CORRELATION OF EEG RESPONSES REFLECTS STRUCTURAL SIMILARITY OF CHORUSES IN POPULAR MUSIC

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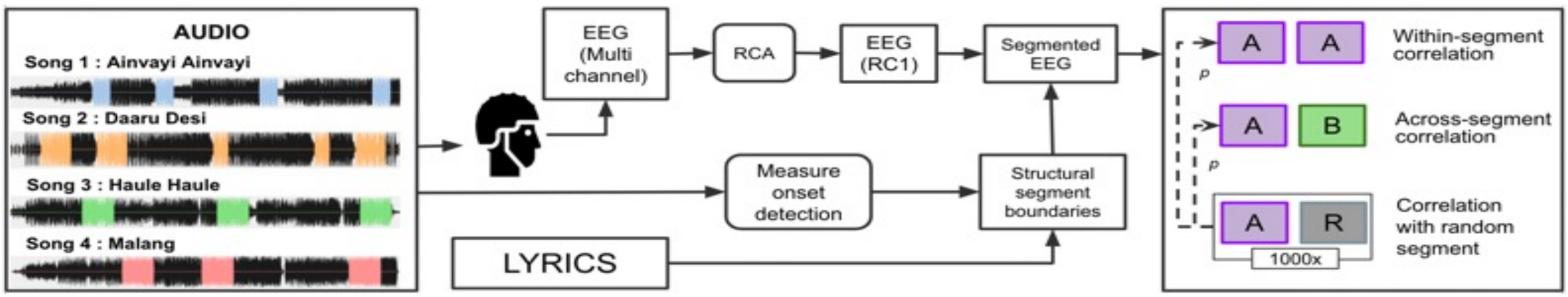
Introduction

- **Music Structure Analysis (MSA)** is a core MIR topic that uses different data modalities such as lyrics, audio representation, and perceptual annotations to recognize song segments.[1]
- We leverage EEG data to investigate MSA.
- For the first time, we study correlation of neural responses for both within and across chorus instances. We also investigate **Inter-Subject Correlations (ISC)** and **Intra-Subject Correlations (IaSC)**.

EEG Dataset and Stimuli

- We used the **NMED-H dataset**, a publicly available dataset of dense array EEG responses to four full-length Bollywood songs where each song was around 4 min 30 sec in length (N=48).[4]
- Each song had **24 trials** from 12 subjects (2 listens for each subject).
- We used the preprocessed **125 channel EEG data sampled at 125Hz**.
- Stimuli was assumed to be unknown to the subjects who did not understand the Hindi dialect lyrics.

Method



Audio Segmentation

Structural segment boundaries were identified on a measure level for all four songs. **Chorus segments** were extracted based on lyrics and further, audio sample indices using timestamps and sampling rate.

EEG Analysis

1. Multichannel EEG data were optimized for ISC via a spatial filtering procedure called **Reliable Components Analysis (RCA).**[3] The spatial filter was computed once across all trials for all four songs.

2. EEG segmentation was done by using timestamp boundaries of audio chorus segments and identifying audio sample indices in EEG using the EEG sampling rate.

3. On a per-song basis, **Inter-subject** and **Intra-subject correlations** were conducted for within-chorus and across-chorus scenarios.

4. **Statistical Significance** of ISC and IaSC was assessed using **permutation testing. One-sided Wilcoxin signed-rank test** was performed to test if correlations were higher within than across choruses, and higher within than across subjects.

Results

1. After multiple comparison correction, the following were **statistically significant**:
   - 14 out of 15 within-chorus ISCs.
   - 12 out of 22 across-chorus ISCs.
   - 10 of 15 within-chorus IaSCs.
   - 2 of 22 across-chorus IaSCs.
2. Within-chorus correlation exceeded across-chorus correlation 7 times for IaSC and 4 times for ISC, often for the first chorus instance of a song.
3. IaSC never significantly exceeded ISC for within- or across-chorus correlations.

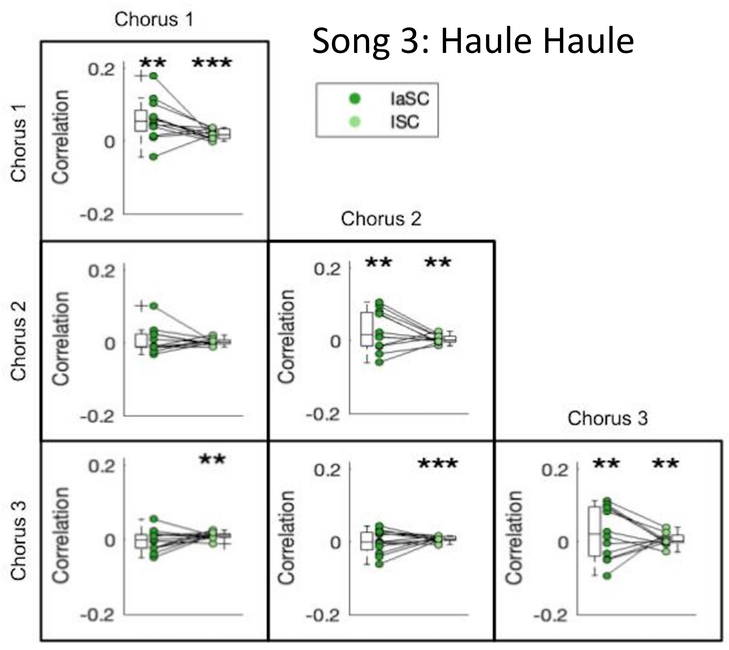


Fig 1: EEG correlations within and across choruses for Haule Haule song in NMED-H.

		IaSC					ISC				
		C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
Song 1	C1	-	*	*	*		-	**	**	*	
	C2	ns	-	ns	ns		ns	-	ns	ns	
	C3	ns	ns	-	**		ns	ns	-	ns	
	C4	ns	ns	ns	-		*	*	ns	-	
Song 2	C1	-	**	**	**	**	-	ns	ns	ns	ns
	C2	ns	-	ns	ns	ns	ns	-	ns	ns	ns
	C3	ns	ns	-	ns	ns	ns	ns	-	ns	ns
	C4	ns	ns	ns	-	ns	ns	ns	ns	-	ns
	C5	ns	ns	ns	ns	-	ns	*	*	ns	-
Song 3	C1	-	***	***			-	***	**		
	C2	ns	-	*			ns	-	ns		
	C3	ns	ns	-			ns	ns	-		
Song 4	C1	-	ns	ns			-	ns	ns		
	C2	ns	-	ns			ns	-	ns		
	C3	ns	ns	-			ns	ns	-		

Fig 2: Results of one-sided Wilcoxin signed-ranked test assessing if within chorus correlations exceeds across chorus correlations.

Discussion

- For the first time, we report significantly correlated neural responses not only in relation to a single stimulus segment, but also across structural repetitions in natural music.
- EEG ISC values are on par with past literature.[2]
- We also see first neural evidence that first chorus of popular songs might be processed differently from later choruses.[5]
- **Future Work** can include a larger song set and comparisons of neural measures against other measures of similarity, such as perceptual or audio-based.

References

[1] O. Nieto, G. J. Mysore, C.-i. Wang, J. B. Smith, J. Schlüter, T. Grill, and B. McFee, "Audio-based music structure analysis: Current trends, open challenges, and applications," Transactions of the International Society for Music Information Retrieval, vol. 3, no. 1, 2020.
[2] Dauer, T., Nguyen, D. T., Gang, N., Dmochowski, J. P., Berger, J., & Kaneshiro, B. (2021). Inter-subject correlation while listening to minimalist music: a study of electrophysiological and behavioral responses to Steve Reich's piano phase. Frontiers in neuroscience, 15, 702067.
[3] Dmochowski, J. P., Sajda, P., Dias, J., & Parra, L. C. (2012). Correlated components of ongoing EEG point to emotionally laden attention–a possible marker of engagement? Frontiers in human neuroscience, 6, 112.
[4] Kaneshiro, B., Nguyen, D. T., Dmochowski, J. P., Norcia, A. M., & Berger, J. (2016). Naturalistic music EEG dataset—Hindi (NMED-H). In Stanford Digital Repository
[5] Kaneshiro, B., Ruan, F., Baker, C. W., & Berger, J. (2017). Characterizing listener engagement with popular songs using large-scale music discovery data. Frontiers in psychology, 8, 416.

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