# Investigating the forensic applications of global and local temporal representations of speech for dialect discrimination

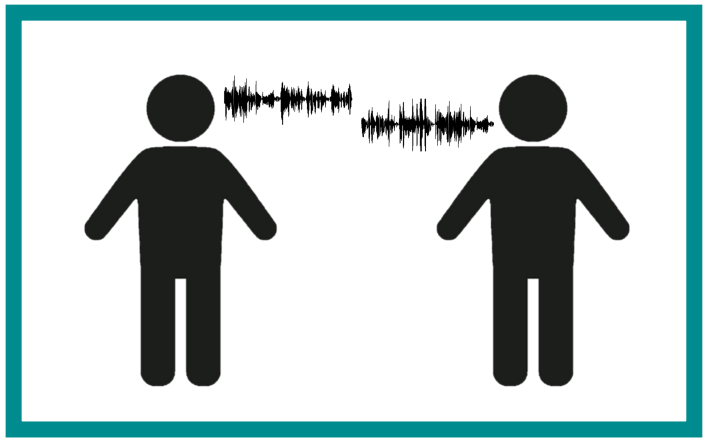
Leah Bradshaw, Vincent Hughes, and Eleanor Chodroff

Department of Language and Linguistic Science
University of York

INTRODUCTION

# Forensic phonetics

Voice analysis



Voice comparison

INTRODUCTION

# Speaker classification

Process of determining speaker-specific features (e.g., gender, age, dialect, idiosyncratic speech markers, etc.) using:

- Auditory analysis
- Acoustic-phonetic analysis
- Automatic speaker recognition approaches

# INTRODUCTION

Acoustic-phonetic analysis frequently involves court-presentable measurements that are strongly focused on segmental information:

- Formants
- F0
- Voice onset time

But what about suprasegmental information, and specifically information about a speaker's rhythmic pattern?

INTRODUCTION

# Rhythm in speaker classification

Previous studies demonstrate some utility of rhythm for dialect discrimination and forensic purposes

Limited in its application in research and casework

Ferragne and Pellegrino 2004, Biadsy and Hirschberg 2009, Torgersen and Szakay 2012, Leemann et al. 2012, 2015, Dellwo et al. 2015

REPRESENTING TIME IN SPEECH

# Rhythm depends on some temporal representation of speech

Rhythm: Temporal characteristics of a spoken utterance

How can temporal characteristics of a spoken utterance be represented in an acoustic-phonetic analysis? In an ASR analysis?

REPRESENTING TIME IN SPEECH

# Global temporal representations

Long-term alternations in vocalic and consonantal intervals which may approximate the rhythmic pattern of speech

Rhythm Metrics: measures examining the degree of variability in the duration of pre-specified intervals (e.g., vowels, consonants, CV sequences, adjacent intervals, etc.)

Rasmus et al., 1990, Grabe and Low 2002, Dellwo 2006

REPRESENTING TIME IN SPEECH

# Rhythm in speaker classification

Syllable vs stress-timed distinctions

Syllable-timed: equal syllable durations

Stress-timed: equal stressed syllable durations (more variability between stressed and unstressed syllables)

Problematic: too coarse – but, possibly a place to start

Pike 1945, Abercrombie 1967, Dauer 1983, Arvaniti 2009

REPRESENTING TIME IN SPEECH

# Local temporal representations

Delta (Δ) and delta-delta (ΔΔ) features: Reflect the change in spectral properties between adjacent temporal frames and the acceleration of that change

Common in ASR systems

e.g., Lee et al. 1990, Matsui and Furui 1990, Gish and Schmidt 1994

# GOALS

1) Analyze rhythmic profile of four varieties of British English: Cambridge, Multicultural London English, Leicester, and Punjabi-Leicester

2) Investigate the utility of global RMs for discriminating among the dialects

3) Compare global and local temporal representations for dialect discrimination

# OUTLINE

Introduction

Corpus Description

Global: Rhythm Metrics

Local: Deltas and Delta-deltas

Discussion

# METHODS

## Four British English Dialects

| | "South" | Leicester ("Midlands") |
|---|---|---|
| Non-contact (Anglo) | Cambridge English (CE) | Leicester English (LE) |
| Contact (Ethnic) | Multicultural London English (MLE) *Caribbean descent* | Punjabi-Leicester English (PLE) *At least one parent as native Punjabi speaker* |

**International Varieties of English (IViE) corpus:** 12 CE, 12 MLE, age 16

**Wormald (2016):** 8 LE, 22 PLE, ages 20–53

# OUTLINE

Introduction

Corpus Description

Global: Rhythm Metrics

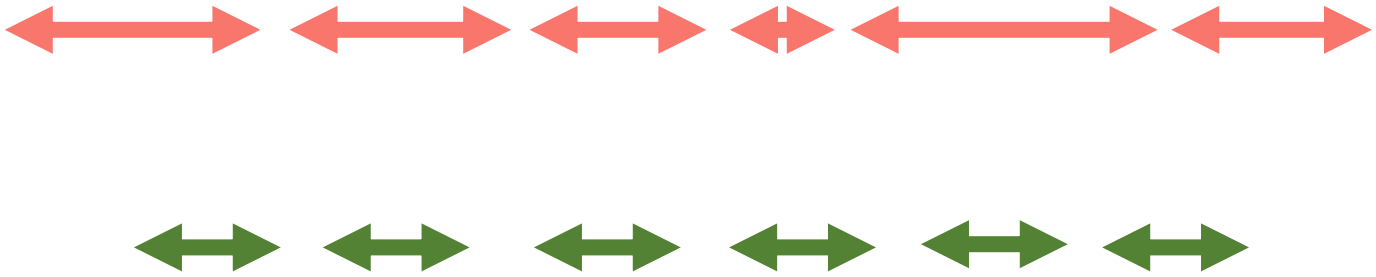
Local: Deltas and Delta-deltas

Discussion

# GLOBAL MEASURES:

# Rhythm Metrics

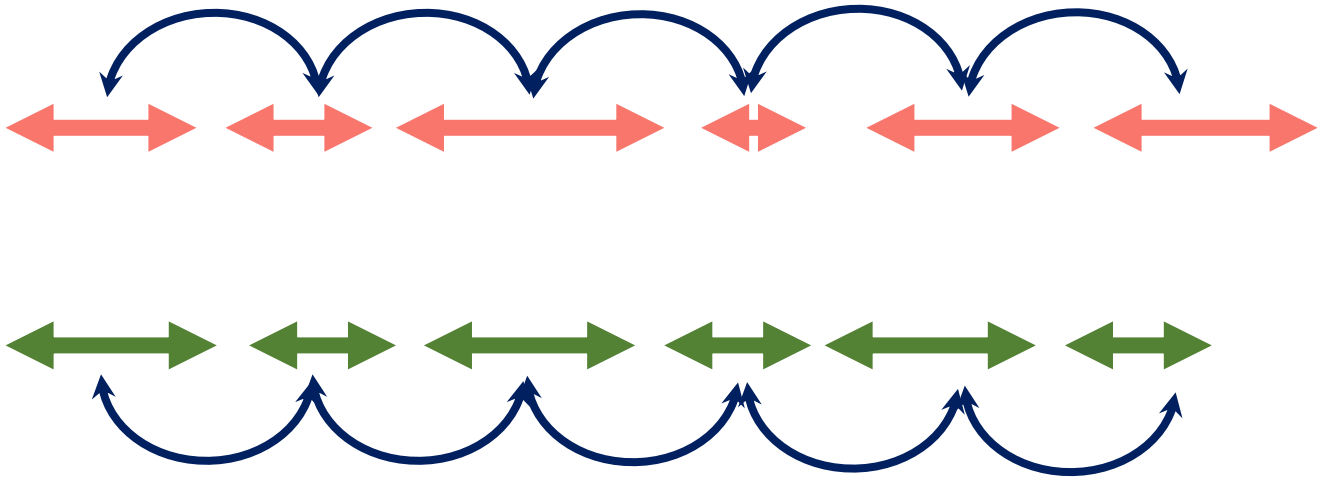
| | |
|---|---|
| stdevV | Standard deviation of vocalic interval duration |
| stdevC | Standard deviation of consonantal interval duration |
| VarcoV | Coefficient of variation for the vocalic interval duration |



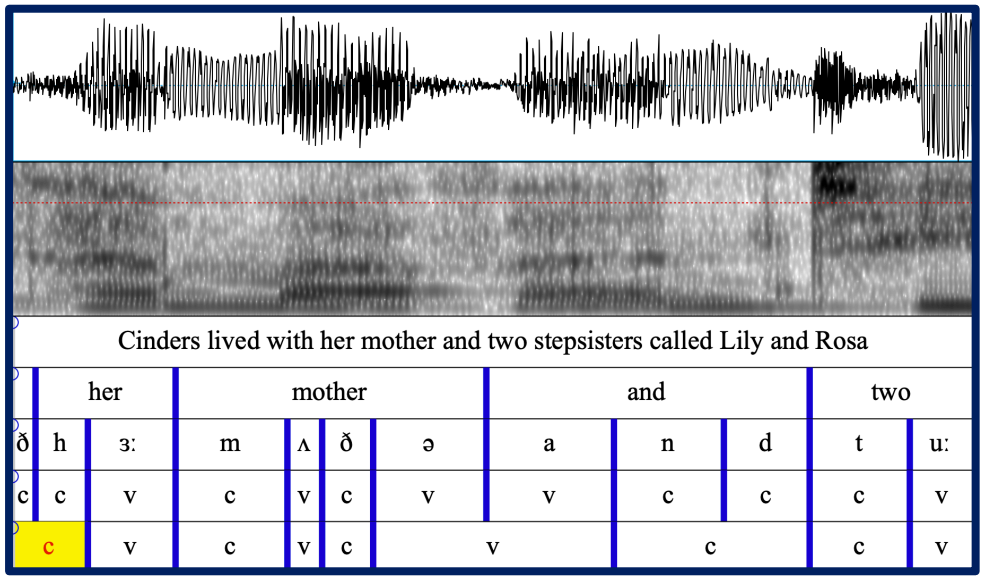
# GLOBAL MEASURES:

# Rhythm Metrics

| | |
|---|---|
| nPVI-V | Pairwise Variability Index for vocalic interval durations |
| nPVI-C | Pairwise Variability Index for consonant interval durations |
| nPVI-CV | Normalised pairwise variability index for summed consonantal and vocalic interval durations |



# METHODS




Cambridge, MLE: Praat EasyAlign for British English

Leicester varieties: Alignments accompanied the recordings

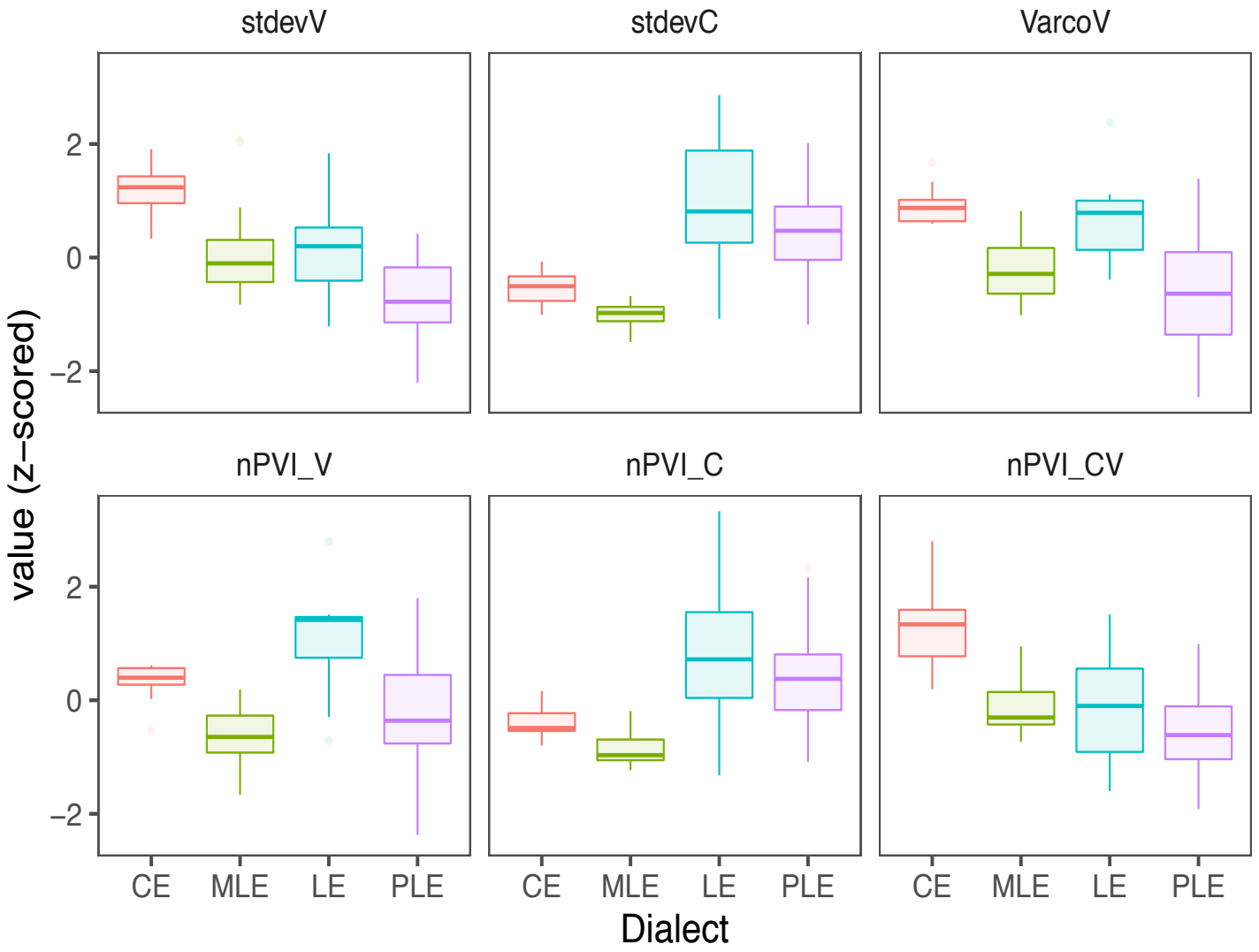
All phone alignments were manually adjusted

Consonantal and vowel intervals determined based on the phone alignments

RMs measured with the Duration Analyzer Praat script

# RESULTS:

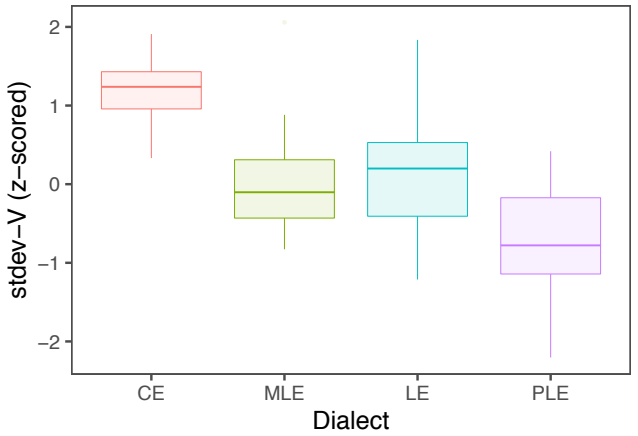
## Rhythm Metrics

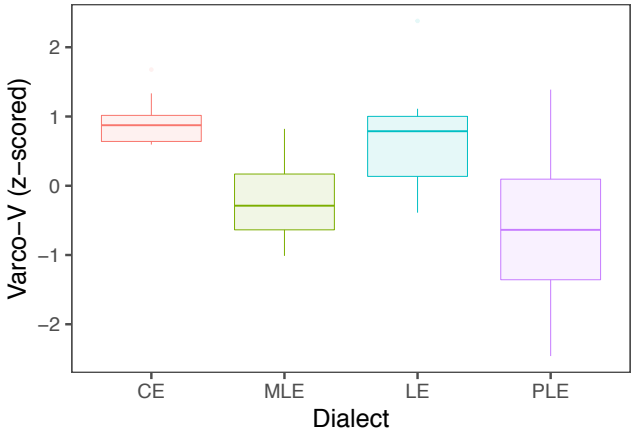


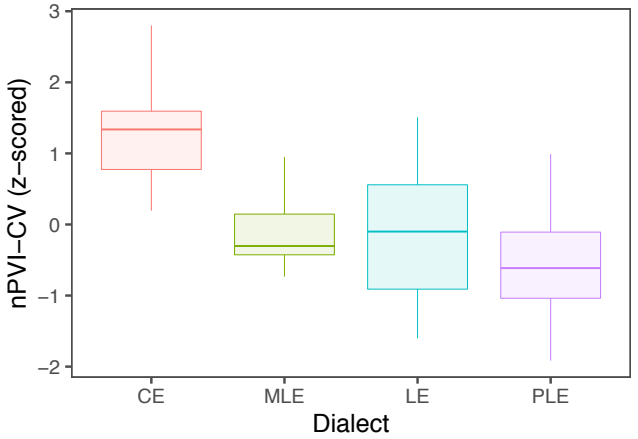

Dialect significantly improved model fit
No gender differences

# RESULTS:

## Rhythm Metrics




Cambridge English: higher
stdev-V, VarcoV, nPVI-CV

MLE: average

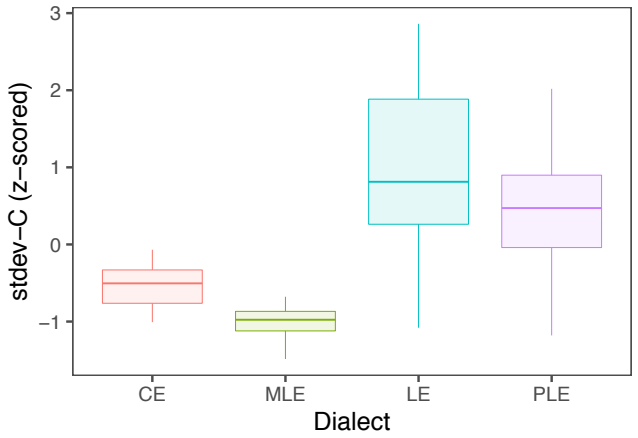
Leicester English: higher
VarcoV

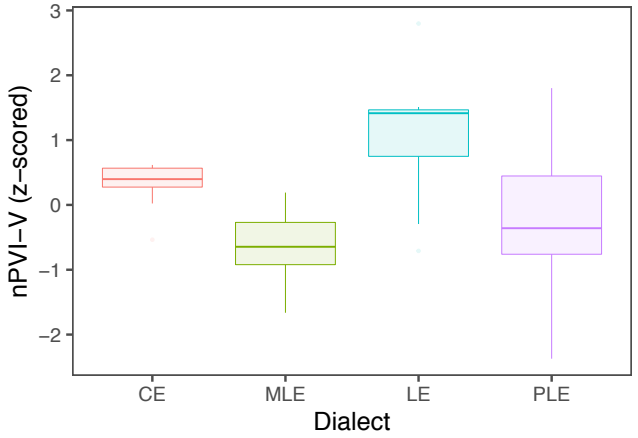
Punjabi Leicester: lower
stdev-V, VarcoV

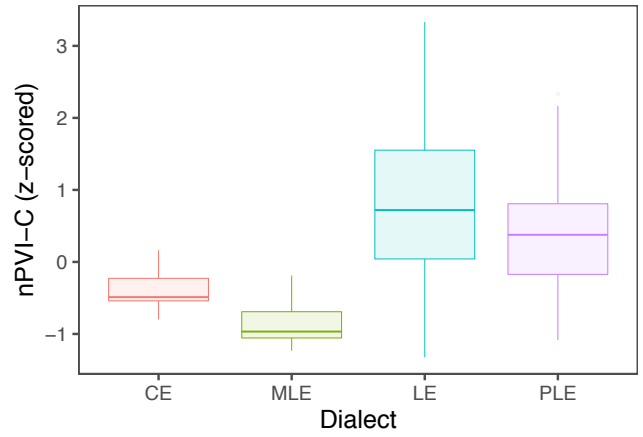
All relative to the average production across all four dialects

# RESULTS:

## Rhythm Metrics




Cambridge English: lower
stdev-C

MLE: lower
stdev-C, nPVI-V, nPVI-C

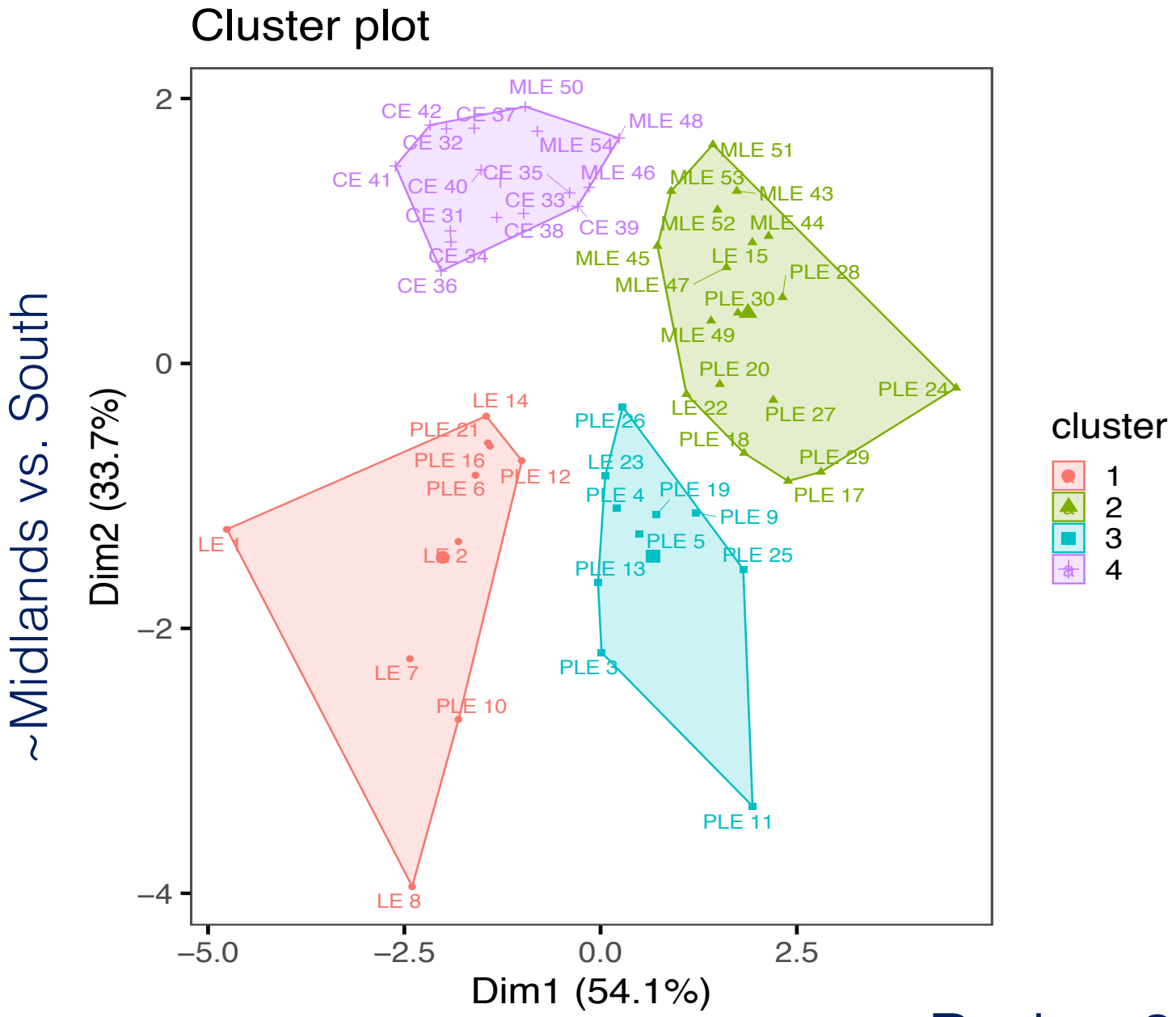
Leicester English: higher
stdev-C, nPVI-V, nPVI-CV

Punjabi-Leicester: higher
stdev-C
lower nPVI-V

All relative to the average production across all four dialects

RESULTS:

Rhythm Metrics




~Midlands vs. South

~Anglo vs Contact

Purity: 0.64

# OUTLINE

Introduction

Corpus Description

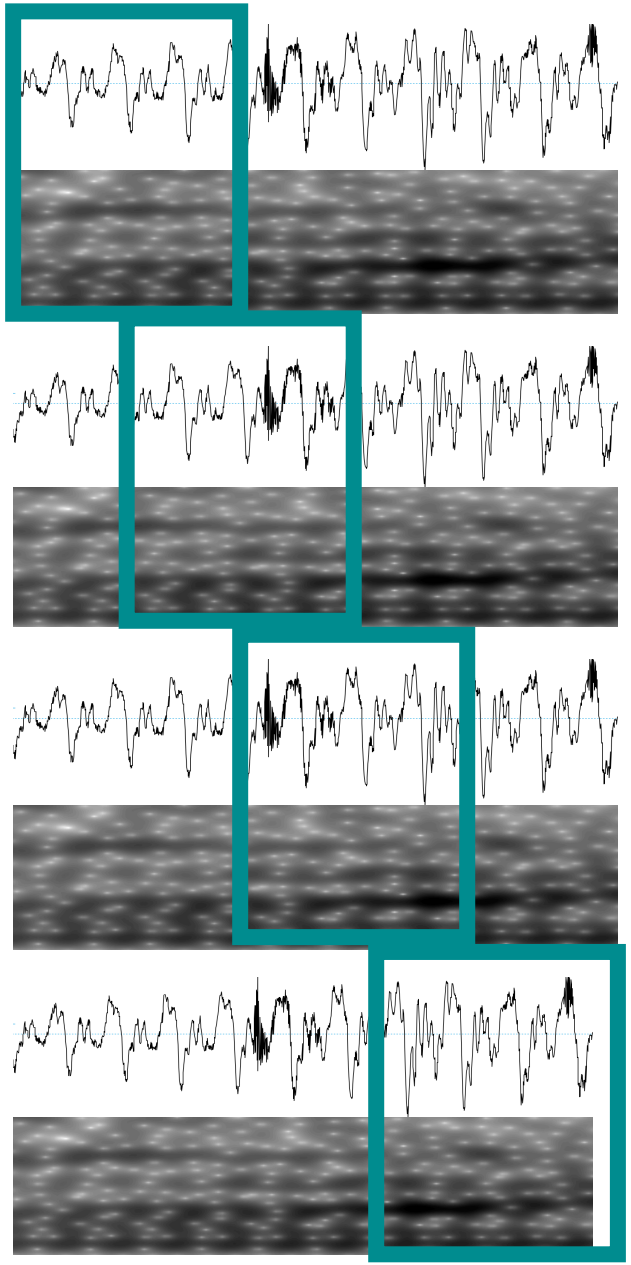
Global: Rhythm Metrics

Local: Deltas and Delta-deltas

Discussion

METHODS:

Δ and ΔΔs



# MFCCs

Voice activity automatically detected + manually corrected

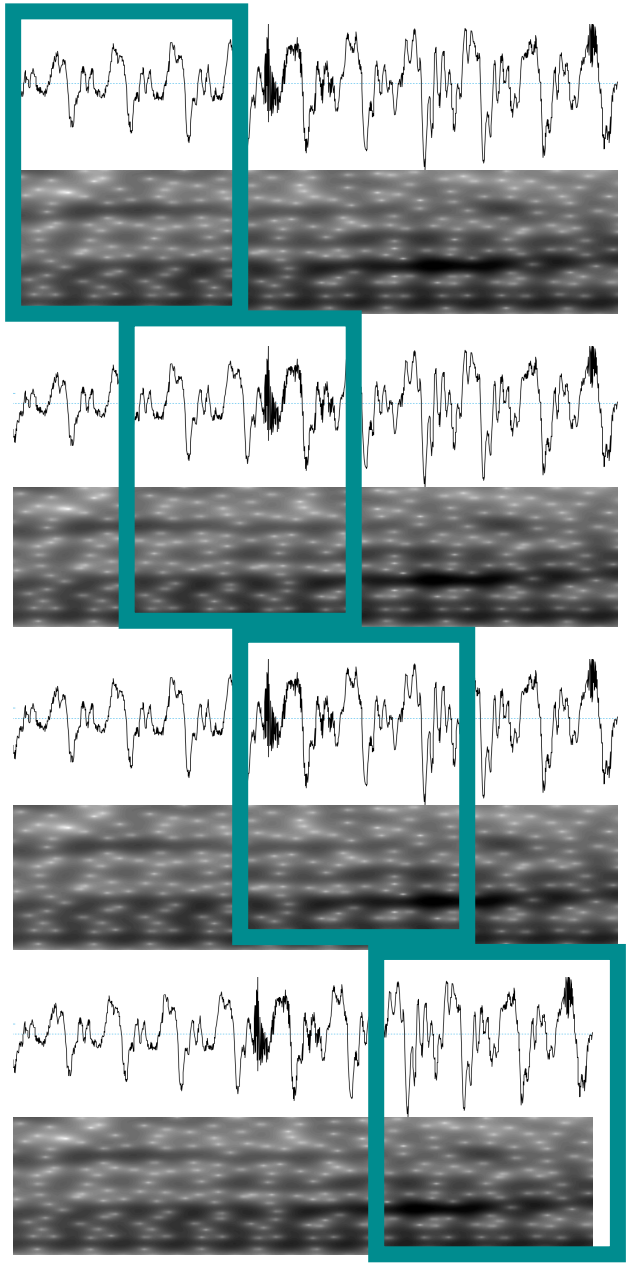
20 ms frames, shifted by 10 ms

0–4000 Hz

CMVN applied for room/equipment normalization

METHODS:

Δ and ΔΔs



## Δs and ΔΔs

Deltas: change between MFCCs in adjacent frames

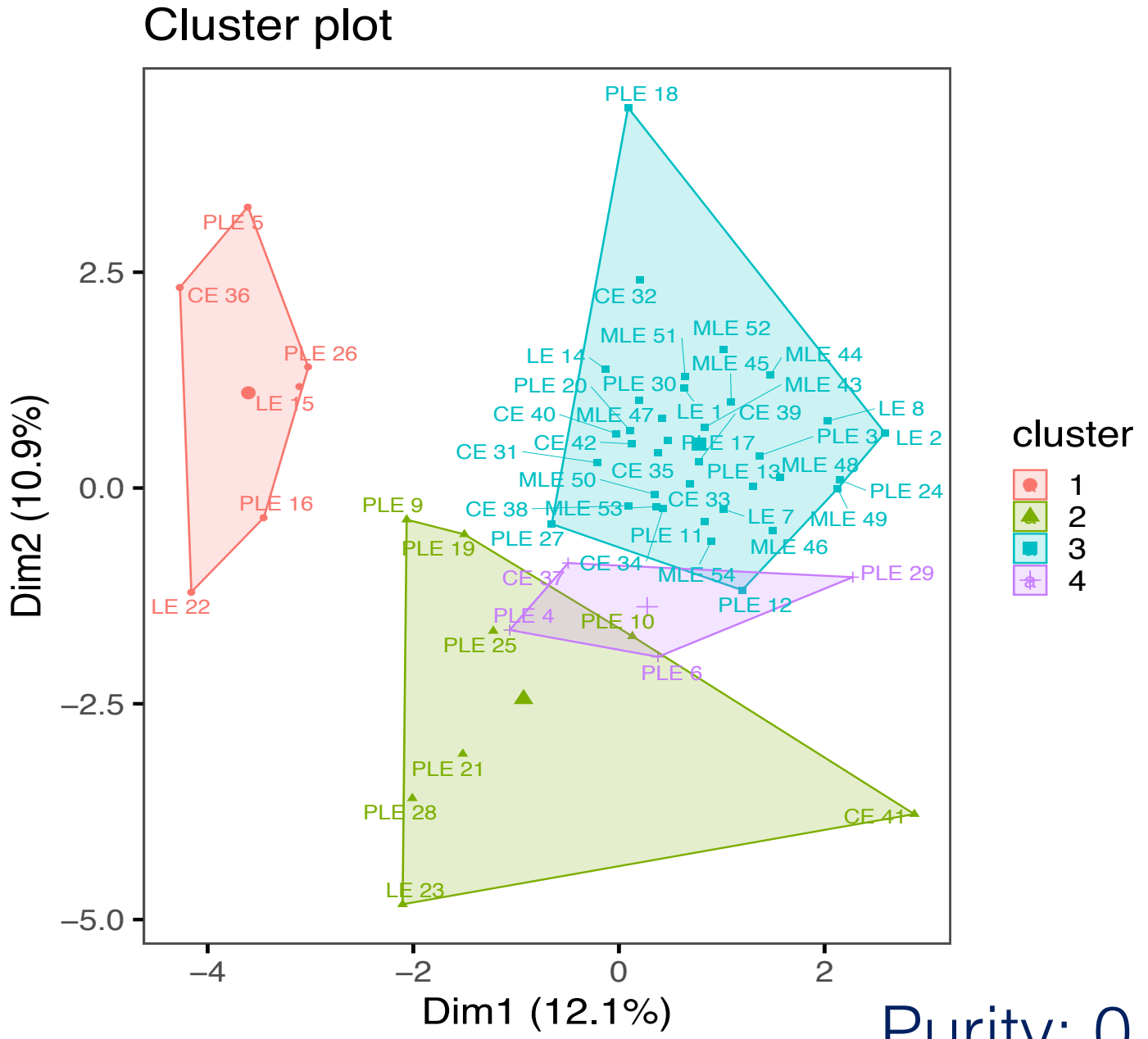
Delta-deltas: change between deltas in adjacent vectors

Averaged for each recording

MFCCs not included in the analysis

RESULTS:

Deltas and delta-deltas




Purity: 0.44

# DISCUSSION

Significant differences in RMs among four British English dialects

CE and LE more stress-timed—but in different ways

MLE and PLE more syllable-timed—but in different ways

Combination of RMs can be used as a Rhythmic Profile

# DISCUSSION

Rhythmic profile is a useful feature in dialect discrimination

Issue: RMs somewhat correlated

Future directions: Which RMs and combinations of RMs are indeed best and least redundant?

Examine whether these results hold for dialects collected in a single corpus

# DISCUSSION

Proof of concept: Global temporal representations > local temporal representations for dialect discrimination

Demonstrates need for global temporal representation in automatic speaker and language recognition systems
(some work done already)

Forensic application of RMs: directly interpretable, court presentable

Adami et al. 2003, Shriberg et al. 2005, Dehak et al. 2007

# Thank you!

Thanks to:

Jess Wormald
Paul Foulkes
Peter French
Sam Hellmuth

# XXX