Exploring the Articulatory Perspective of Mel-Frequency Cepstral Coefficients: Unravelling the Link between MFCCs and Vocal Tract Features

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'work in progress' poster

BACKGROUND

- Mel-frequency cepstral coefficients (MFCCs; Davis and Mermelstein, 1980)
- Capture the spectral characteristics of speech signal Spectral characteristics are a function of vocal tract (Fant, 1971)
- Claimed that MFCCs capture the shape and features of the human vocal tract
- Widely used as the input features in speech technology (Prakash & Gangashetty, 2012; Zhang et al., 2013; Pellegrini et al., 2014 Hughes et al., 2017)

HOWEVER,

- No studies have attempted to investigate how MFCCs and vocal tract features, if there are any, are related.

AIM

To investigated the interpretability of MFCCs from an articulatory perspective

HOW

- Three corner vowels: FLEECE, TRAP, FOOT
- Single words, i.e., not connected speech
- First 12 MFCCs
- 12 articulatory kinematics:
  - movement of tongue dorsum (TD), tongue lateral (TL), tongue blade (TB), upper lip (UL), lower lip (LL), lateral lip corner (LC)
  - Two dimensions, i.e., x: front and back, y:height,
- Speakers
  - 20 Midwestern standard American English speakers (10 male and 10 female; Ji et al. 2014)
- PCA performed on the first 12 MFCCs as well as 12 articulatory kinematics data (i.e., 6 sensors * x-axis * y-axis)

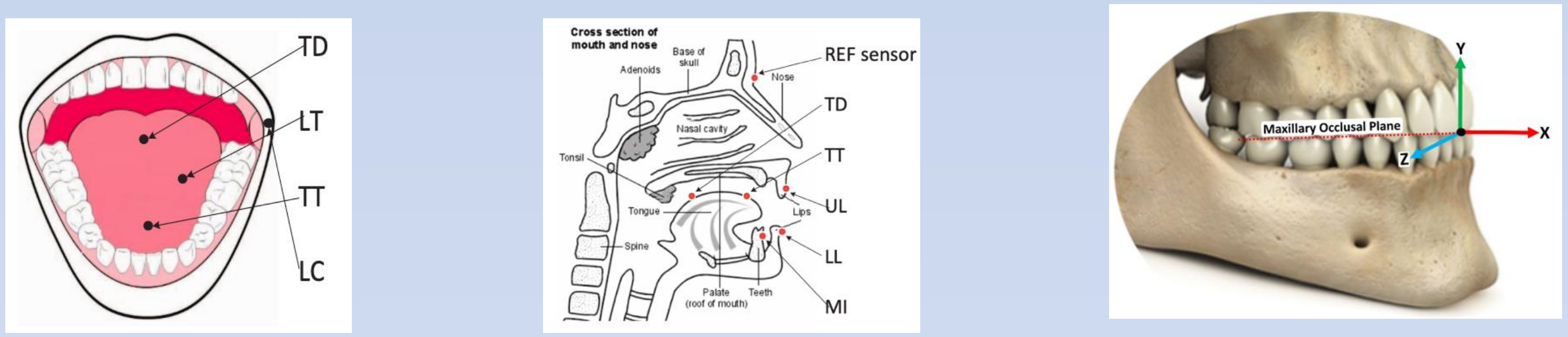
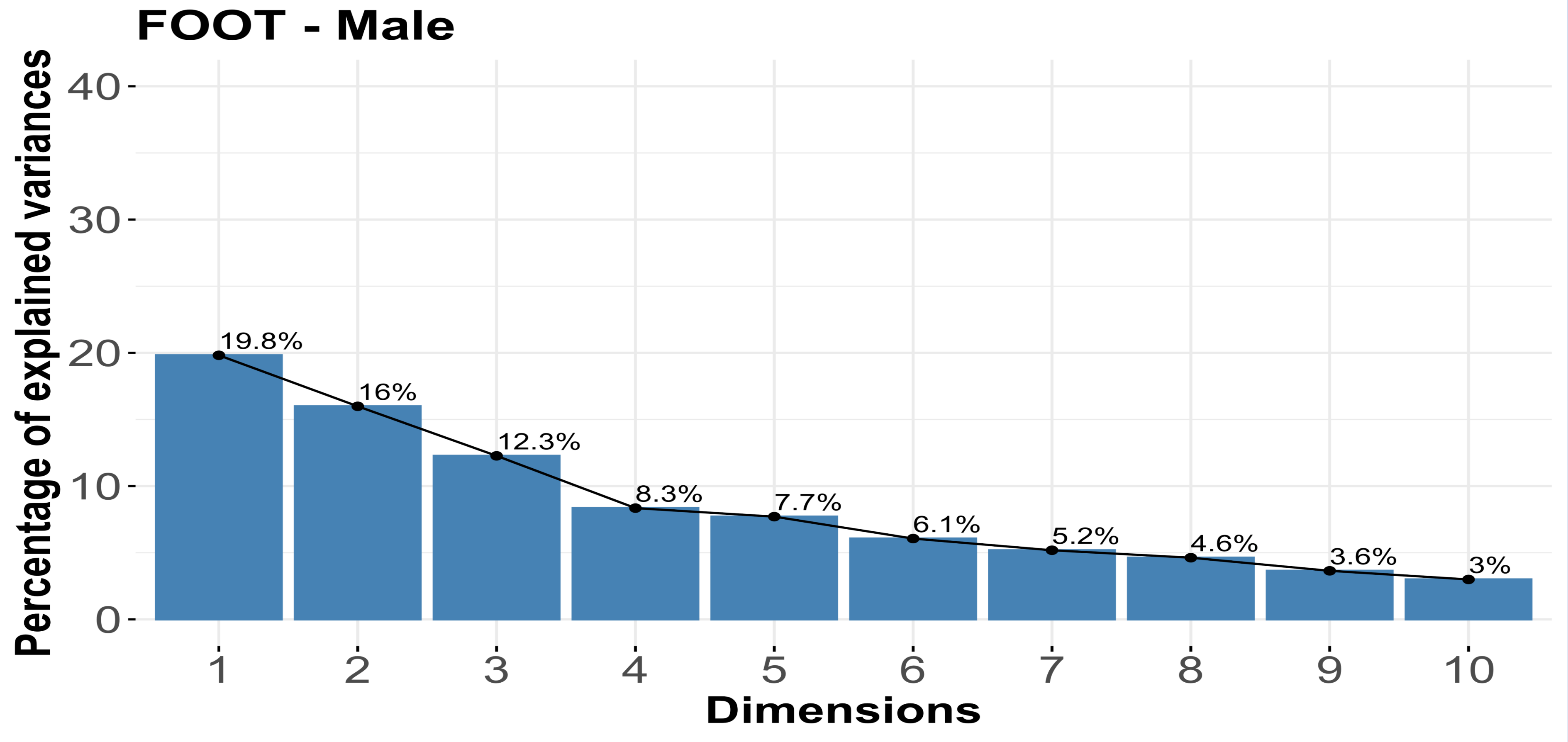
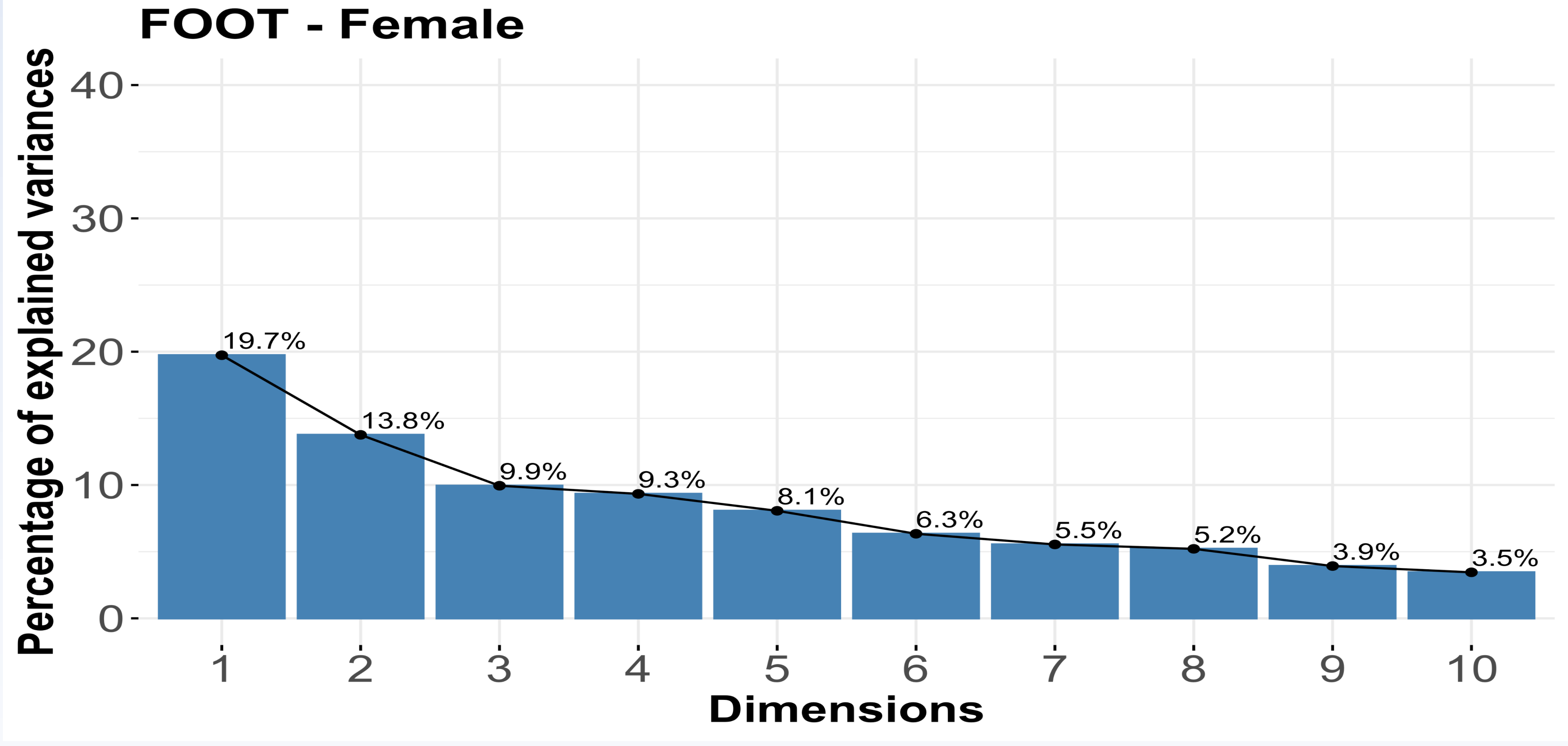
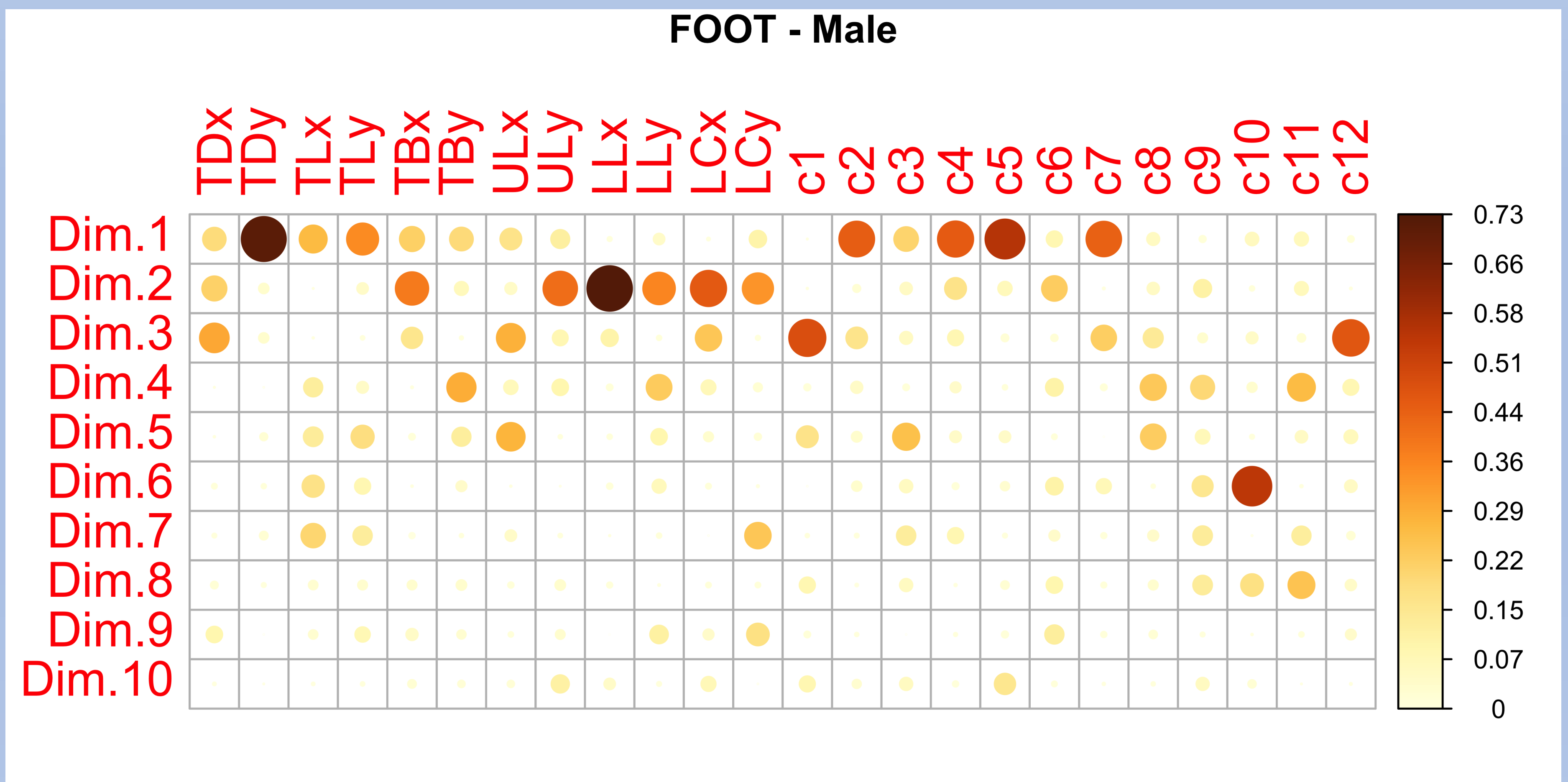


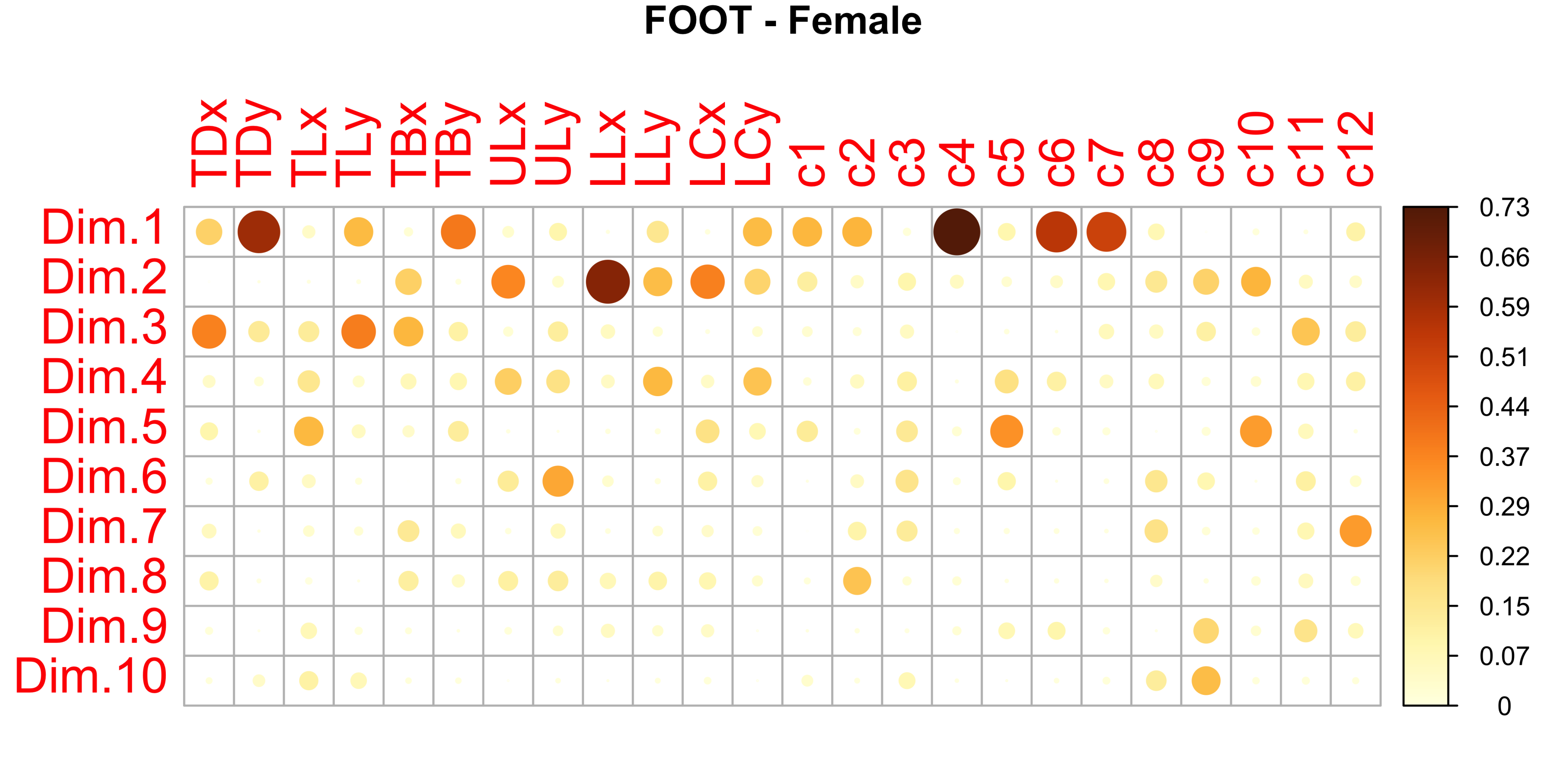
Fig. 1 Leftmost and central panel: sensor placement (Figure 1 from Ji et al. 2014). Rightmost panel: Target anatomically-referenced coordinate system. Positive increases in sensor values denote forward, upward, and rightward movement along x, y, z, respectively (Figure 2 from Berry et al., 2016 EMA-MAE corpus User's Handbook).

SOME RESULTS









PCA was carried out using the `nsprcomp` (Sigg & Buhmann, 2008) package, and the plots were generated using the `factoextra` (Kassambara & Mundt, 2020) package in R (R Core Team, 2022).

Discussion

Figures 1 &2

First six dimensions account for over 60% of variance explained for male (64.13%) and female (60.85%)

Figures 3 & 4

Dim. 1 TDy (vertical movement) well represented for both genders

Dim. 2 LLx (front and back) well represented for both genders

- **These are sensible similarities between male and female speakers from an articulatory perspective.**

Discrepancies in the wellness of the representation of MFCCs

Dim. 1 c2, c4, c5, c7 well represented for male speakers
c4, c6, c7 for female speakers

Sensible discrepancies in MFCC representation between male and female?

- MFCCs capture vocal track characteristics & articulatory movement
- Articulatory kinematics only captures articulatory movement
- Biological factor - male generally have longer vocal track and larger larynxes and thicker vocal folds than females (Yule 2010:275).

Future studies

- How can we take biological factors into consideration?
- More controlled data in terms of participants' height and weight?
- Explore the strength of association between MFCCs and articulatory data
- How does the change of articulatory gestures affect the MFCCs values?

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