

# Triangle Simplex Plots for Representing and Classifying Heart Rate Variability

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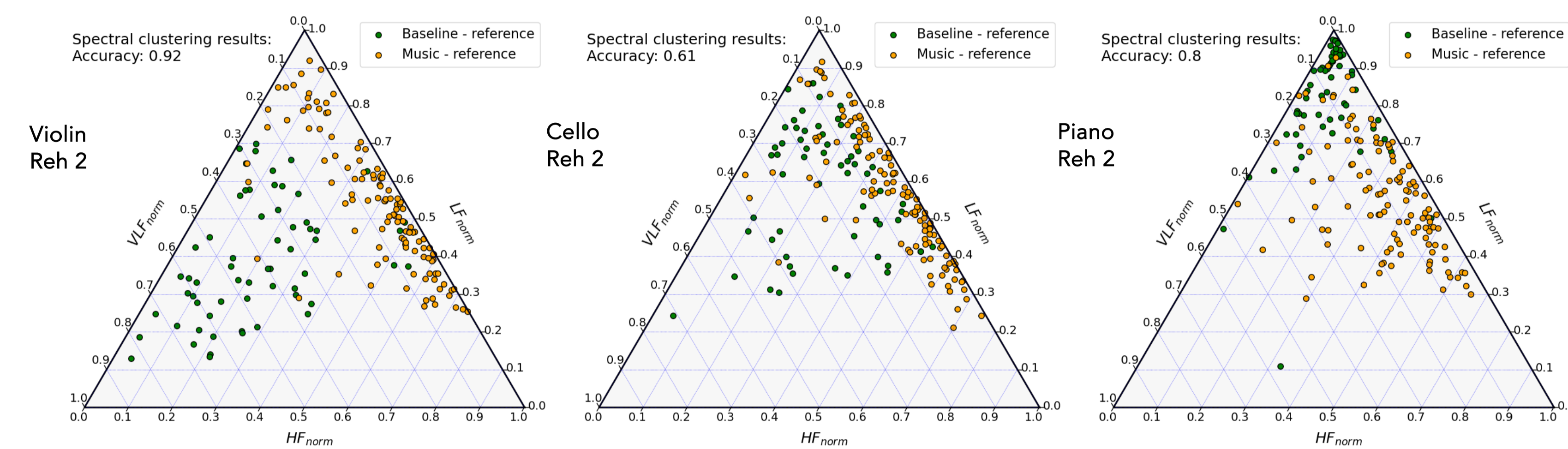
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Heart rate variability (HRV) and beat-to-beat RR intervals are important predictors of autonomic nervous system response. Power spectrum HRV (PS/HRV) comprises very low (VLF), low (LF), and high (HF) frequencies [1]. There are several methods for visualising the PS/HRV, including power spectrum density in the frequency domain, spectrogram (time-frequency analysis) or numerical values (total power in the frequency components).

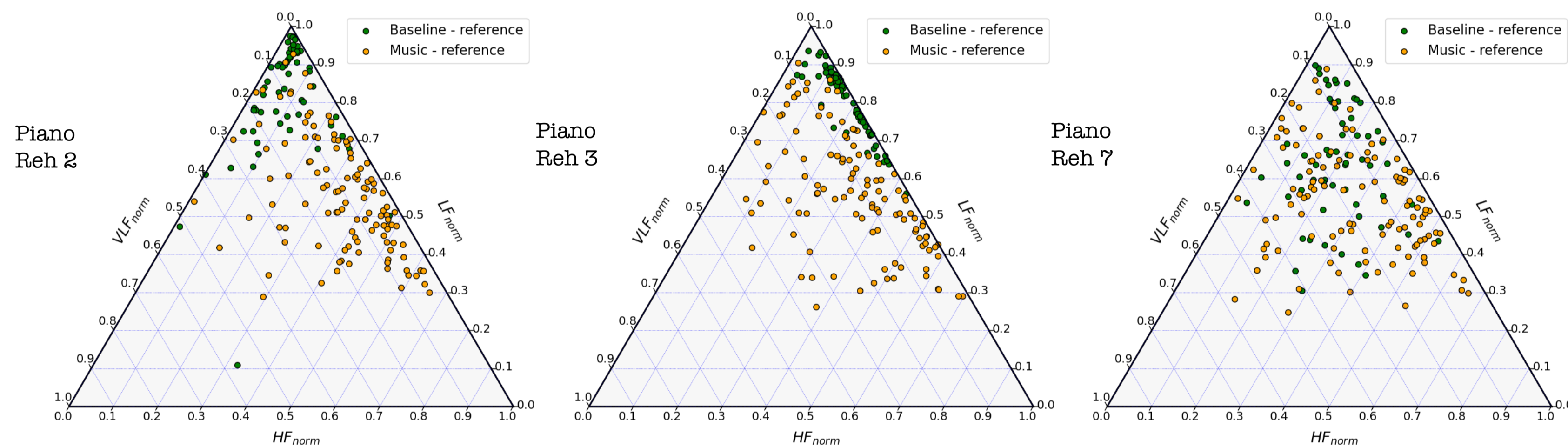
In this study, we use **triangle simplex plots** [2,3], as a novel visualization method to characterise HRV data from a trio of musicians.

## Results

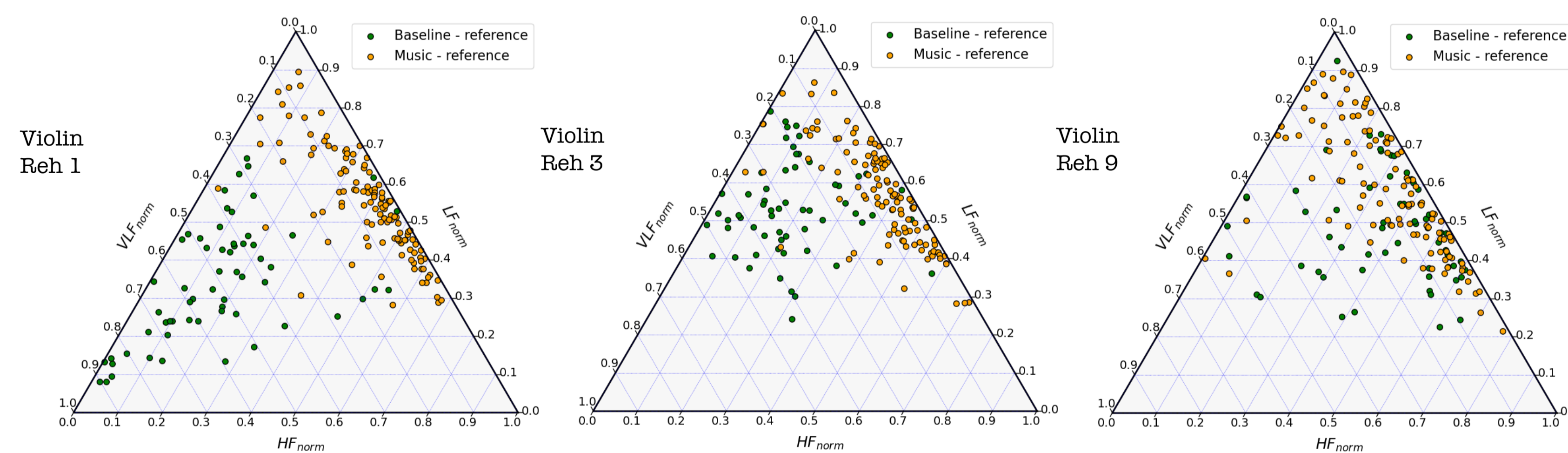
### Example I: All players, rehearsal 2



### Example II: Pianist, rehearsals 2, 3, 7

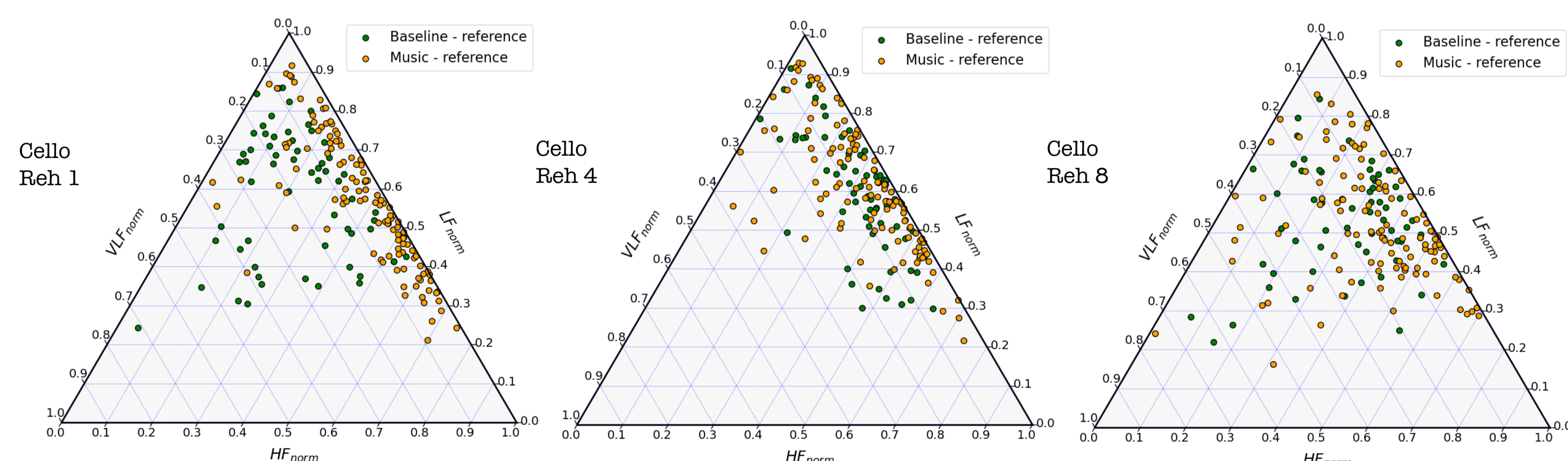


### Example III: Violinist, rehearsals 1, 3, 9



The the baseline and performance become less distinguishable over rehearsals, which may indicate a learning effect or adaptation to the task over repeated performances, significant for violin, weakly for piano, and less so for cello.

### Example IV: Cellist, rehearsals 1, 4, 8



## Conclusions

We applied triangle simplex plots as a novel method for computational cardiology. The clustering on the simplex representation showed visible and quantifiable trends in the changes between baseline and performance over nine recordings.

Simplex plots can be a useful research tool for assessing autonomic changes in cardiovascular research.

## Method

We collected RR interval series from a professional violin, cello, piano trio over 9 performances of Schubert's Trio Op. 100, *Andante con moto*. We computed VLF, LF, and HF components from RR intervals in moving windows (30s, hop size 15s).

### How to create a Triangle Simplex Plot?

Triangle Simplex Plots are 2D plots that depict three variables summed to a constant, typically 1.

Taking frequency components extracted from RR interval series, calculated in moving windows, the normalised frequency components:

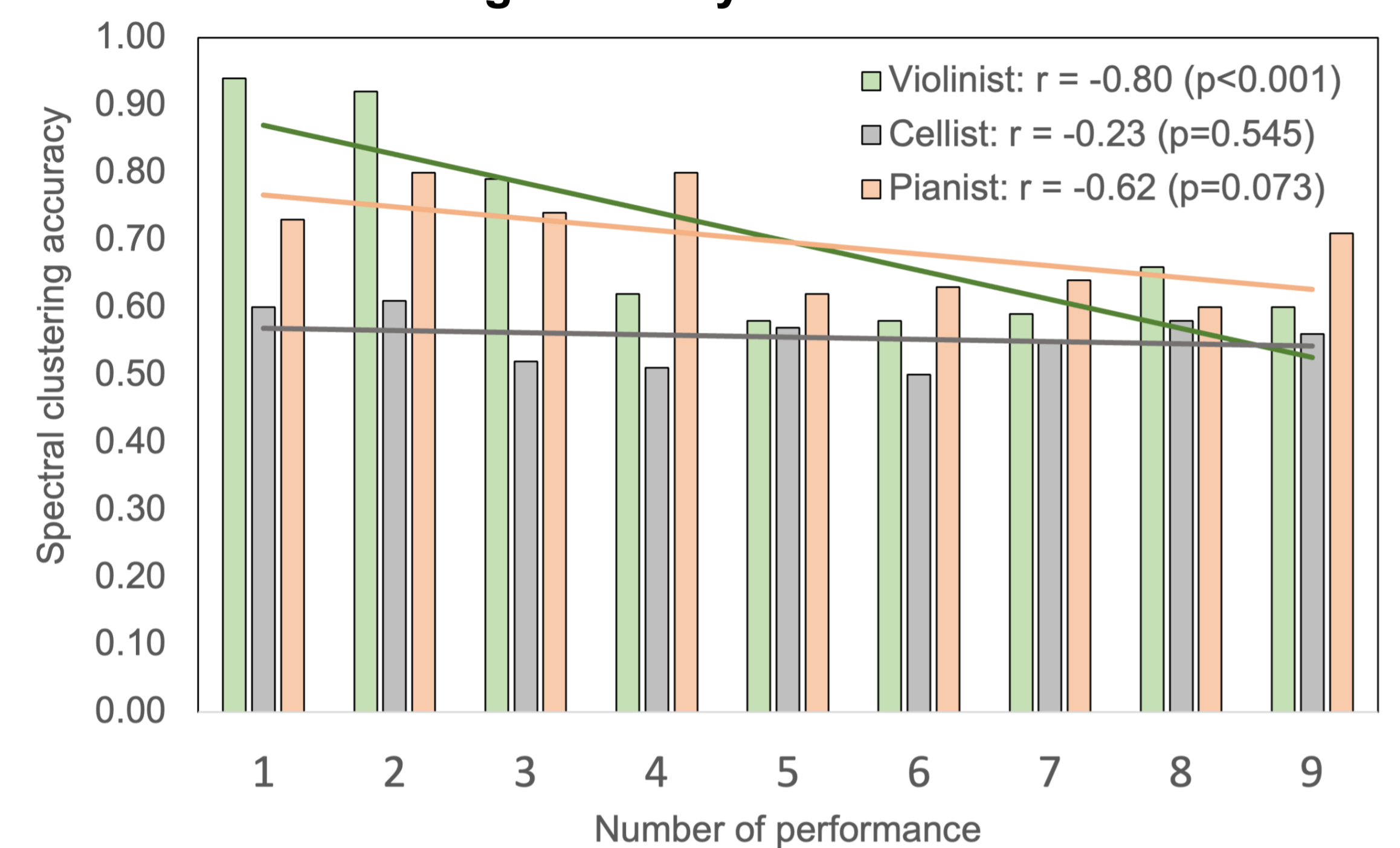
$$VLF_{norm(i)} = VLF_i / (VLF_i + LF_i + HF_i)$$

$$LF_{norm(i)} = LF_i / (VLF_i + LF_i + HF_i)$$

$$HF_{norm(i)} = HF_i / (VLF_i + LF_i + HF_i)$$

A single point on the simplex plot consists of three coordinates:  $[VLF_{norm(i)}, LF_{norm(i)}, HF_{norm(i)}]$ .

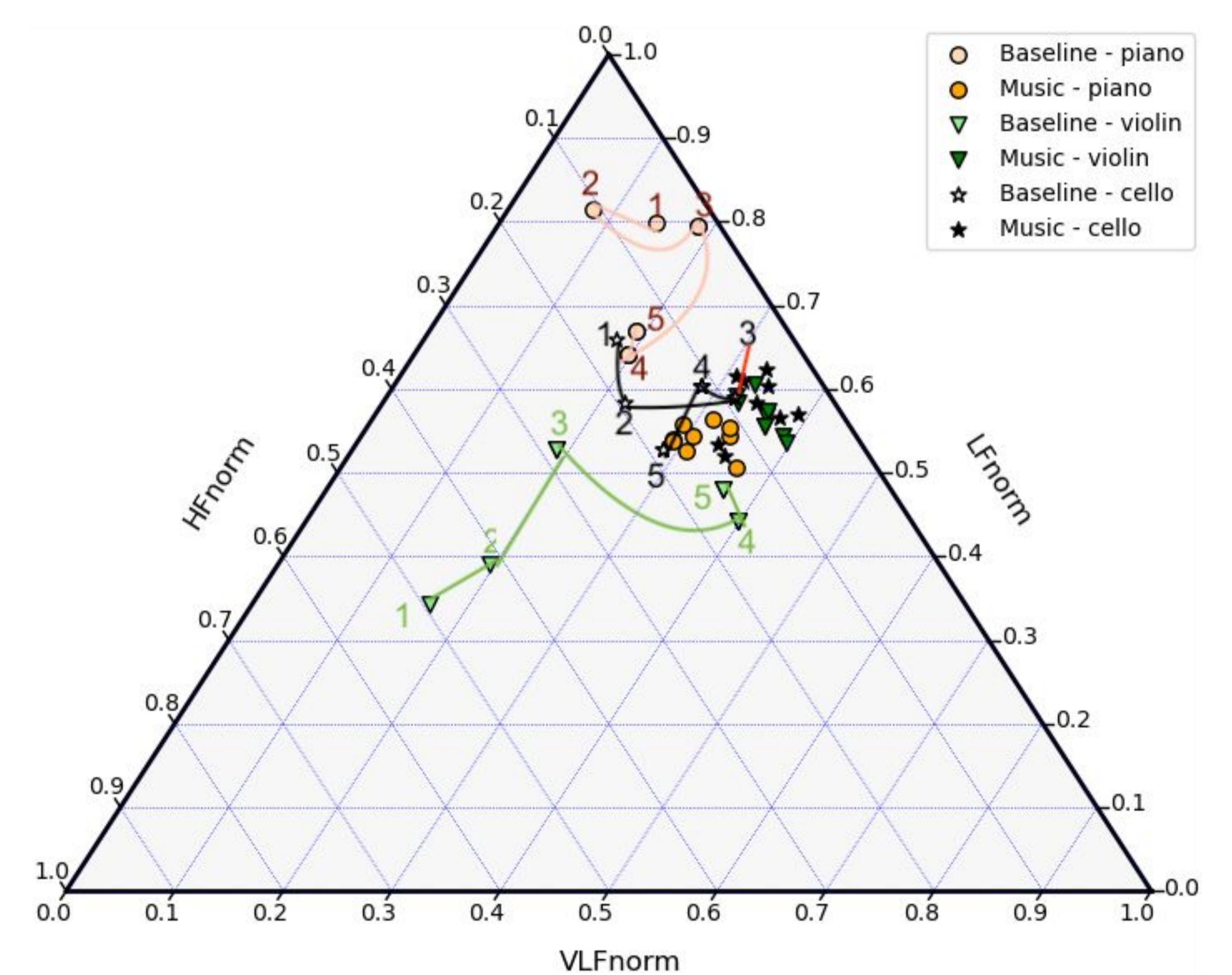
### Clustering Accuracy Over Rehearsals



Spectral clustering categorized data into baseline and music. Linear correlation determined the relationship between clustering accuracy over subsequent performances.

The negative correlation between baseline and performance found for the violinist and pianist suggests that, over time, the difference between baseline and performance decreased.

### Cluster Centroid Trajectories Over Rehearsals



[1] Malliani A, Lombardi F, Pagani M. Power spectrum analysis of heart rate variability: a tool to explore neural regulatory mechanisms. *Heart* 1994;71(1):1-2.  
[2] Holland SM. Data Analysis in the Geosciences. 2016. <http://stratigrafia.org/8370/rtps/ternaryPlots.html>.  
[3] Jacoby N, et al. Universality and cross-cultural variation in mental representations of music revealed by global comparison of rhythm priors. *PsyArXiv Preprints* 2021

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