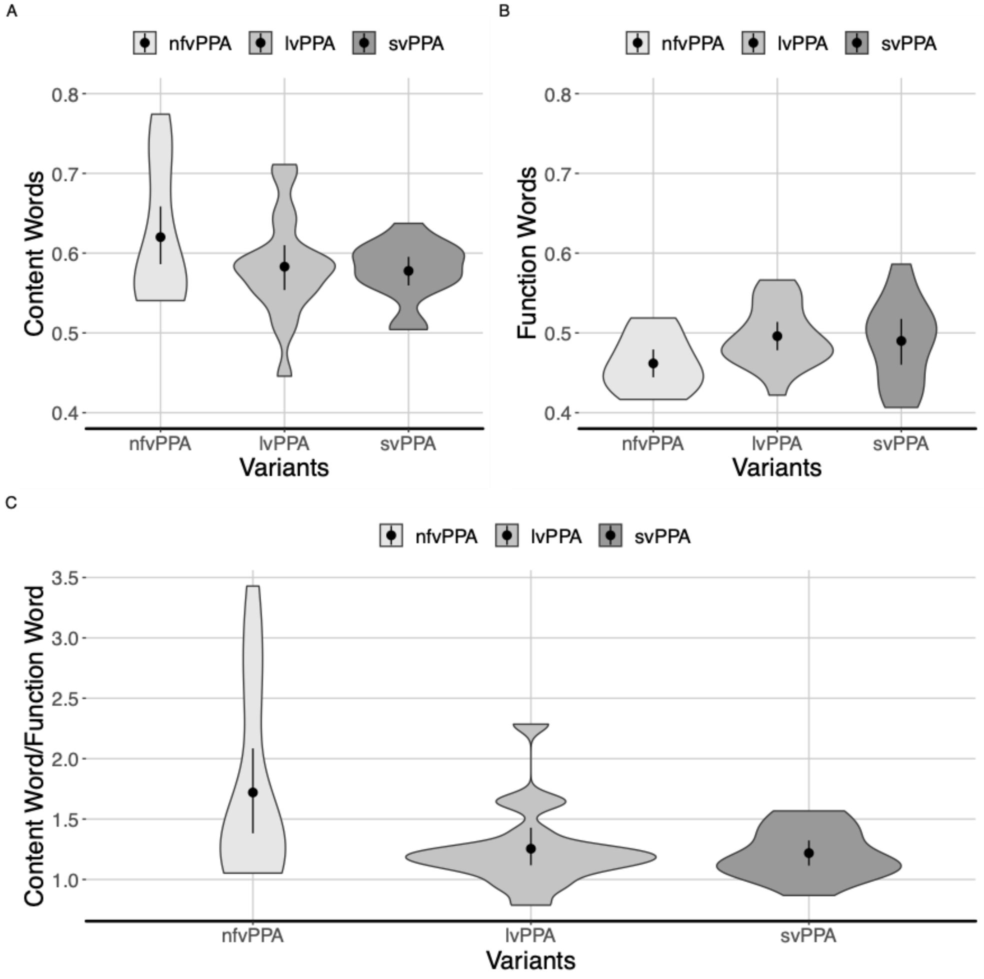
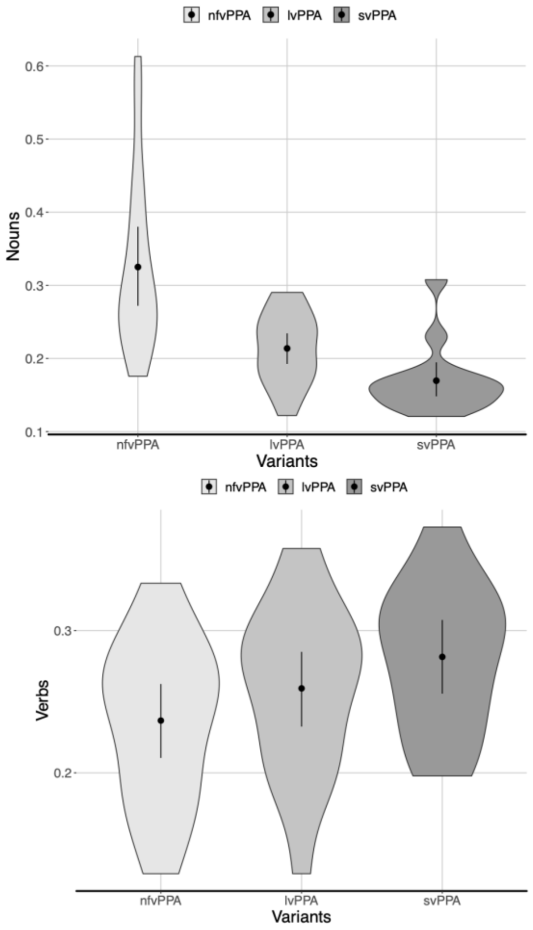


Themistocleous Charalambos, Bronte Ficek, Kimberly Webster, Dirk-Bart den Ouden, Argye E. Hillis, Kyrana Tsapkini (2021). Automatic subtyping of individuals with Primary Progressive Aphasia. Journal of Alzheimer's Disease, https://doi.org/10.3233/JAD-201101

Automatically elicited Morphosyntactic measures distinguish patients with different PPA variants

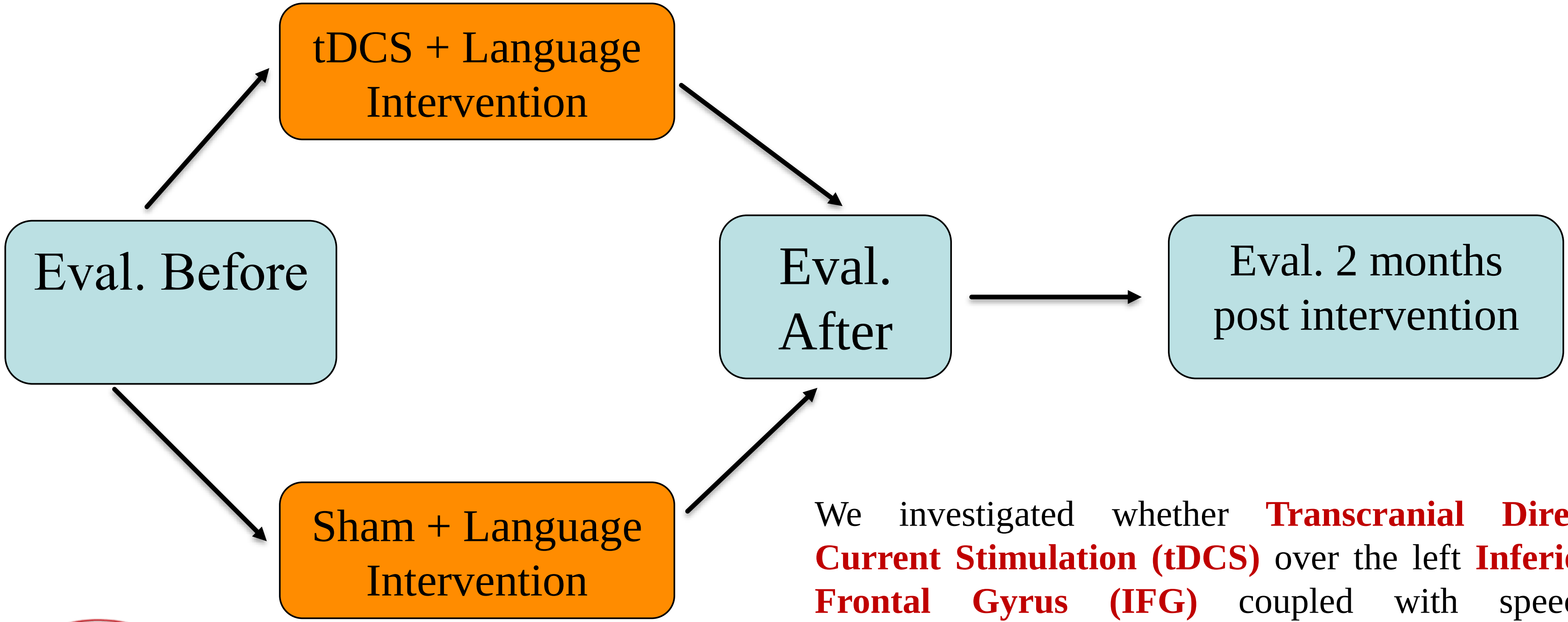




Themistocleous Charalambos, Webster Kim, Afthinos Alexandros, & Tsapkini Kyrana (2020). Part of Speech Production in Patients With Primary Progressive Aphasia: An Analysis Based on Natural Language Processing. American Journal of Speech-Language Pathology.

Evaluating Treatment Effects in Patients that Received tDCS vs. Sham

Language Intervention: Repetition of words with increasing syllable-length (Dabul, 2000).



We investigated whether **Transcranial Direct Current Stimulation (tDCS)** over the left **Inferior Frontal Gyrus (IFG)** coupled with speech intervention improved speech production in 11 patients with nfvPPA and AOS.

Themistocleous Charalambos, Webster Kimberly T., Ficek Bronte, Tsapkini Kyrana (2020). Effects of tDCS on apraxia of speech in non-fluent variant of Primary Progressive Aphasia.

Other Applications

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- Scoring of Spelling Errors
- Scoring of Phonological Errors
- Scoring of Semantic Errors

Themistocleous, Charalambos, Neophytou, Kyriaki, Rapp, Brenda, & Tsapkini, Kyrana (2020). A Tool for Automatic Scoring of Spelling Performance. Journal of Speech, Language, and Hearing Research. doi:10.1044/2020_JSLHR-20-00177.

Identifying a speaker of CG from AG from a single vowel or consonant

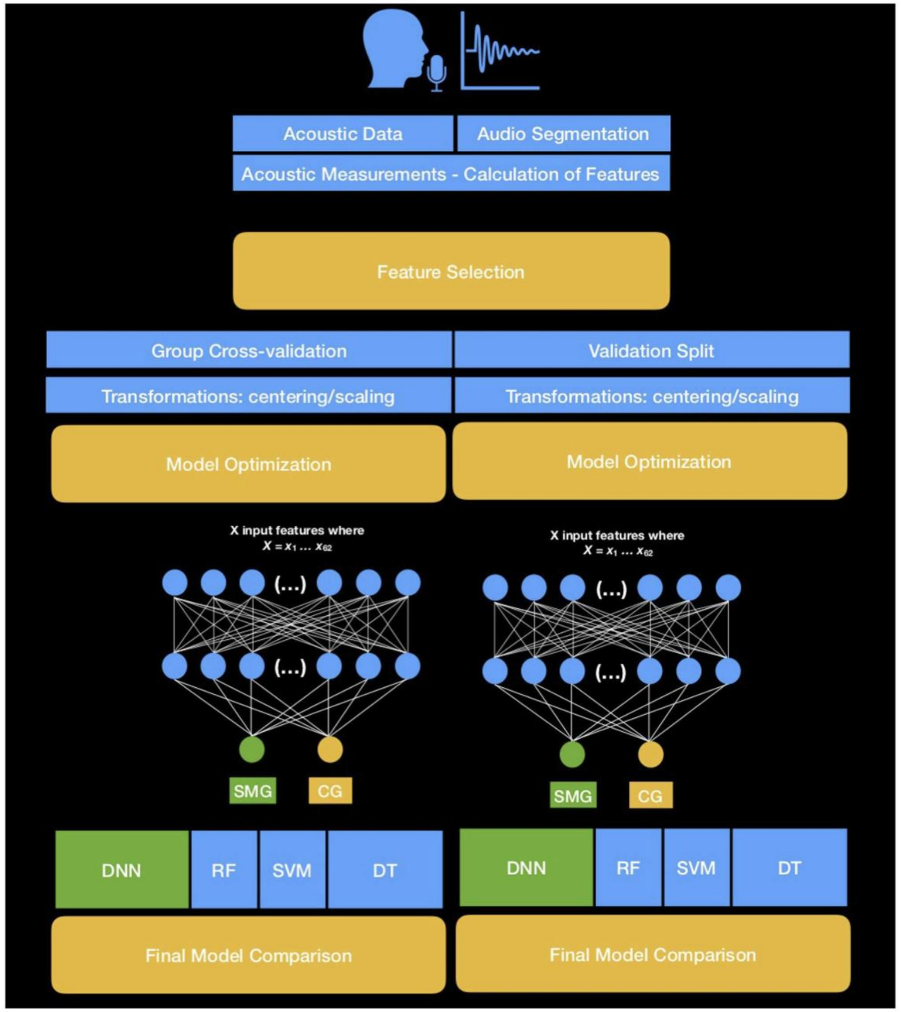


FIGURE 1 | Process diagram showing the steps required to select the best model for the classification of Standard Modern Greek (SMG) and Cypriot Greek (CG) for each one of the two classification approaches.

Themistocleous Charalambos (2019). Dialect Classification from a Single Sonorant Sound Using Deep Neural Networks*Frontiers in Communication*. doi: 10.3389/fneur.2018.00975.

Usage of morphological forms using ML

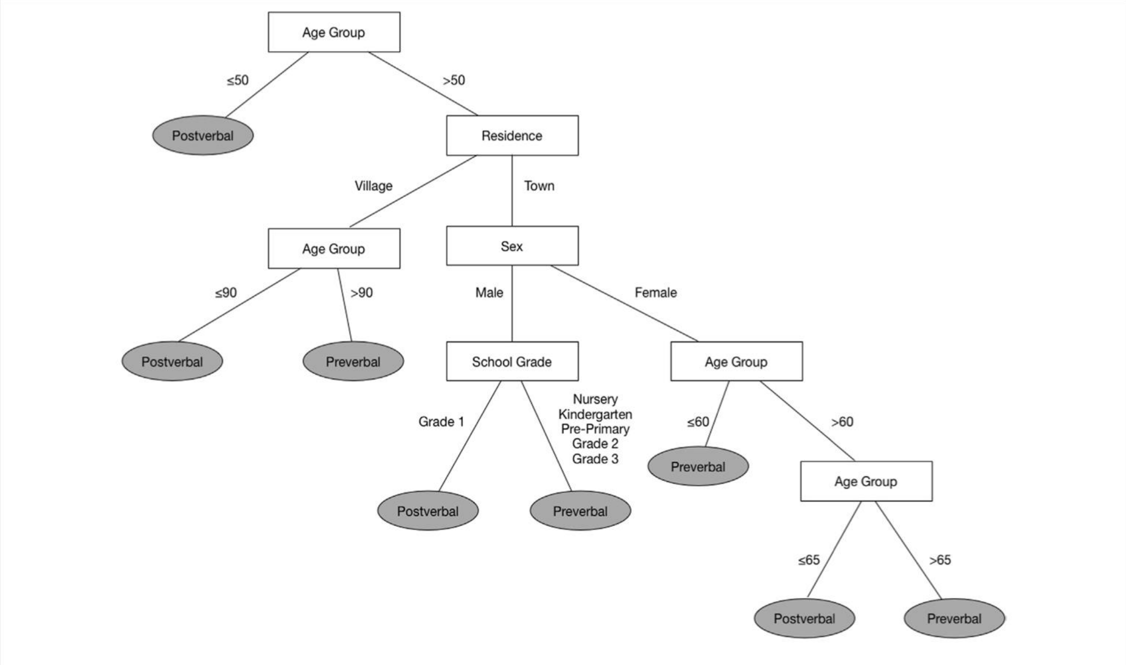
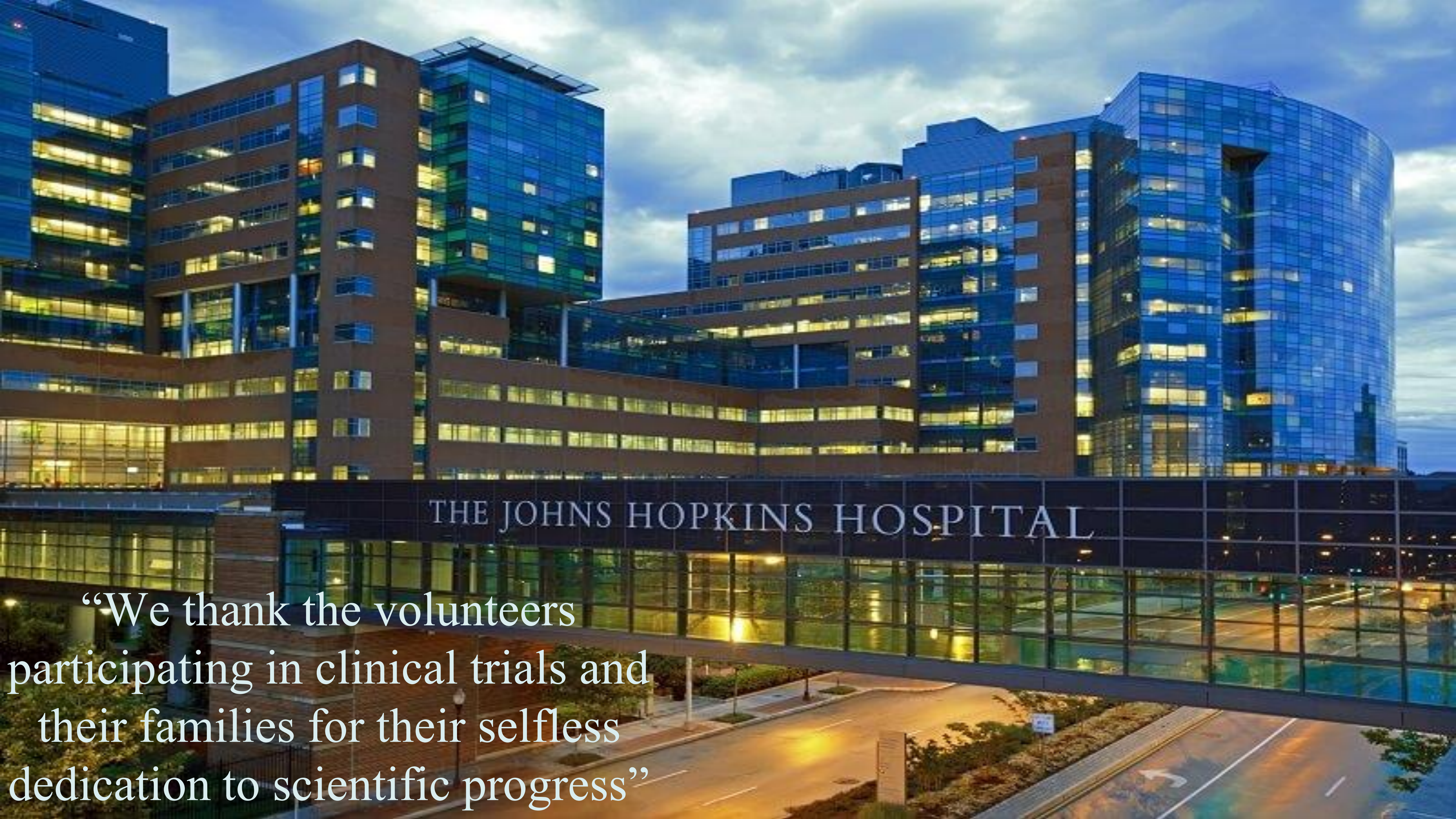


FIGURE 5 | **C5.0 decision tree.**

- Grohmann Kleanthes, Papadopoulou Elena and Themistocleous Charalambos (2017). Acquiring Clitic Placement in Bilectal Settings: Interactions between Social Factors. *Frontiers in Communication* 2:5. doi:10.3389/fcomm.2017.00005.


THE JOHNS HOPKINS HOSPITAL
“We thank the volunteers participating in clinical trials and their families for their selfless dedication to scientific progress”

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