Temporal Dynamics of Electrodermal Responses to Music: A Step Towards Multimodal Brain–Body Analysis

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Research Question

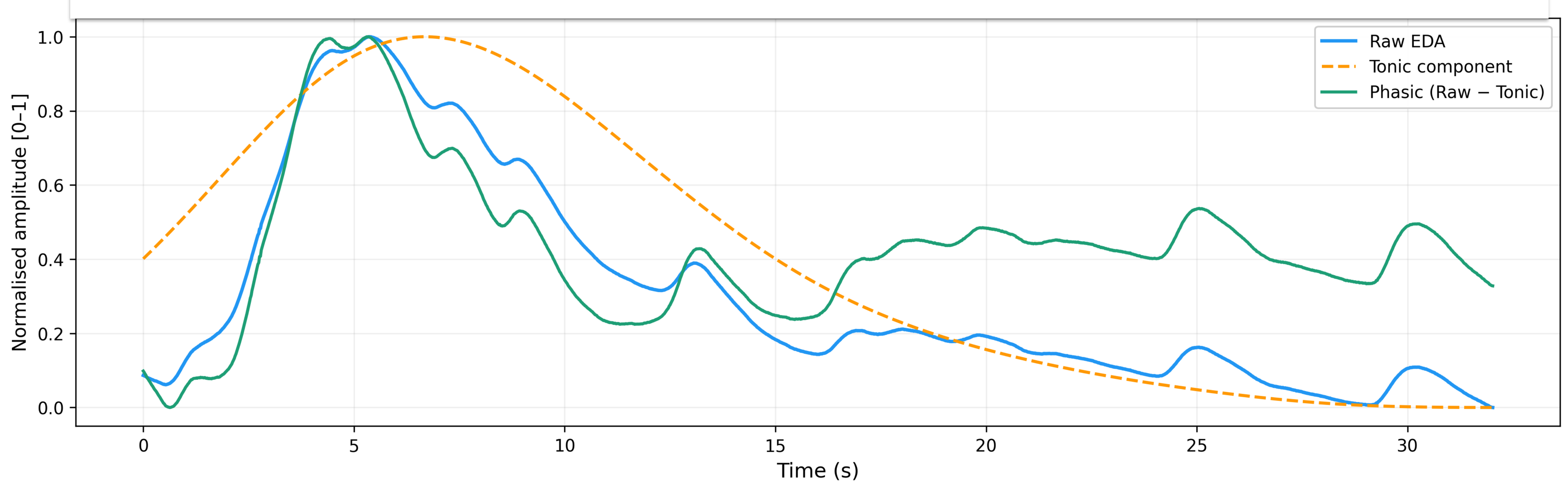
What are the temporal dynamics of electrodermal activity (EDA) during music listening?

Music can evoke physiological responses that unfold over several seconds [1]. Electrodermal activity (EDA) is a widely used measure of autonomic arousal and is characterised by skin conductance responses (SCRs).

Objectives

- Characterise how phasic EDA evolves during listening to short music excerpts [2].
- Identify the timescales over which autonomic responses emerge in relation to the musical signal.
- Establish the EDA component of an ongoing multimodal framework, with EEG analyses currently in progress.

Eda decomposition



Tonic = slow baseline drift | Phasic = fast SCR events (raw - tonic)

Dataset

PMEmo2019 🖐 ⚡ 🎵

Western Pop Music Excerpts, EDA recorded at 50 Hz during listening [2].

- 794 Songs
- 401 Participants
- 7960 Recordings

MUSIN-G 🧠 🎵 – Analyses Ongoing

Full length songs, Electroencephalography (EEG) through 128 channels, recorded during naturalistic music listening [3].

- 12 Songs
- 20 Participants
- 240 Recordings

Selected Acoustic Features extracted via Librosa

Features extracted at native audio rate, then resampled to 50 Hz to align with EDA sampling rate

- **Envelope (RMS)** – Overall loudness over time
- **Onset Strength** – Rhythmic Attack Strength
- **Pitch (pyin)** – Perceived Note Frequency
- **Spectral Centroid** – Spectral Brightness
- **Spectral Bandwidth** – Spectral Spread
- **MFCC3** – Timbral texture

Methodology

EDA Processing

Raw EDA signal (50 Hz, PMEmo2019)

↓

Tonic / Phasic decomposition via NeuroKit2

↓

Phasic EDA z-scored per song

↓

Mean phasic EDA averaged across participants

Phasic EDA captures skin conductance responses (SCRs) driven by sympathetic

Lag-Correlation

Pearson r between each feature and phasic EDA at lags -10 to +10 s.

- Lag-correlation profiles were computed at the participant level and aggregated across participant-song recordings
- Results summarize temporal coupling patterns across 794 songs and 401 participants
- Adaptive overlap constraints were applied to reduced edge effects at large lag values

Temporal Response Function(TRF):

$$r(t) = \Sigma\, w(\tau) \cdot s(t-\tau) + \varepsilon(t)$$

where **r(t)** = phasic EDA, **s(t)** = acoustic feature, **w(τ)** = TRF weight at lag τ, **ε(t)** = residual

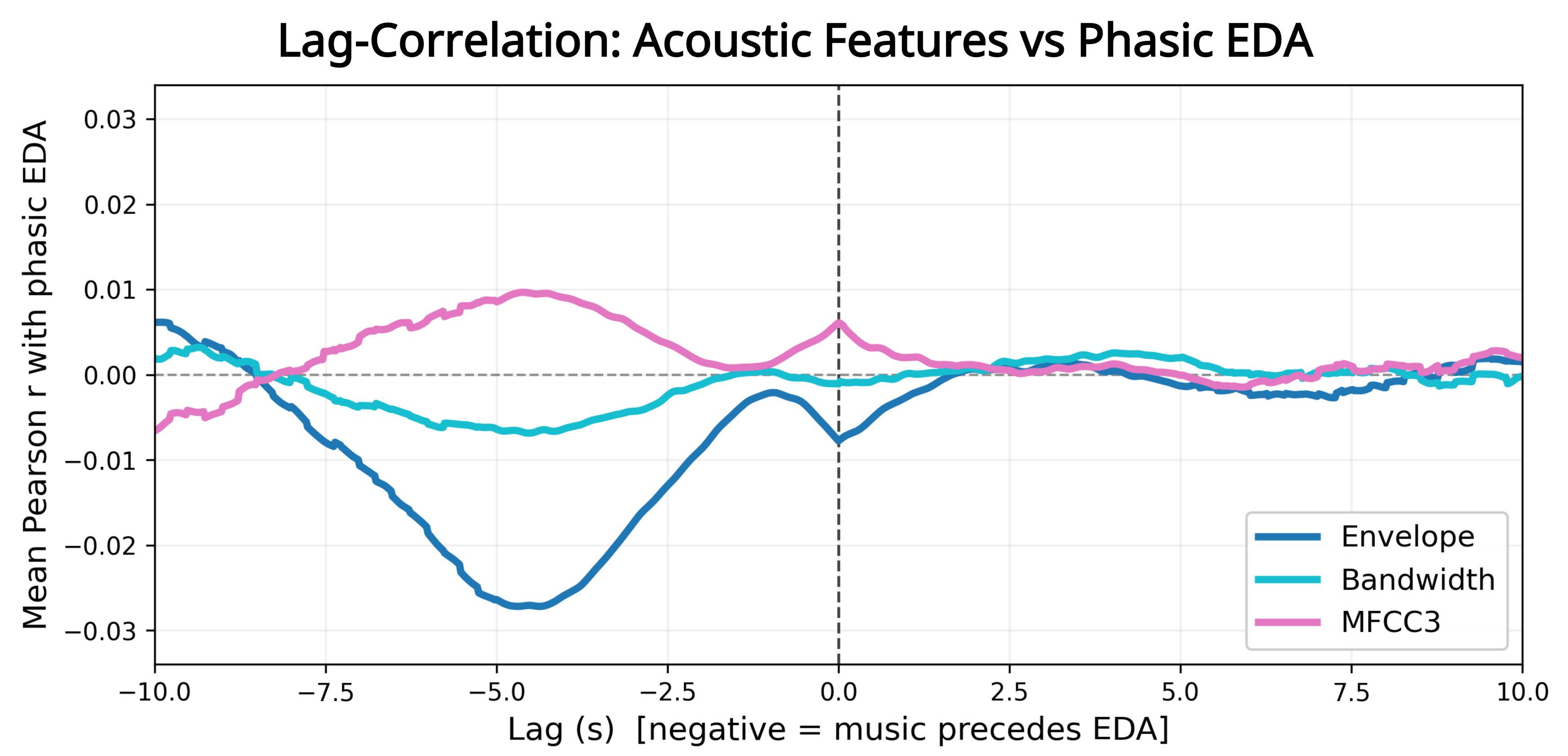
Encoding

Linear filter: acoustic feature → phasic EDA, cross-validated boosting (±10 s, 0.05–0.5 Hz)

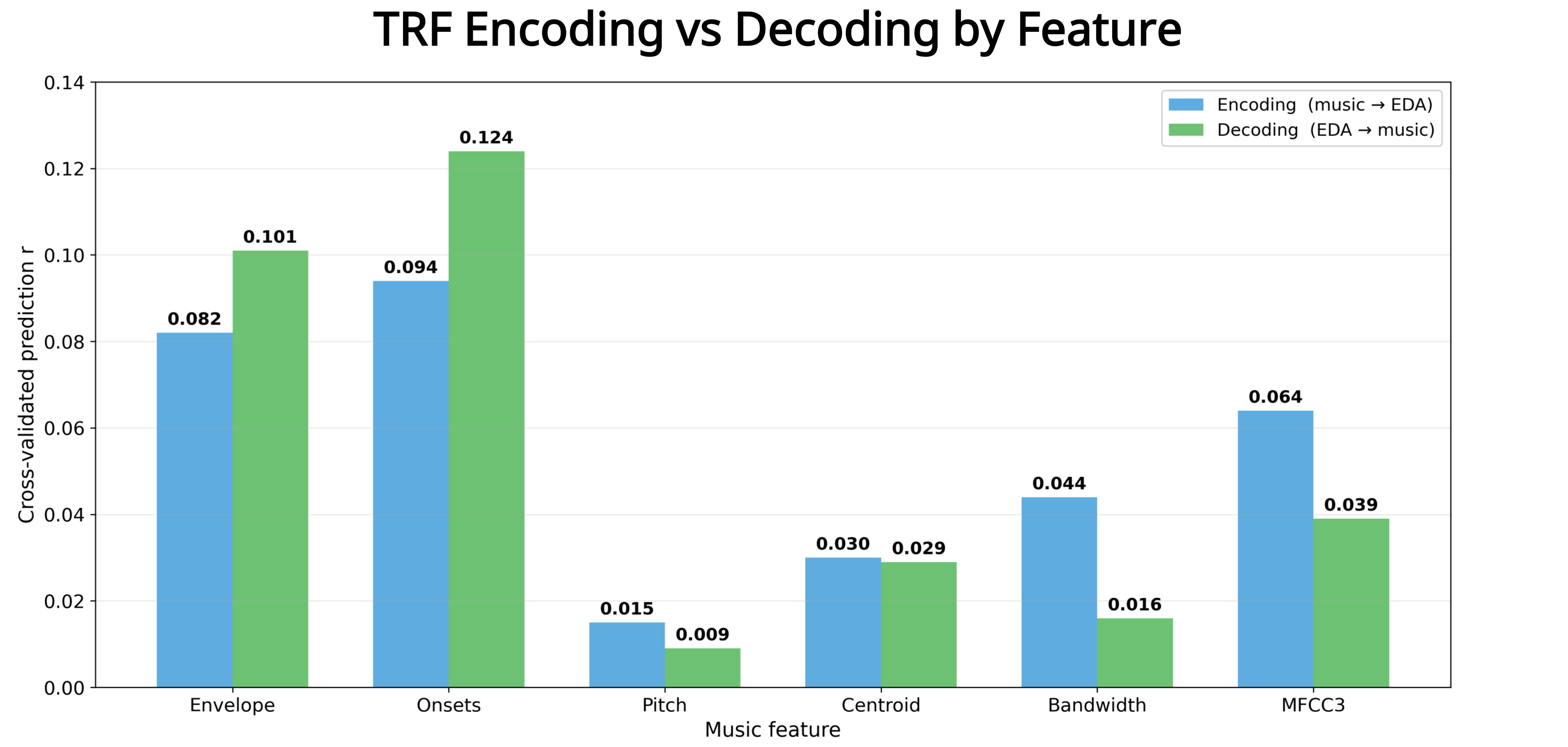
Decoding

Reverse mapping: phasic EDA → acoustic feature, same framework as encoding [4,5].

Results

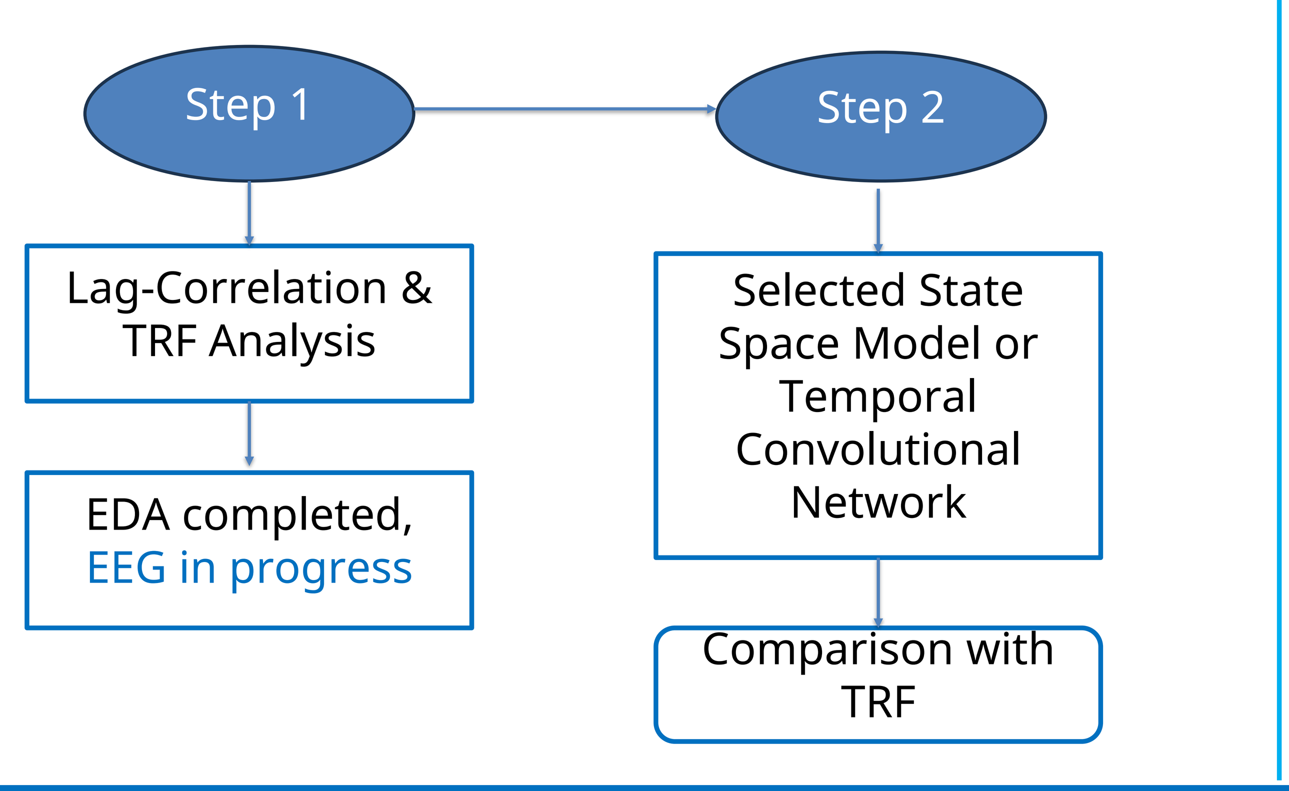


Three representative features show consistent coupling with phasic EDA, peaking around -5 s, reflecting the slow latency of skin conductance responses. Envelope, Bandwidth and MFCC3 show distinct coupling profiles.



For Onset and Envelope, decoding outperforms encoding, suggesting the autonomic response contains information not fully captured by forward linear modelling. Spectral features show weaker coupling.

Towards Modelling



💡 Main Findings

- Phasic EDA exhibits measurable coupling with musical stimuli.
- Associations emerge on a slow timescale, consistent with known EDA physiology.
- Decoding outperforms encoding for selected features, indicating temporally distributed autonomic responses.
- These findings support the use of EDA as a marker of music-evoked physiological dynamics.

References

[1] Koelsch (2010) Towards a Neural Basis of Music-Evoked Emotions. Trends Cogn. Sci. 14(3). doi:10.1016/j.tics.2010.01.002
[2] Zhang et al. (2018) The PMEmo Dataset for Music Emotion Recognition. ACM ICMR. doi:10.1145/3206025.3206037
[3] Miyapuram et al. (2022) Music Listening-Genre EEG Dataset (MUSIN-G). OpenNeuro. doi:10.18112/openneuro.ds003774.v1.0.2
[4] Crosse et al. (2021) Linear Modeling of Neurophysiological Responses to Speech and Other Continuous Stimuli. Front. Neurosci. doi:10.3389/fnins.2021.705621
[5] Crosse et al. (2016) The Multivariate Temporal Response Function (mTRF) Toolbox: A MATLAB Toolbox for Relating Neural Signals to Continuous Stimuli. Front. Hum. Neurosci. 10:604. doi:10.3389/fnhum.2016.00604

Potential Applications: Music therapy• Physiological Biomarkers • Affective computing • Personalised healthcare