

Introduction

Cadences and Pre-Cadential Contexts

- In Western tonal music, **cadences** are harmonic progressions composed of two fundamental chords that conclude musical phrases. There are various cadence types, and those with endings increasingly deviating from the tonic (the most stable note of a key) introduce more syntactic irregularities and provide a reduced sense of resolution.
- The pre-cadential context is the tonal quality, or mode (Major or minor), of the musical material preceding the cadence. The precadential context and the final chord of a cadence can have a congruent (Major-to-Major, minor-to-minor) or incongruent (Majorto-minor, minor-to-Major) relationship.



Neural Correlates of Cadential Processing

- Early right anterior negativity (ERAN) refers to the negativity of the event-related potential (ERP) elicited in response to large syntactic irregularities within musical chord progressions, typically in the right frontocentral region with a latency around 200ms [1-5].
- The ERAN is generally followed by a P3a (200-400ms) and N5 (400-600ms), both observed in the frontocentral area.
- The **P3a** is considered to reflect the processing of low-probability, infrequent stimuli or novel, salient stimuli during tasks that do not require attention [6].
- The N5 is a late negative component that elicits in response to violations of harmonic expectations and is sensitive to the integration of tonal contexts [2-4].

Present Study & Hypotheses

• The current study examines the ERAN and subsequent ERPs for more realistic, various cadence types. We explore how different types of syntactic irregularities in cadences are reflected in the ERPs.

Cadence Type x Type of Syntactic Irregularity	Final Chord	In-Key vs. Out-of-Key Final Chord	Pre-Cadential vs. Cadential Mode
Authentic	Tonic	In-Key	Congruent
Parallel-Mode Tonic	Tonic	Out-of-Key	Incongruent
Deceptive	Non-Tonic chord built on the Sixth scale degree	In-Key	Incongruent
Neapolitan	Non-Tonic, Major chord built on the flatted Second scale degree	Out-of-Key	Congruent in Major mode; Incongruent in minor mode

- In addition, the P3a and N5 are anticipated to succeed the ERAN for deviant (non-Authentic) cadence types. These ERP components may share a similar relationship to the ERAN where greater syntactic irregularity and years of music experience may correlate with heightened responses.
- Through secondary analyses, participants' behavioral responses to cadences may reflect their ERP responses.

Neural and perceptual correlates of modal incongruence between local and global syntax

¹Center for Computer Research in Music and Acoustics (CCRMA), Department of Music, Stanford University, USA

Methods

Participant

• 39 participants (22 females, 17 males; 5 left-handed, 1 ambidextrous, rest right-handed) • Age (years): Mean = 23.1, SD = 6.1

• Musical experience (years): Range = 0:40, Median = 7, Q1 = 2.8, Q3 = 10.5

- Stimuli • Each chord sequence contains 5 chords in which the first 4 chords (500ms each) provide tonal context and the final 5th chord (900ms) indicates
- the cadence type. • The penultimate chord (4th chord) is always the dominant (V).
- There are 8 cadence conditions: 4 cadence types (Authentic, Parallel-Mode Tonic, Deceptive, and Neapolitan) x 2 pre-cadential modes (Major or minor`
- 5 unique variations were composed and transposed to 4 different keys per cadence condition (5 x 4 x 8 = 160 possible trial combinations).
- Per block, 16 chord sequences were presented in marimba timbre for a simple timbre deviant identification task (button press) in addition to the 160 presented in piano timbre

8 Cadence Conditions per Variation



Procedure and Apparatus

 Neuroscan SymAmpRT with whole-head 64-channel Neuroscan Quik-Cap (10-20 system) • Recordings conducted in a sound-attenuated and electrically-shielded room Audio stimuli delivered through insert stereo earphones

• 4 blocks total (4sec ITI x 176 trials = 11.73min for each block). Block order rotated one place for each following participant

Data Analysis

- EEG epochs (-500ms to 3000ms) for chord sequences
- Trials with channels exceeding \pm 70µv discarded
- Baseline: 50ms before onset of final chord at 2s
- Electrode groupings:
- Frontocentral Left (AF3, F7, F5, F3, FT7, FC5, FC3, T7, C5, C3)
- Frontocentral Middle (F1, Fz, F2, FC1, FCz, FC2, C1, Cz, C2)
- Frontocentral Right (AF4, F4, F6, F8, FC4, FC6, FT8, C4, C6, T8) ERPs were obtained for each cadence condition and difference waveforms were obtained for deviant cadence types by subtracting the ERP for the Authentic cadence.

• Using the grand average difference waveforms, peak amplitudes were determined by the minimum amplitude (for ERAN and N5) or maximum amplitude (for P3a) within typical time windows for each component. Time windows were determined by half of the peak-to-peak amplitude between the identified component amplitude and neighboring peaks to the left and riaht

• Three-way repeated measures ANOVAs for all ERP components were conducted with factors of pre-cadential mode (Major, minor), cadence type (PMT, Dec, Nea), and electrode group (FCL, FCM, FCR).



ERAN Major Difference **Topographies** and Waveforms

ERAN mino Difference Topographies and Waveforms

within FCR. separate modes.

The ERPs of the PMT cadences elicit an N5 in FCM which is significantly larger for the Major PMT than the minor PMT cadence. Since the N5 reflects context integration [2-4], the observed N5 implies that modal incongruence is processed as a violation in tonal context integration. Furthermore, the enhanced N5 for the Major PMT cadence may suggest that it is more difficult to integrate than its minor counterpart (the Picardy Third).

Window = 400-500m



Hannah Choi¹, Takako Fujioka¹

Results

ERAN response is observed for all deviant cadence type difference waveforms, and the main effect of cadence type is significant (p < 0.001). The Neapolitan cadence produces the strongest ERAN response, followed by the Deceptive and Parallel-Mode Tonic (PMT) cadences. P3a and N5 did not show systematic differences between conditions.

FCL ERAN Window = 142-242ms following final chord onset at 2s



The ERPs of the Authentic cadences exhibit a significant, large sustained divergence between Major and minor modes at a latency of 700 to 1000ms

We speculate that the late processing is unique to modal congruence which may



Conclusions

• The ERAN indexes local syntactic regularity in tonal music where greater syntactic irregularity results in an enhanced ERAN response.

• The ERPs following the ERAN may reflect larger contextual processing such as modal congruence. Interestingly, mode and its shift may be uniquely processed in different regions and time windows.

 DOC is more sensitive to the context than valence and specifically highlights the importance of tonic-concluding cadences.

Valence: Valence ratings are generally higher for a Major pre-cadential mode than minor mode, except for the PMT. Therefore, if the final chord is the tonic, its mode may matter more than the context.

Only cadences that conclude on a tonic chord have significant differences between pre-cadential modes. Similar to valence, Major Authentic is rated higher than minor Authentic, and minor PMT is rated higher than Major PMT. However, unlike valence, minor PMT is rated lower than minor Authentic. Thus, DOC is influenced both by the mode of the final chord and context Degree of Completion Interaction Plot

12(3):520–41





Behavioral Rating Results

Degree of Completion:





References

Garza Villarreal, E. A., Brattico, E., Leino, S., Ostergaard, L., & Vuust, P. (2011). Distinct neural responses to chord violations: a multiple source analysis study. Brain research, 1389:103-114 Koelsch, S., Gunter, T., Friederici, A. D., & Schröger, E. (2000). Brain indices of music processing: "nonmusicians" are musical. J Cogn Neurosci,

Koelsch, S., Rohrmeier, M., Torrecuso, R., & Jentschke, S. (2013). Processing of hierarchical syntactic structure in music. Proceedings of the National Academy of Sciences of the United States of America, 110(38):15443–15448 4. Loui, P., Grent-'t-Jong, T., Torpey, D., & Woldorff, M. (2005). Effects of attention on the neural processing of harmonic syntax in Western music. *Brain* research. Cognitive brain research, 25(3):678–687 Pagès-Portabella, C., Toro, J. M. (2020). Dissonant endings of chord progressions elicit a larger ERAN than ambiguous endings in

musicians. *Psychophysiology*, 57:e13476 6. Seppänen, M., Pesonen, A. K., & Tervaniemi, M. (2012). Music training enhances the rapid plasticity of P3a/P3b event-related brain potentials for unattended and attended target sounds. *Attention, perception & psychophysics*, 74(3):600–612

Contact: hchoi20@ccrma.stanford.edu

This poster was presented at the NeuroMusic Conference held at McMaster University, Hamilton, ON, November 19, 2022.