Does Harmony Function Emerge from Sequential Notes in a Diatonic Mode? An Event-Related Potential Study

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Introduction

Cognitive Neuroscience

Neural Correlates of Harmonic Syntax Processing (Event Related Potentials)

- **Early Right Anterior Negativity (ERAN)** reflects the pre-attentive harmonic syntax violation. (150-210ms latency from sound onset)[1] It has been found to correlate with **subjects' musicianship level (year of training).**
- **N5** correlates to musical integration process which reflects current cognition on tonal schema and the hierarchy of harmonic stability (550-610ms)[1].

Behavioral Psychology

Belongingness of a probe chord to preceding global and local tonal context

- **Harmonic Belongingness Test: listeners can rate** the degree of which the probe chord of each sequence sounded appropriate and seemed to belong with the preceding tonal context. It has highly correlated to degree of completion rating. **Likert-Scale rating (1-7)** and **Reaction Time** are reliable measures [2].

Music Theory

Modal Interchange

- refers to the practice of borrowing chords from a parallel mode or key. For instance, if you're in the key of C Major (Ionian), you might borrow a chord from C Phrygian.

Tonicization

- refers to a brief modulation where one chord or a series of chords are treated as if they are the tonic (I chord) of another key. Often achieved by using a secondary dominant.

Tonal Ambiguity

- is the extent to which a set strongly implies a single key or is ambiguous among multiple keys [3].

Questions & Hypotheses

Questions:

- Does Harmony Function Emerge from Sequential Notes in a Diatonic Mode?
- Will different interpretation of borrowed chord (ascending scale) in modal interchange affect the subsequent chords' sound and harmonic expectancy?
- Will different tonicization strategy with varied local tonal center affect the subsequent chords' sound and harmonic expectancy?

Hypotheses:

- Both modal Interchange and tonicization affects subsequent chords' harmonic expectancy.
- Different interpretation of a borrowed chord (induced by a scale in modal interchange) affect the subsequent chords' harmonic expectancy differently.
- Different tonal center of tonicization (induced by a local perfect cadence) affect the subsequent chords' harmonic expectancy differently.

Methods

Participants

- 20 participants (18 right-handed) / Age (years): M = 23.84, SD = 1.42
- Musical Experience: M = 7.42, SD = 8.40, 13 out of 20 self-identified as musician

Stimuli

- A 2 chords- 1 scale prime, 3 target chords piano tone design. (Note: the real audio is one octave lower than the illustrated figure) BPM =100

EEG Stimuli

- Stimulus sequences contained 10 repetitions of 2 voicing versions for each of 6 mode conditions and 4 transpositions, resulting in 480 Stimuli in total (each 6 seconds, total 48 mins)
- All the stimuli are played in a randomized order.

Behavioral Task Stimuli

- Same as EEG but every sequence was played only once.

Apparatus

- **EEG:** NeuroScan Synamps RT System with 64-channel Quikcap
- **Sound Stimulus:** Kontakt Grandeur Piano
- **Behavioral Task:** PsychoPy

Procedure

- **EEG:** Participants are asked to watch a silent movie of their choice with subtitles during the recording session. The recording was divided into 4 blocks and rest time are inserted in between.
- **Behavioral Experiment:** Participants are asked to rate the target A belongingness to the ascending scale context preceding it as soon as possible. Total session time is 5 minutes.

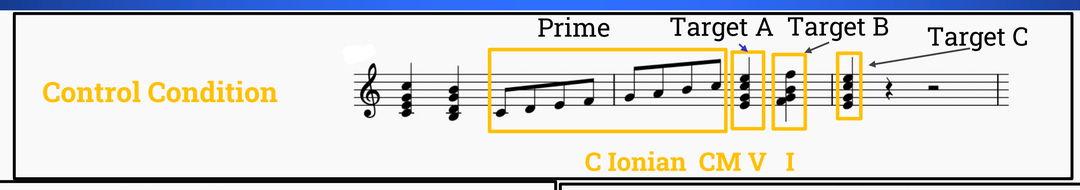
EEG & Behavioral Data Analysis

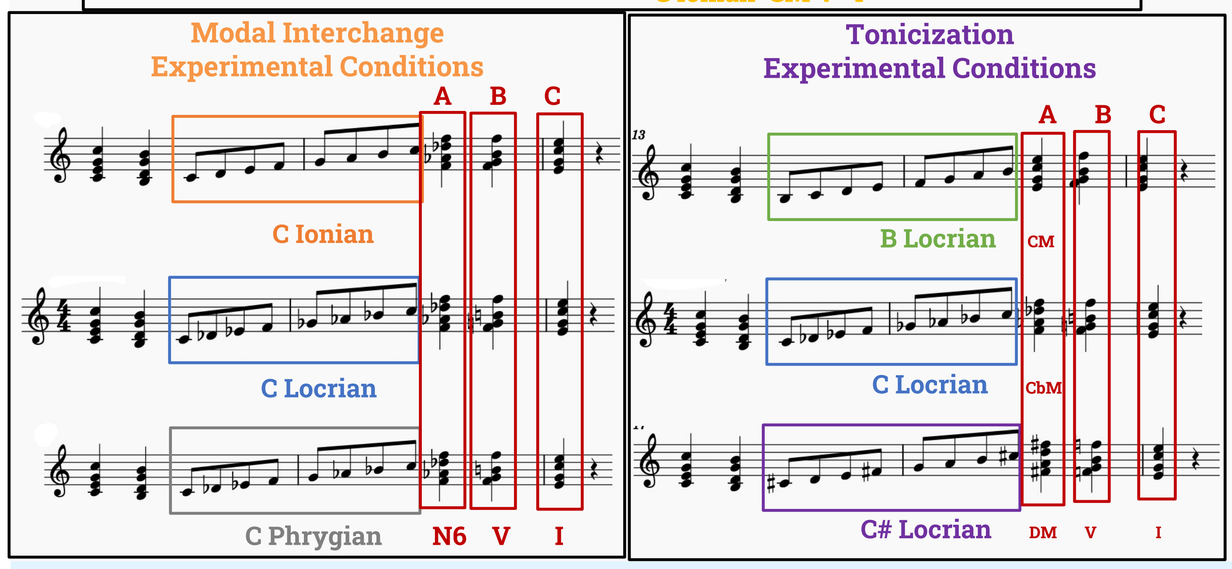
- EEG epochs (3.4-6.0 seconds after the beginning of each stimulus sequence). This covers target A, B, and C positions because the target A chord starts at 3.6 seconds.
- Performed baseline-correction for each target onset (-0.2-0.0 second)
- Removed eye-artifact with Signal-space projection (SSP).
- Rejected channels with peak amplitudes exceeding ±70μV.
- Calculated ERAN by subtracting each Experimental Condition to Control Condition(*Harmonic Deviant – Harmonic Standard*).
- Used three-way repeated measures ANOVAs

References

1. Koelsch, S., Gunter, T., Friederici, A. D., & Schröger, E. (2000). Brain indices of music processing:"nonmusicians" are musical. *Journal of cognitive neuroscience*, *12*(3), 520-541.
2.Bigand, E., & Pineau, M. (1997). Global context effects on musical expectancy. *Perception & Psychophysics, 59(7),* 1098–1107.
3.Temperley, D. (2007). The Tonal Properties of Pitch-Class Sets: Tonal Implication, Tonal Ambiguity, and Tonalness. *Computing in Musicology*, *15*.

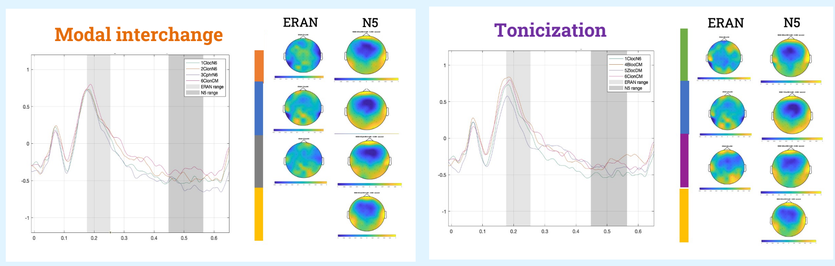
Conditions



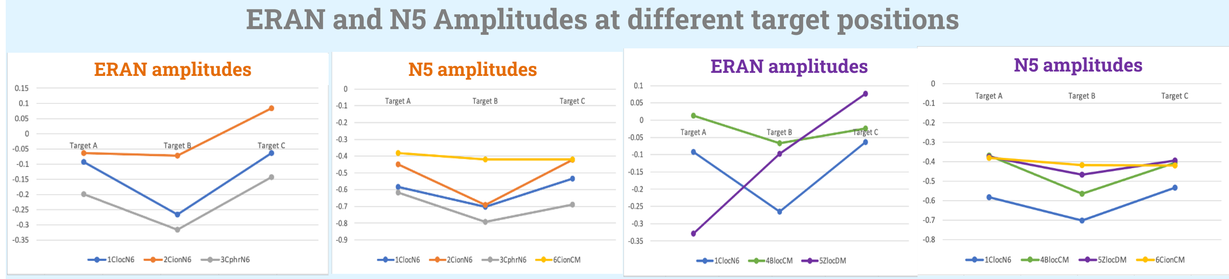


Results

ERP waveforms and Topomaps



ERAN and N5 Amplitudes at different target positions



All_position: Cond_type x Electrode x Position: p=0.10
TA_position: Cond_type x Electrode: p=0.12
TC_postion: Cond_type x Electrode: p=0.0752

All_position: Position: **p=0.028***
TB_position: Cond_type: p=0.094

All_position: Cond_type x Position: **p=0.003****
TA_postion: Cond_type: **p=0.0051****

All_position: Position: p=0.175

Modal Interchange

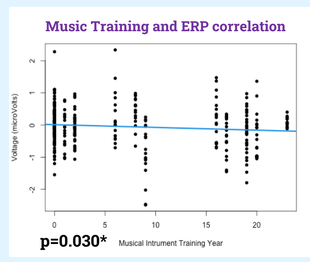
- marginally significant effect on the ERAN amplitude for Target A and C.

→ the perceived tonality (tonal ambiguity) might be unstable at Target A and C.

Tonicization

1. significant effect on the ERAN amplitude for Target A.

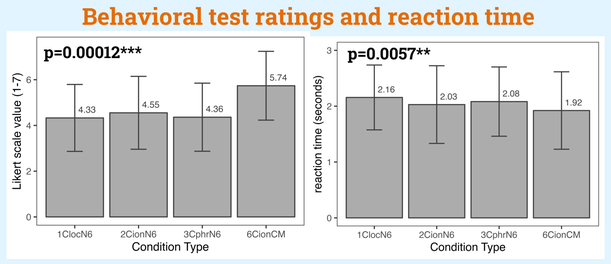
→perceived tonality (tonal ambiguity) is unstable at target A.



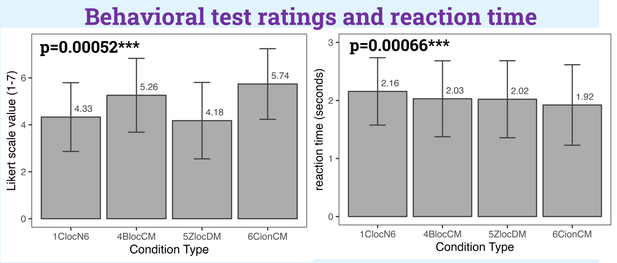
Tonicization: significant long-term training effect on ERAN amplitudes

Behavioral task results

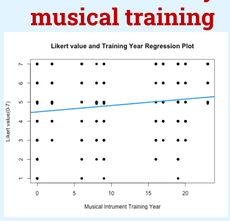
Behavioral test ratings and reaction time



Behavioral test ratings and reaction time



Regression on ratings in all conditons with # of years musical training



p=0.00000016***

Modal Interchange: Participants rated highest for the control condition (C Ionian+Cmajor) which does not have tonality shift. Although N6 does not belong to C Ionian scale, participants still rate it similarly to the two other conditions. RT result also shows the same pattern.

Tonicization: Participants rated lower for the two conditions with a new tonal center.

Music Training Effect on Rating: The more experienced musicians have a significant tendency to rate the sequences higher.

Discussions

1. Ascending mode altered the harmonic syntactical context in subsequent chords. It suggests harmonic function emerges from ascending scale notes.
2. ERAN reflects the harmonic syntax violation induced by (1) an inserted scale (mode interchange) and (2) a local cadential motion (tonicization) which can be interpreted as momentary tonal ambiguity.
3. Behavioral rating likely reflected the harmonic structure of the whole sequence rather than the target A chord only despite the instruction.
4. Music training experience appears to matter for tonicization perception and the harmonic incongruence of the whole sequence.

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