Characterizing music for pain relief: a computational approach using music features and deep audio embeddings

Jelle J.F. Kouters[1, 2*], Emy S. van der Valk Bouman, MD[1**], Antonia S. Becker, MD[1], Gerard J.P. van Westen, PhD[2], Markus Klimek, MD, PhD[3]

[1] Department of Neuroscience, Erasmus Medical Center, Rotterdam, The Netherlands; [2] Division of Medicinal Chemistry, Leiden Academic Centre for Drug Research, Leiden University, Leiden, The Netherlands; [3] Department of Anesthesiology, Erasmus Medical Center, Rotterdam, The Netherlands.
*Presenting author (j.j.f.kouters@umail.leidenuniv.nl)

** Corresponding author (e.vandervalkbouman@erasmusmc.nl)

ERASMUS MC AI ACCELERATOR

BACKGROUND AND AIMS

- Music shows promise as an adjunctive treatment for acute and chronic pain, potentially reducing the need for pharmacological analgesics and their associated side effects [1].
- While self-selected and favourite music enhances music-induced analgesia [2], the specific characteristics of music used for pain relief remain poorly understood.
- **Aim: identify and analyze the characteristics of music for pain relief, selected by participants in two clinical studies, with "everyday music" (Dutch Top 40) using Spotify Audio Features, deep audio embeddings [3], and genre analysis.**

MATERIALS AND METHODS

Pain Music Dataset (PMD)
- 164 playlists / participants.
- ~1.900 tracks.

Mosart Dominant

Everyday Music Dataset (EMD)
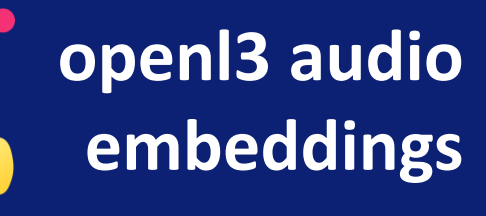- Music from 1980 – 2023.
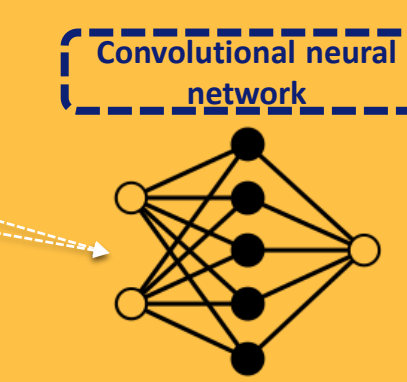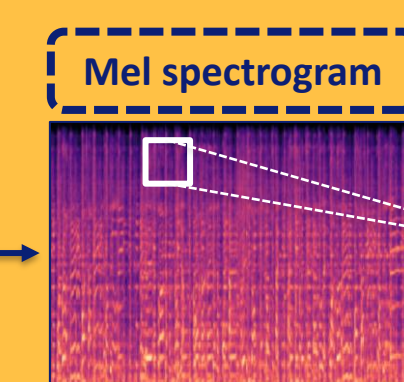- ~9.000 tracks.

TOP 40

Feature extraction

Spotify Audio Features
- Interpretable music features, such as **danceability, energy,** and **valence,** were extracted from the Spotify API using the Python package Spotipy.
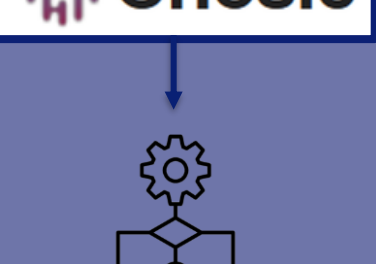
openl3 audio embeddings

Audio waveform → Mel spectrogram → Convolutional neural network → Audio feature vectors

PMD and EMD comparison

Genre analysis — Chosic

Feature quality assessment in genre clustering
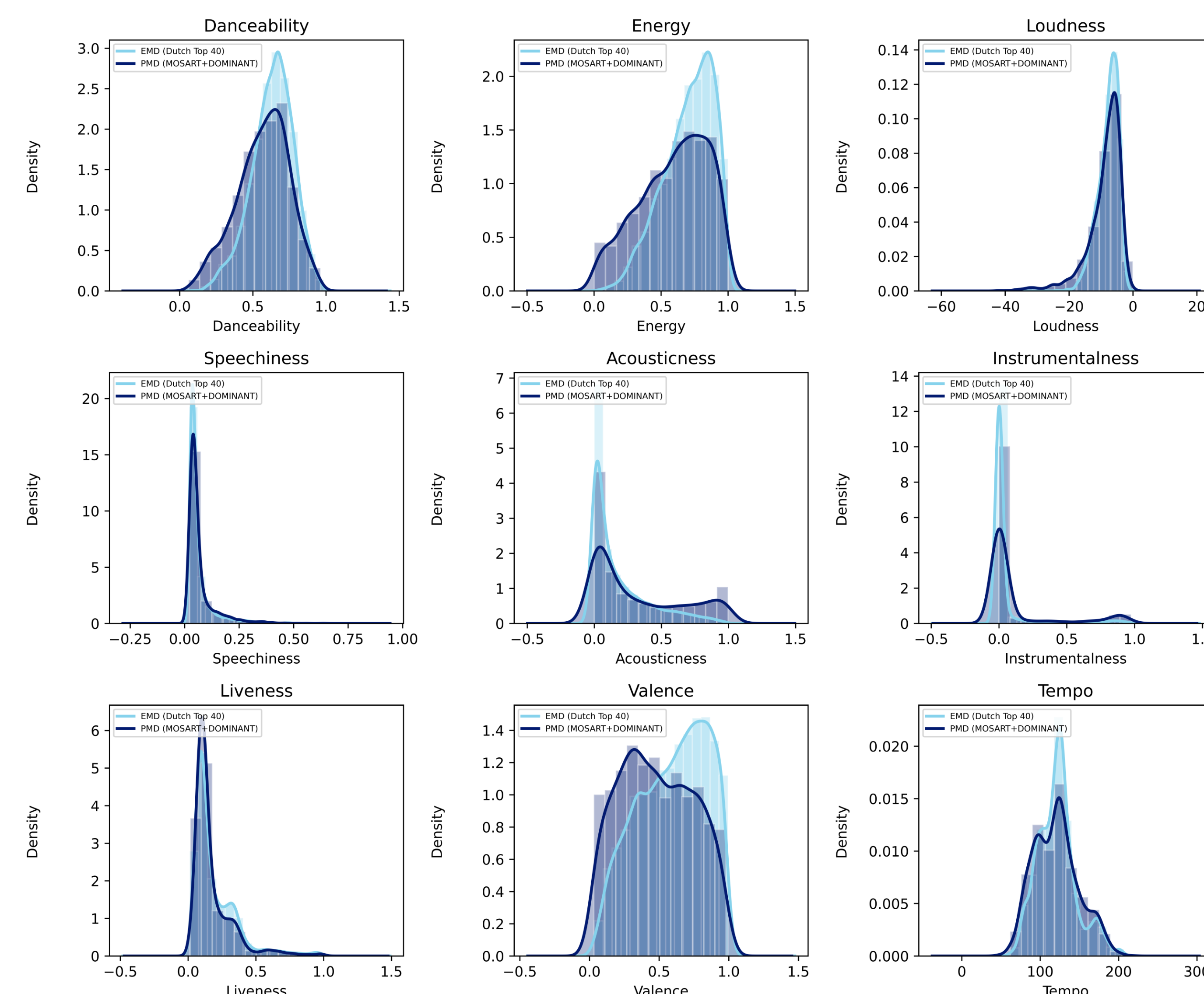
RESULTS

Figure 1. Comparison of Spotify Audio Features distributions between PMD and EMD. All audio features exhibit significant differences as determined by the Mann-Whitney U and the Kolmogorov-Smirnov tests.
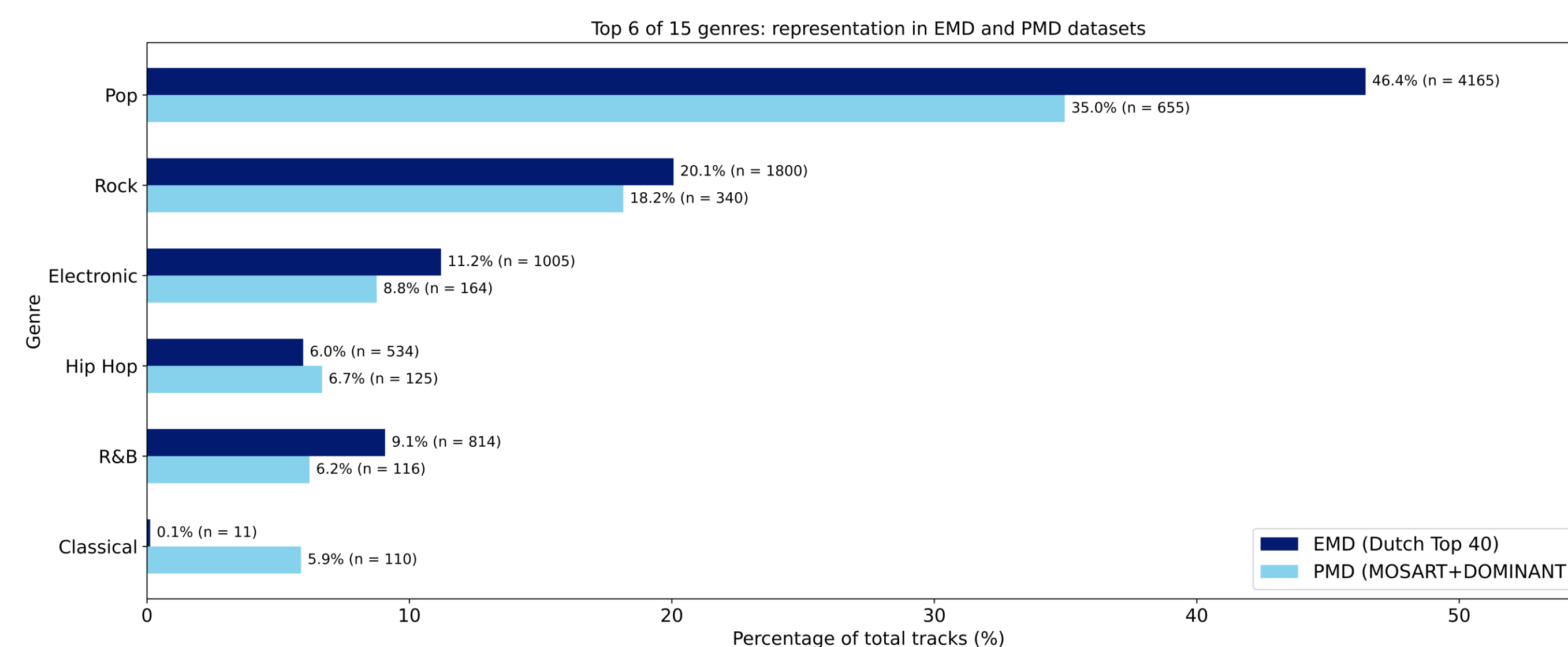

Top 6 of 15 genres: representation in EMD and PMD datasets

Genre	EMD (Dutch Top 40)	PMD (MOSART+DOMINANT)
Pop	46.4% (n = 4165)	35.0% (n = 655)
Rock	20.1% (n = 1800)	18.2% (n = 340)
Electronic	11.2% (n = 1005)	8.8% (n = 164)
Hip Hop	6.0% (n = 534)	6.7% (n = 125)
R&B	9.1% (n = 814)	6.2% (n = 116)
Classical	0.1% (n = 11)	5.9% (n = 110)

Figure 2. Genre analysis reveals overlap in the number of tracks per genre between EMD and PMD.

- The genre diversity score (entropy) for PMD is **3.06**, compared to **2.38** for EMD, indicating greater genre diversity in PMD.
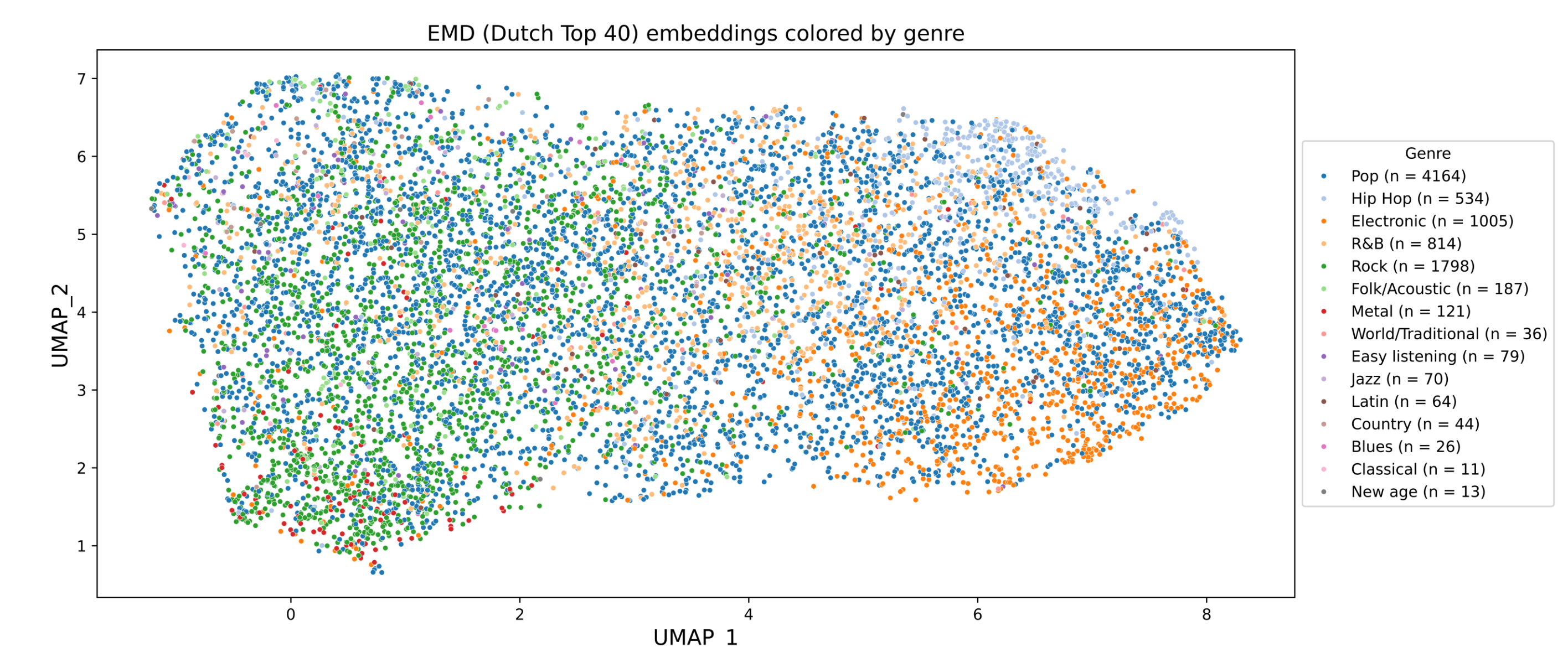

EMD (Dutch Top 40) embeddings colored by genre

Genre
- Pop (n = 4164)
- Hip Hop (n = 534)
- Electronic (n = 1005)
- R&B (n = 814)
- Rock (n = 1798)
- Folk/Acoustic (n = 187)
- Metal (n = 121)
- World/Traditional (n = 36)
- Easy listening (n = 79)
- Jazz (n = 70)
- Latin (n = 64)
- Country (n = 44)
- Blues (n = 26)
- Classical (n = 11)
- New age (n = 13)

Figure 3. Deep audio embeddings clearly capture and represent genre-specific characteristics.

Pairwise k-means clustering (Everyday Music Dataset)

Feature set	mean Silhouette score	mean Adjusted Rand Index	mean Normalized Mutual Information
Spotify Audio Features	0.4270	0.0243	0.0309
openl3 audio embeddings	0.4848	0.1050	0.0967

CONCLUSION

- The analysis of Spotify Audio Features and audio embeddings showed significant differences between PMD and EMD.
- Genre analysis demonstrated greater genre diversity in the music selected by participants for pain relief (PMD) compared to the EMD.
- *K*-means clustering of tracks categorized under the same genre achieved improved clustering quality with the audio embeddings, highlighting their enhanced performance for genre visualization and potential applicability in tasks such as genre prediction or music characterization.

REFERENCES

1. Hole J, Hirsch M, Ball E, Meads C. Music as an aid for postoperative recovery in adults: a systematic review and meta-analysis. The Lancet 2015;386(10004):1659-1671.
2. Basinski K, Zdun-Ryzewska A, Greenberg DM, Majkowicz M. Preferred musical attribute dimensions underlie individual differences in music-induced analgesia. Sci Rep 2021;11(1):8622.
3. Cramer AL, Wu H, Salamon J, Bello JP. Look, Listen, and Learn More: Design Choices for Deep Audio Embeddings. ICASSP 2022 - IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) 2019;3852-3856.

MUZIEK ALS MEDICIJN