Syntax in a pianist's hand

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Introduction

Shared syntactic processing in music and language is well established [1,2], and a recent behavioral study provided first evidence for shared syntactic representations in music and action [3]. By letting skilled pianists watch and imitate syntactically congruent and incongruent chord sequences in the absence of sound, the authors showed that rule-based action sequences induce strong expectancies about forthcoming movements (required to produce the harmonically congruent next chord). These data were taken as evidence for an acquired equivalence of "musical grammar", i.e. the syntactic organization of chords into auditory sequences, and a "grammar of action" in highly trained musicians.

The present study aimed to zoom in to the neurophysiological processes behind this "embodied" harmonic knowledge and isolate brain potentials that indicate the syntactic nature of sequential motor acts during music performance.

Questions

How do motor-syntactic expectancies during the observation of music playing: (1) map onto brain signatures? (2) interfere with imitation?

Methods

Full 2 x 2 design [3]:

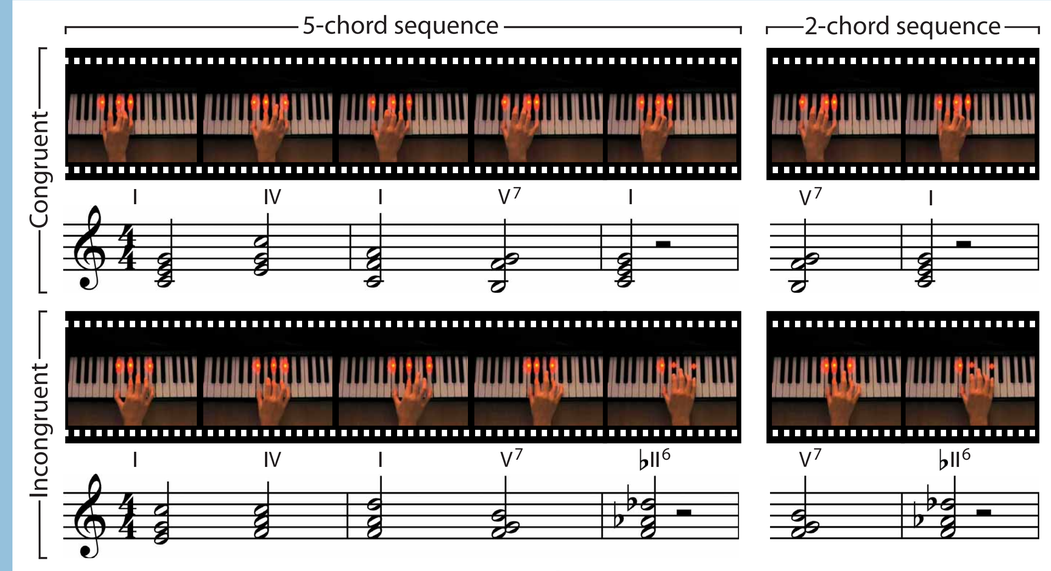
- **Final chord** (Tonic vs. Neapolitan) – **confirms or violates syntactic expectancies**
- **Length of context** (5 vs. 2 chords) – **modulates strength of expectancies** [1] and controls for differences in (i) familiarity, (ii) visual appearance, and (iii) motoric complexity of congruent and incongruent chords

Task: Watch and imitate the sequences as quickly and accurately (keys and fingering) as possible on a muted piano.

Stimuli:

- 60 x 4 = 240 movies of a right hand playing chord sequences
- 3 major keys: F, C, D; ø 2 s / chord
- Movies and performance were mute!

Participants: 27 expert pianists (10 males, ø 25 years old), ø 17 years piano training (classical formation), ø 6.4 years old at training onset



Hypothesis

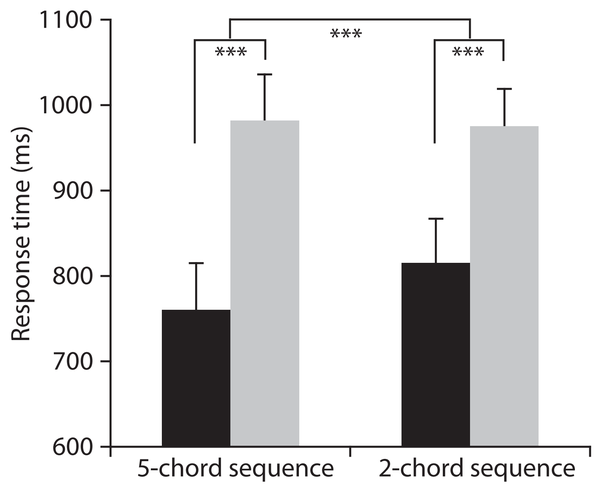
Any behavioral effects or brain potentials associated with the syntactic regulation of motor acts during mute piano playing should be stronger in the 5-chord compared to 2-chord sequences (i.e. be reflected in an interaction of Chord x Context).

EEG recording and analysis:

- 61 Ag/AgCl electrodes, 500 Hz sampling rate, linked mastoids reference
- average time-locked to the onset of the final chord in the movie
- EEGlab 6.01 analysis [Delorme & Makeig (2004). *J Neurosci Meth, 134*, 9-21.]

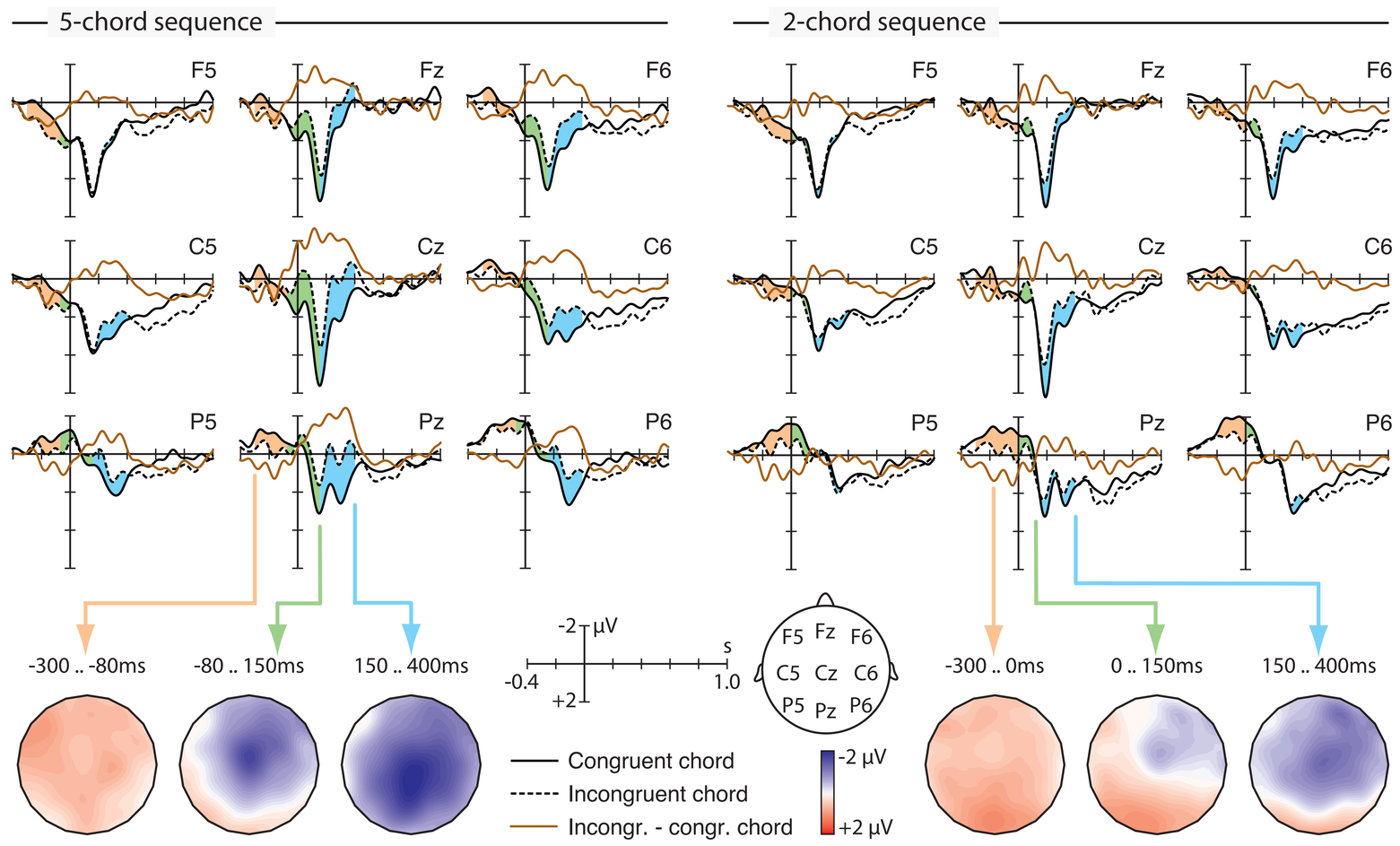
Results

Response times: Interaction of Chord x Context



Participants were faster in playing congruent than incongruent final chords, more so in 5- than 2-chord sequences.

Three-phasic ERP pattern: Interaction of Chord x Context in the 2nd and 3rd phase



1st phase: Positivity already before the keys of the chord were struck in the movie (orange), significantly more posteriorly distributed in 2- than 5-chord sequences.

2nd phase: Right anterior negativity (green) in the 5-chord sequences, non-significant in the 2-chord sequences.

3rd phase: Negativity (light blue), significantly stronger and more posteriorly distributed in the 5- than 2-chord sequences.

Discussion

Behavioral data

The results replicate findings from [3] and confirm **context-dependent action prediction** in music-syntactically organized movement sequences.

EEG data - 1st phase

The **positivity in both 5- and 2-chord sequences** is most likely associated with the recognition of the visually different trajectory of congruent and incongruent chord.

The posterior distribution in 2-chord sequences may reflect **enhanced attention to these surface differences** during early periods of harmonic context build-up.

EEG data - 2nd phase

The right **anterior negativity** in 5- but not 2-chord sequences may represent **(i) a "motor-equivalent" of the early right anterior negativity (ERAN)** [1] usually elicited by music-syntactic expectancy violations in the auditory domain, **(ii) an error-related negativity (ERN)** [5] evoked by observed errors, or (iii) a superposition of both.

It cannot be ruled out that the negativity may be partly **overlapped by a contingent negative variation (CNV)** that is ahead in time **for the expected Tonic chord** (see response times) possibly indexing the facilitated motor-preparation of syntactically primed movements [6].

Irrespective of functional interpretation, the modulation of the negativity by context length suggests a **syntactic analysis of motor acts during the observation of music performance.**

EEG data - 3rd phase

The **anterior negativity in 2-chord** (and most likely also 5-chord) sequences may represent a **CNV** that is larger for the **preparation of motorically more complex and less familiar movements** [6,7] such as the ones required for playing a Neapolitan chord.

The **posterior negativity in 5-chord** sequences may reflect the **revision or inhibition of the syntactically primed motor plan** to play a Tonic chord [8,9], i.e. the violation of an overlearned, syntactically triggered motor sequences in an expert pianist's hand.

References:

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Conclusion

Like in the auditory domain - but in the absence of sound - the observation of "syntactically incongruent" sequences of motor acts leads to an enhanced (right) anterior negativity. Although the exact nature of this ERP remains to be clarified, it suggests **context-dependent build-up of expectancies about forthcoming motoric elements** that are analogous to those that occur when listening to auditory chord sequences.

These "motor-syntactic" expectancies coincide with a **facilitation of overlearned sequences of musical movements** that need to be inhibited when the imitation of incongruent harmonic patterns is required.

The combined data support a **domain-general representation of harmony**, i.e. an **"embodied musical syntax"** acquired through deliberate practice in the course of a musician's development [3].

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