Music Cognition: The Complexity of Musical Structure

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Goals and Scope

Music is highly complex and provides a rich variety of insights into the human mind, its mental structures, and processes. Experienced musicians are able to create complex structures in real time effortlessly, yet there is at present no successful model of full musical structure. The integration of different musical aspects such as melody, rhythm, voice leading, and form as well as the representation of long-term structure are particularly challenging. To open new possibilities for the study of higher-order structure in music and its perceptual correlates, cognitive music research would benefit from further mutual integration of theoretical, mathematical, computational, and psychological research, similar to advancements in linguistics. This symposium therefore focuses on the formal understanding and empirical investigation of music-theoretically motivated research questions in music cognition. It connects perspectives from music theory, behavioral research, corpus research, and computational modeling, and aims to initiate interdisciplinary discussions about the currently most challenging topics related to the cognition of higher-order structures in music.

The symposium will consist of four talks, followed by a round-table discussion. David Sears opens the symposium by presenting computational and behavioral studies that investigate the asymmetry and the order of musical sequences. In the second talk, Louis Bigo, Mathieu Giraud, and Florence Levé focus on predictors of cadences (i.e., closure statements) in Western classical music, which support the large-scale structure of musical pieces. Daniel Shanahan subsequently proposes testable hypotheses about the organization of large musical units based on the principles of repetition and variation. In the last talk before the discussion, Daniel Harasim, Christoph Finkensiep, and Martin Rohrmeier discuss computational models of hierarchical structures in monophonic and polyphonic music that are based on the domain-general principle of recursion.

David R. W. Sears
Priming for tonal harmony: Effects of temporal order

Like language, much of the world's music exhibits organizational principles associated with the statistical distribution, temporal order, and hierarchical organization of sequences of events. These structural parallels are especially evident in the pitch structures associated with tonal harmony, an organizational system (or set of systems) reflected in many musical traditions—from Western art, to popular and commercial—that produces stylistically plausible sequences according to language-like principles. Nevertheless, the structural or syntactic features these domains presumably share remain poorly understood. According to contemporary theories of tonal harmony, for example, temporal order is a fundamental organizing principle, but harmonic priming studies have failed to demonstrate inhibited processing for scrambled chord sequences (e.g., Tillmann & Bigand, 2001).

To address effects of temporal order on harmonic processing, this paper presents findings from both computational and behavioral studies. The first computational studies examined order effects in four annotated corpora, revealing pronounced temporal asymmetries for two-chord progressions in each case. The second behavioral studies used these corpora to train a variable-order n-gram model that identified scrambled versions of tonal chord progressions reflecting either medium or high estimates of model uncertainty (Pearce, 2005). During the experimental session, participants (N=120) indicated as quickly as possible whether the target chord was in or out of tune. Correct response times replicated the ascending low-to-high staircase found in the model estimates, with scrambled sequences inhibiting the speed and accuracy of processing. These data provide the first behavioral evidence that harmonic priming effects reflect the order of chords in a sequence.

Louis Bigo, Mathieu Giraud, and Florence Levé
From local markers to global form: Computational modeling of musical structure

Musical structure plays an essential role in the listener's perception of a piece of music. In Western tonal tradition, the structure of a musical score results from a number of factors including repetitions, variations, and typical harmonic progressions such as cadences. Cadences contribute to the segmentation of the musical discourse into successive phrases by the feeling of closure or relaxation they provide to the listener (Blombach, 1987). Modelling cadences is therefore a promising task to improve our understanding of the perception of musical structure.

We present an approach to model cadences, based on automatic corpus extraction of theory driven features that are commonly used to describe cadences. Experiments on two different corpora from J.-S. Bach and J. Haydn show that despite their perceptive salience and apparent univocity, cadences turn out to be challenging to model computationally and variable depending on the musical style.

We will then present how the retrieval of local structural markers such as cadences can be extended to target the modeling of large-scale structures and therefore bring new modeling and cognitive challenges. This approach will be illustrated with the computational retrieval of the "sonata form" which has been intensively used in the classical style.

Daniel Shanahan
The transmission of musical structure and repetition

The ability of a listener to perceive a larger musical structure (and the cues that often delineate such structures), can be an informative measurement of both their knowledge of stylistic constraints and their ability to perceive relationships between temporally distant formal units. Granot and Jacoby (2011) found that participants were able to reposition musical segments at a rate better than chance, and that musical sophistication was a significant predictor of their ability to do so. Relatedly, Ollen and Huron (2004) have argued that there is likely a less stylistically-constrained aspect of musical form, using cross-cultural examples to demonstrate that repetition tends to happen at the beginning of musical works, and variation tends to occur later. One might therefore argue that while local details of musical structure (such as cadence and key) are informative to those accustomed to the musical style, more global aspects of structure (such as repetition) are not as dependent upon musical sophistication. This study hypothesizes that, in a linear transmission chain paradigm, participants tend to arrange structures in such a way that front-loaded repetition is more prominent, but that participants with more knowledge of stylistic constraints will be informed by more local cues.

Daniel Harasim, Christoph Finkensiep, and Martin Rohrmeier
Modeling recursive hierarchical structure at the note level

Music exhibits properties of complex hierarchical organization across many cultures. A central principle behind these structures is *recursive elaboration*, the repeated and nested application of ornamenting or embellishing operations. Since the resulting structures have been argued to be comparable to the ones found in language, attempts at formalizing theories about hierarchical structures in music have generally relied on the formal tools developed in computational linguistics (Harasim, 2020).

In our talk, we discuss recursive elaboration in the context of melodies and voice leading, which is largely based on ornamentation through neighbor and passing notes. While monophonic melodies can still be understood as sequences—and thus modeled using conventional string grammars—ornamentation in polyphonic music does not follow a simple sequential structure. As a solution, we propose a graph-based approach to representing polyphonic structure at the note level and discuss its implications for processing and learning. We argue that, despite the common underlying principles, the correspondence between language and music is more complex and subtle than a simple syntactic equivalence. Consequently, a domain-general mechanism for hierarchical processing in music an language—or for perception of hierarchical structure in general—has to account for complex non-sequential representations that are substantially different from those found in linguistic syntax.

Organizers and Moderators: Daniel Harasim and Christoph Finkensiep

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