Vocal markers of neuropsychiatric conditions: assessing the generalizability of machine learning models and their clinical applicability

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Introduction

BACKGROUND

- Voice atypicalities, e.g.longer pauses or flattened intonation, are a **distinctive feature of schizophrenia often associated with specific symptoms.**
- **Computerized voice analysis** is a promising tool for identifying vocal markers of neuropsychiatric disorders:
- **Machine learning (ML) models** have shown **high classification performance in predicting patients' diagnosis and symptoms** (De Boer et al., 2021; Cohen et al., 2021)

OPEN ISSUES

- However, recent works (Parola et al. ,2020, 2022 a,b) show that **generalizability of voice-markers is an issue.**
- **It is unclear whether voice-based ML models generalize to different samples and languages:** can we use a model trained on English to predict Danish data?
- The assessment of **generalization performance is crucial for clinical applicability.**

AIMS

We assessed the generalizability of voice-based ML models:

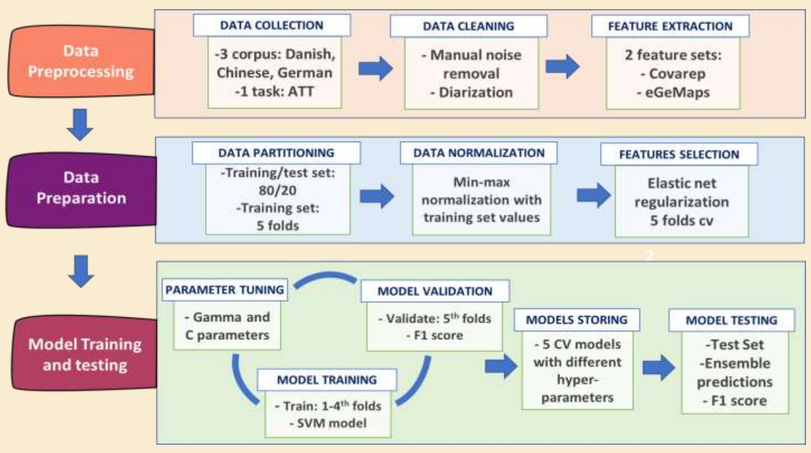
- **Q1:** How well do ML models generalize to different participants **speaking the same language?**
- **Q2:** How well do ML models generalize to participants **speaking a different native language?**
- **Q3:** Does combining models trained on different languages help improve generalization performance when predicting participants **speaking a different language?**
- **Q4: Does training models on a multilingual training set, i.e. combining participants speaking different languages,** help improve generalization performance?

Methods and design

PARTICIPANTS & PROCEDURE

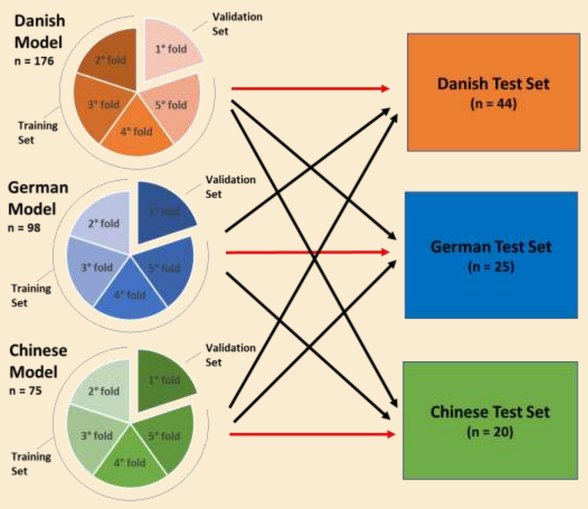
- **Participants: large cross-linguistic dataset (4 languages: Danish, German, Mandarin, Japanese)** involving 162 participants with SCZ (104 DK, 51 CH, 7 JP) and 172 matched controls (116 DK, 43 CH, 13 JP).
- **Speech task**: the **Animated Triangle Task, open-ended description of animated videos.**
- **Clinical data: SANS, SAPS, PANSS**

ML PIPELINE



- **A rigorous pipeline to minimize overfitting:**
- **Acoustic features:** Covarep, eGeMaps
- **Elastic net feature selection**
- **Train, validation and hold-out sets to avoid data leakage**
- **Five-fold CV on the training set only**
- **Stratified training sets (sex and diagnosis)**
- **Mixture of Experts (MoE) models**
- **Peformance: F1 metric**

MODEL TRAINING AND TESTING



We tested model generalizability on:

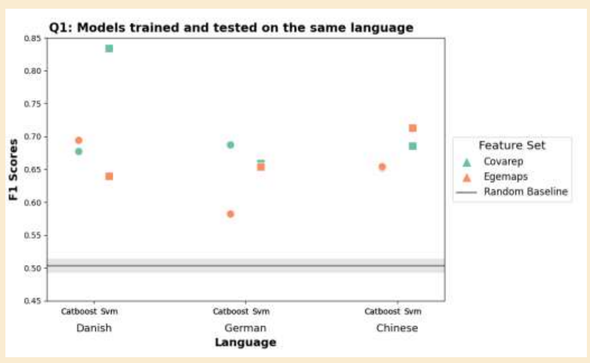
- **Q1: different participants, speaking the same language (hold-out test set);**
- **Q2: different participants, speaking a different language.**

We compared predictive performance:

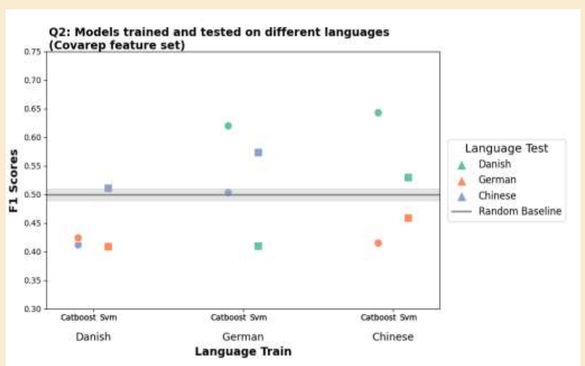
- **(i) models tested on a single language**
- **(ii) MoE models, i.e., ensemble of predictions of models trained on different languages**
- **(iii) multi-language models trained on multi-languages datasets.**

Results

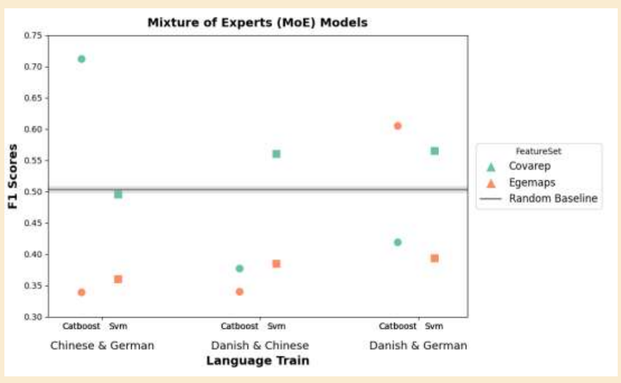
Q1: Train/Test same language



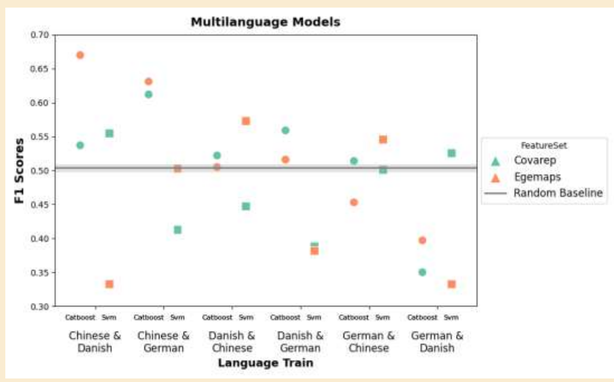
Q2: Train/Test different language



Q3 : Mixture of Experts Models



Q4: Multilanguage Models



Discussion

MAIN FINDINGS

- **Q1) Model performance comparable to state-of-the art findings** (F1 ~ 70%-80%) **when trained and tested on** participants speaking **the same language** (out-of-sample performance).
- **Q2)** Crucially the **ML models did not generalize well** - performance close to chance - **when trained in a language and tested on new languages**
- **Q3 and Q4) MoE and multi-language models show a slight increase of performance** (F1 up to 55%-60%), but still far from those requested for clinical applicability.
- **Cross-linguistic generalizability of voice-based ML models of schizophrenia is limited. If our first goal clinical appliicability, we need to account for this variability.**

RECOMMENDATIONS FOR FUTURE STUDIES

- 1) Larger open datasets to test: a) the generalizability of voice-based ML models across different speech tasks, heterogeneous clinical profiles, languages b) presence of bias
- 2) Rigorous pipeline to increase robustness and generalizability of ML models
- 3) Transfer learning: Tasks which allow a better transfer: e.g., emotional content, or relevant psychopathological dimensions.

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