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Composition and Analysis as Communication

Outline for a Compositional Theory based on »Musical Information«

Vanessa Hawes

The concept of »information« in association with music recently re-emerged in music psychology and cognition in the form of statistical learning and as the basis for models of music perception. The first time music and information were associated in a systematic manner was in the 1950s and 60s when, particularly in North American music theory, researchers applied concepts from information theory to analysis and composition. Among the work of the 1950s was Edgar Coons' and David Kraehenbuehl's *Information as a Measure of Structure in Music* (1958). The authors suggested that information could be developed into a useful compositional tool that would aid decision-making in terms of form, but would not hamper the composer's personal style or freedom of choice with regards to musical materials. In this article, the fundamental concepts behind the development of a musical information theory are outlined, giving some simple examples of its possibilities and proposing directions for future development. The outline embraces the necessity for a contemporary musical theory to combine formal, scientific methods and an awareness of contexts and relationships inspired by the New Musicology and the study of music as a cultural activity.
As a theory of communication, information theory is presented as a far more subjective and pliable concept than is implied in Claude E. Shannon's *Mathematical Theory of Communication* (1948), the work upon which many of the musical information theories in the 1950s were based. A flexible view of information theory and the concept of information must be maintained to enable them to take part in contemporary musicological discourse.

1. Music and Information

This essay is a comment on trends and problems explored in a historical study of interaction between music theory and information theory.[1] »Musical information« is referred to here not as a rigidly defined concept, but as a conceptually useful numerical representation of an analysis of number of different kinds of musical data or combinations thereof. Common for any type of musical information, however, is that it is derived from an examination of a specific arrangement of musical objects or events which form a specific musical structure. For example, many studies in the 1950s and 60s derived measures of musical information from an examination of pitch[2], scale-degree[3], combinations of pitch attributes and rhythmic attributes[4] or

1 Hawes, *Music's Experiment with Information Theory.*
2 Hiller/Bean, *Information Theory Analysis.*
3 Pinkerton, *Information Theory and Melody;* Brooks, *An Experiment in Musical Composition*; Youngblood, *Style as Information.*
4 Hiller/Fuller, *Structure and Information*.

various other musical features of melody.[5] The compositional theory referred to in the title is a suggestion for the use of musical information in the examination and manipulation of musical structures made up of any musical features at any level of detail a composer chooses. Contextualizing the method proposed as a *compositional* theory emphasizes its flexibility and potential as a support tool for individual creativity.

After much initial activity using concepts from information theory for musical analysis in the 1950s and 60s, interest in these kinds of methods decreased. This was, in the main, because Noam Chomsky's analysis of language in *Syntactic Structures* undermined the relevance of information theory in linguistic study, and music duly followed suit particularly since many of the earliest combinations of information theory and music were directly influenced by linguistics.[6] Chomsky proposed »transformational grammar« as an alternative to an information theoretical model of language, incorporating the conceptualisation of surface and deep structure for the generation of sentences.[7] Generative methodologies in music theory such as Schenkerian analysis[8] and cognitive approaches such as those proposed by Fred Lerdahl and Ray Jackendoff[9] were far closer to Chomsky's model of language than to information theory, and so these methodologies thrived in music theory as communication-based information-theoretical methods declined.

More recently, musical analysis using the concept of musical information and models from information theory have resurfaced, primarily because of the increased availability of powerful computational tools to take such work to a level of complexity where results relevant to music theory could be achieved.[10]

The disadvantage of the use of a non-musical theory such as information theory in musical research, and part of the reason the relationship between music and information theory weakened in the 1970s, is that music is not a single sequence of discrete symbols, but multi-layered, with numerous relationships between musical events. Hence, a theory of musical information cannot claim to represent *all* musical information but, rather, provide new perspectives on specific structures within music.

In his study of musical communication and information theory, Werner Meyer-Eppler emphasized that communication could depend on any aspect of the media in question.[11] In the case of music, successful communication may rest on the arrangement of pitch materials and their relative occurrence as well as other features and musical attributes: gesture, extra-musical influences or any other musical or psychological phenomena. The important factors in examining musical information, accor-

5 Cf. Hughes, *A Quantitative Analysis*; Knopoff/Hutchinson, *Entropy as a Measure of Style*; Snyder, *Entropy as a Measure of Musical Style*; Pearce, *Expectation in Melody*.

6 Pierce, *An Introduction to Information Theory*, pp. 150–164.

7 Chomsky, *Syntactic Structures.*

8 Forte/Gilbert, *Introduction to Schenkerian Analysis*.

9 Lerdahl/Jackendoff, *A Generative Theory of Tonal Music*.

10 Potter/Wiggins/Pearce, *Toward a Greater Objectivity in Music Theory*.

11 Meyer-Eppler, *Musical Communication*, p. 7.

ding to Meyer-Eppler, are the relationships existing within and between those features.[12]

Figure 1: Meyer-Eppler's example diagram of musical communication (Meyer-Eppler, *Musical Communication*).

Meyer-Eppler also emphasized that the primary materials of musical communication vary for different stages of the communication process (Fig. 1). Measurements of information based on pitch frequencies as they are set out in a score may be appropriate at one stage of the musical communication process (the »optical« channel in Figure 1), but inappropriate at another: for example when describing the »information« of a sound entering a listener's ear – the listener does not hear notes.[13] The listener will also respond to additional communication channels different from the primary channel at the same time, for example: the performers' body language, the shape of the room in which the performance is taking place, outward manifestations of the mood of other audience members, and so on.

The method discussed below is a transferable, flexible and general method, which can be employed for any part of the communication process the user (in this case, the composer) wishes.

2. Music as Communication: Coons and Kraehenbuehl

The method proposed here for the examination of musical information and the use of its representation in compositional processes emphasizes the relationship between musical events in terms of whether they are the same as or different to each other. Music is modelled as a series of events represented by arbitrary symbols (a system not uncommon in music theory, especially in the description of form: »ABA« for small ternary form, for example). The process of deciding which musical data constitute a single event is a subjective process carried out by the composer. The process of calculating musical information based on the symbols representing those decisions is a development of Edgar Coons' and David Kraehenbuehl's work on music and information theory from the 1950s.[14] This work was not advanced past its initial conception by its progenitors because the computing power necessary to make

12 Ibid.

13 The question of how much the culturally based signs of notation represent the psychological signs of the process of listening is an argument too large to be appropriately addressed here. See Moles, *Information Theory and Esthetic Perception*.

14 Coons/Kraehenbuehl, *Information as a Measure of Structure*; Kraehenbuehl/Coons, *Information as a Measure of the Experience of Music*.

calculations for sequences longer than four events was not available until later.[15] »Information« is calculated by assessing the number of possible predictions the system – modelling an abstracted, ideal listener – can make about the nature of a specific event in a sequence, compared to what actually happens. The information of an event is the sum of the predictions not confirmed by the occurrence of that event. Coons' and Kraehenbuehl's definition of information is an expression of predictability by an ideal listener in the moment-to-moment experience of music. Predictions are calculated by comparing both single events and – once they have happened and therefore become available to the system *as* a prediction – groups of events. Comparisons produce arrays of »same« (1) and »different« (-1), forming the basis for the summation. The calculation then produces a result for the amount of information of an event as a percentage of the maximum amount of information possible (which would occur if no predictions at all are confirmed by an event). The method is dynamic in that the group of possible predictions is different at each event; possible predictions change as the sequence proceeds based on what has happened. For example, in the sequence ABC, the event A has 0% information because the system is unable to make any predictions at that point. The event B has 100% information because just before the second event the system cannot predict anything except A and so none of its predictions are confirmed. The event C has 66.67% information because even though C is an event that has not occurred yet in the sequence, the system can partially predict its occurrence because an unknown event has occurred before when B followed A.

Drawing on learning theory[16], Coons and Kraehenbuehl characterized events associated with an increase in information from the previous one as being those that will be interesting; events which will draw the attention of a listener and retain it. Events associated with decreases in information are those that reward a listener for making correct predictions. A mixture of these two, either alternately within the sequence or simultaneously in two different sequences, based on different musical data or at different levels of detail in the music, would provide a listener with both the surprise needed to keep his attention and the predictability to make the sequence rewarding for him. By referring to a representation of various levels of information in a sequence within his music, a composer can manipulate his listeners' experience of these two.

Coons and Kraehenbuehl derived two additional measures representing a further analysis of the information measures: »Articulateness« and »Hierarchy«.[17] »Articulateness« is an expression derived from calculating the average change in information in a sequence: the amount of variety in a whole sequence. Relatively high Articulateness for a sequence, compared to other sequences under consideration, indicates that there are many changes in the amount of information from one event to another within it. Leonard Meyer[18], Meyer-Eppler[19], Abraham Moles[20] and Coons

15 Since the number of possible predictions and the nunber of comparisons which have to be made increase, after about six events, to levels that can only realistically be dealt with by a computer. The first part of Coons and Kraehenbuehl's analysis of a four-event sequence was a three-page table. See ibid., pp. 135–138.

16 Coon/Kraehenbuehl, *Information as a Measure of Structure*, p. 148.

17 Ibid., p. 134.

18 Meyer, *Emotion and Meaning in Music*.

and Kraehenbuehl all emphasize that *change* in information measures indicate sequences of high »articulateness« (in the ordinary definition of that word as something well-formed or meaningful).

»Hierarchy«[21], like Articulateness, is a measure derived from the information levels. It is the average amount by which information is *reduced* in a sequence. In other words, it is an expression of the extent to which the listener is rewarded. A very high average hierarchy measure for a sequence might indicate that its structure allows for specific events to be particularly rewarding (hence, »Hierarchy«: those events would be hierarchically more important than the others in the sequence).

Music that both interests and rewards a listener would have high Articulateness and high Hierarchy measures.[22] The composer can use these two measures to assess those attributes of a sequence. How he wishes to arrange a sequence of musical information in order to highlight or undermine these attributes is a creative decision of the composer.

3. Information, Articulateness and Hierarchy of Rondo Forms

The method is used here to produce information and measures of average articulateness and hierarchy for single-event sequences. Different sequences of events with different information graphs can have similar articulation and hierarchy measures, meaning different arrangements of events can interest and reward a listener to similar extents. Therefore, there is no »ideal« musical form, but some arrangements will have higher articulateness and hierarchy than others.

The examples used here are sequences of musical events representing large forms in Classical music, in particular, rondo forms. Rondo form provides an ideal set of event sequences for this kind of analysis, since the rondo is characterized by both the repetition of recognisable themes and the insertion of contrasting events between them. Different rondo forms are examined from small to large, simple to more complex.[23]

Figure 2 shows the information graphs for the small rondo forms ABABA and ABACA. The shapes of the graphs show differences in information due to the difference at the fourth event, B in the first sequence – a previously experienced event – C in the second sequence – a previously unknown event. As shown in Table 1, changing the fourth event means that there is increased Articulateness since there is, within the sequence as a whole, more change in information between events. There is also a slightly increased Hierarchy measure because there are stronger reductions in information as the result of the recurring A events.

19 Meyer-Eppler, *Musical Communication.*

20 Moles, *Information Theory and Esthetic Perception.*

21 Coons/Kraehenbuehl, *Information as a Measure of Structure*, p. 136.

22 Ibid.

23 For a common categorization of rondo forms see, for example, Schoenberg, *Fundamentals of Musical Composition*, pp. 191–198.

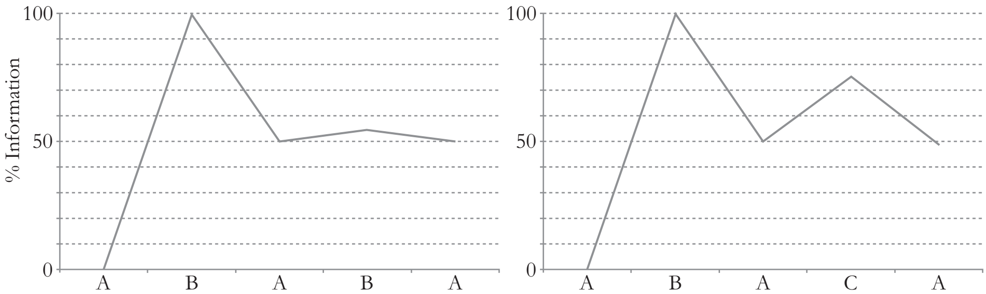

Figure 2: Information graph for the small rondo forms ABABA and ABACA.

Sequence	Average Articulateness	Average Hierarchy
A-B-A-**B**-A	40.40	27.30
A-B-A-**C**-A	42.19	27.92

Table 1: Average articulateness and hierarchy for ABABA and ABACA.

According to Coons and Kraehenbuehl's theory, ABACA is both more interesting and more rewarding than ABABA. The difference between the two formal sequences, however, is not substantial. Large rondo forms, more representative of the kind of masterpiece examined by theories of musical form[24], should, according to Coons' and Kraehenbuehl's theory, imply more interest and reward and, therefore, should have higher average Articulateness and Hierarchy than small rondo forms.

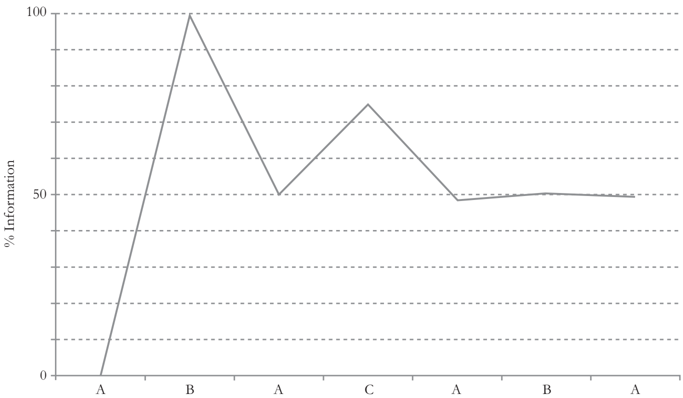

Figure 3: Information graph for the large rondo form ABACABA.

Figure 3 shows the information graph for a large symmetrical (sonata) rondo form, ABACABA. The average Articulateness for this longer sequence is 45.46, and the Hierarchy is 32.74. These higher measures can largely be attributed to the fact that this sequence is longer than the small rondo form by two events. For an *asymmetrical* rondo form, ABACADA (also including seven events), Articulateness is 45.56 and Hierarchy 32.77. Thus. there is a smaller change in Articulateness and Hierarchy

24 Cf. ibid., p. 192.

between the two large rondo form than between the two small rondo forms, which can be explained by the fact that differences later on in a sequence only lead to slight changes of the overall Articulateness and Hierarchy. This is due to the huge increases in the number of predictions the system can make about an event at a later stage in a longer sequence, so that a single »non-confirmation« has less effect on the overall information measure for an event. The longer asymmetrical rondo form, ABACADAEA has both higher average Articulateness and Hierarchy, as does the Great Sonata Rondo form ABACCABA (Fig. 4).

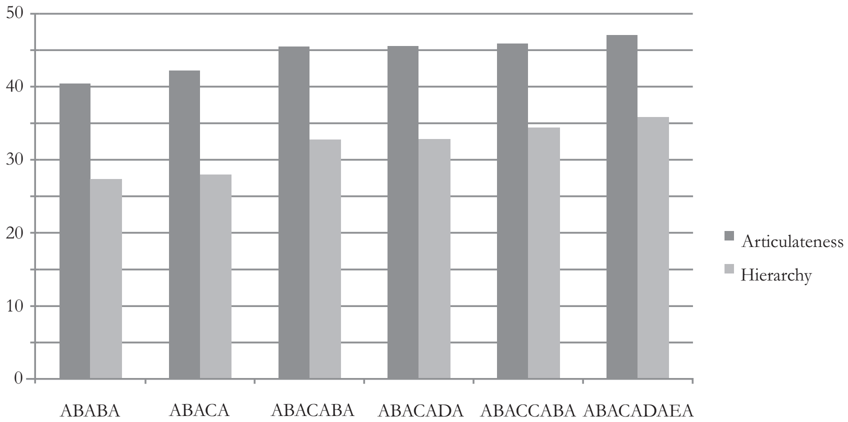

Figure 4: Average Articulateness and Hierarchy measures for different rondo forms.

Rondo forms, then, have average Articulateness measures in the range 40.40 to 47.03, and average Hierarchy measures in the range 27.30 to 35.87. These results contrast with two non-rondo sequences, AABAACDBC and the continuously different, ABCDEFGHI (Fig. 5 and 6).

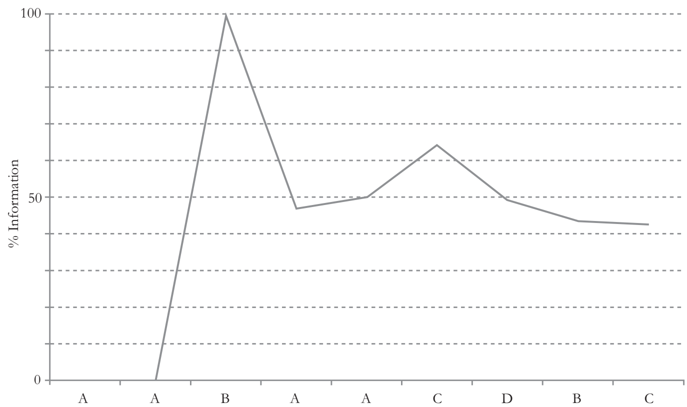

Figure 5: Information graph for the formal sequence AABAACDBC.

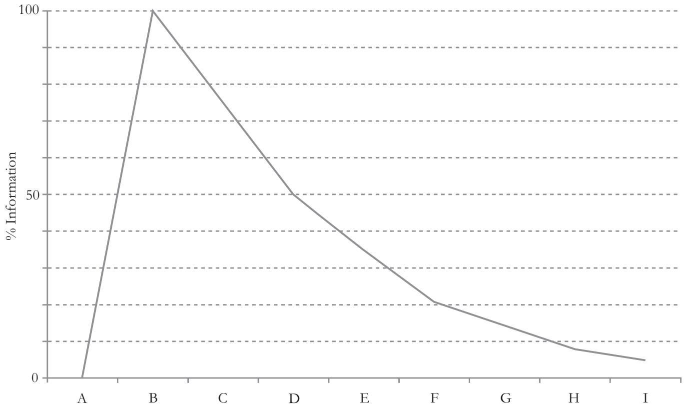

Figure 6: Information graph for the formal sequence ABCDEFGHI.

The information graphs in Figures 5 and 6 are very different when compared to the more regularly fluctuating rondo form graphs above. Average Articulateness and Hierarchy for AABAACDBC is 31.72 and 18.46 respectively, far lower than in any of the rondo forms examined above. Articulation and Hierarchy for ABCDEFGHI are 41.93 and 35.32 respectively, higher than in the small rondo forms in Figure 2 due to the regularity of the form (continual introduction of previously unknown events). The sequence has similar Hierarchy but lower Articulateness than the large rondo forms with the same number of events shown in Figure 4. The lower Articulateness measure indicates that the continuous introduction of new events rewards the listener because he can predict that the next event will be one which has not been previously heard in the sequence. However, there is not the same balance between similarity and difference as the large rondo forms offer, and which would keep the interest of the listener.

These very generic descriptions need not be limited to large-scale form, but can be applied at different levels of detail and to different musical features. For example, if a composer makes a pitch sequence with very high Hierarchy and lower Articulateness (as in Figure 6), he may wish to balance it with a sequence of durations or intervals with high Articulation and low Hierarchy. Alternatively, he may wish to emphasize the effect of the pitch sequence by composing interval or duration sequences with similar information graphs. If a composer wants to compose a sequence maximizing a listener's interest, but building an impression of a lack of reward, he can use sequences with high Articulation and low Hierarchy at that particular point in the music. If he wishes to compose a sequence to finish a piece maximizing listener reward, he can use a sequence that strongly reduces information, and therefore maximizes Hierarchy, at its end.

Options for using information measures to inform decisions about structure will also vary according to the function of a sequence and its length. The analyst or composer can choose which sequences he wishes to examine using this method. The intentions of a composer are, then, present in the particular manner in which he chooses to apply the theory, and so information measures reflect these intentions.

4. Future Work

A traditional role of music theory is that it serves as a formalisation of musical organisation. The theoretical outline here, developed from the work of Coons and Kraehenbuehl, proposes such a formalisation of musical organisation represented by musical information based on the moment-to-moment availability of predictions for a listener as a sequence proceeds and the relationship of those predictions to what actually happens. How closely this model fits the cognitive reality of listener experience is a question needing further examination, but the fact that common musical forms such as large rondo forms do have both high Articulateness and Hierarchy compared to other forms which are not commonly found in Classical music, indicates that these measures of musical information do reflect at least a partial reality of the experience of structural variety and balance.

A composer writes a musical sequence either by purposefully arranging musical materials in a specific order or by arranging those materials according to some more general plan, goal or purpose. He might, then, consciously use the idea of musical information, Articulateness and Hierarchy to model an ideal listener's responses to the structure of that sequence and order his musical events according to his goals in terms of that modelled listener response.

The next step in this research is to continue to illustrate a close connection between results using this method and existing musical theory. Producing an informational analysis of music composed within a specified formal structure allows for the development of an informational picture of sequences that have stood the test of time as in the rondo examples above and it is only through this process that tangible, useful and interactive tools can be developed that allow composers to use musical information in the consideration of new and non-traditional structures within large-scale and small-scale musical sequences.

References

Brooks, Frederick P. et al.: *An Experiment in Musical Composition*, in: IRE Transactions on Electronic Computers 6 (1957), pp. 175–182.

Chomsky, Noam: *Syntactic Structures*, The Hague / Paris: Mouton 1957.

Cohen, Joel E.: *Information Theory and Music*, in: Behavioral Science 7/2 (1962), pp. 137–163.

Conklin, Darrell / Whitten, Ian H.: *Multiple Viewpoint Systems for Music Prediction*, in: Journal of New Music Research 24/1 (1995), pp. 51–73.

Cook, Nicholas / Everist, Mark: *Preface,* in: *Rethinking Music*, ed. by Nicholas Cook and Mark Everist, Oxford: Oxford University Press 1999, pp. 1–14.

Coons, Edgar / Kraehenbuehl, David: *Information as a Measure of Structure in Music*, in: Journal of Music Theory 2/2 (1958), pp. 127–161.

Forte, Allen / Gilbert, Steven E.: *Introduction to Schenkerian Analysis*, New York: Norton 1982.

Hawes, Vanessa: *Music's Experiment with Information Theory*, Dissertation, University of East Anglia 2008.

Hessert, Norman: *The Use of Information Theory in Musical Theory*, Dissertation, Indiana University 1971.

Hiller, Lejaren / Bean Jr., Calvert: *Information Theory Analysis of Four Sonata Expositions*, in: Journal of Music Theory 10/1 (1966), pp. 96–137.

Hiller, Lejaren / Fuller, Ramon: *Structure and Information in Webern's Symphonie, Op. 21*, in: Journal of Music Theory 11/1 (1967), pp. 60–115.

Hughes, Matt: *A Quantitative Analysis*, in: *Readings in Schenker Analysis and Other Approaches*, ed. by Maury Yeston, New Haven: Yale University Press 1977, pp. 144–164.

Knopoff, Leon / Hutchinson, William: *Entropy as a Measure of Style. The Influence of Sample Length*, in: Journal of Music Theory 27/1 (1983), pp. 75–97.
Kraehenbuehl, David / Coons, Edgar E.: *Information as a Measure of the Experience of Music*, in: Journal of Aesthetics and Art Criticism 17/4 (1959), pp. 510–522.
Lerdahl, Fred / Jackendoff, Ray: *A Generative Theory of Tonal Music*, Cambridge, MA: MIT Press 1980.
Meyer-Eppler, Werner: *Musical Communication as a Problem of Information Theory* [1962], in: Die Reihe [English Edition] 8 (1968), pp. 7–10.
Meyer, Leonard B.: *Emotion and Meaning in Music*, Chicago: Chicago University Press 1956.
— *Meaning in Music and Information Theory*, in: Journal of Aesthetics and Art Criticism 15/4 (1957), pp. 412–424.
Moles, Abraham: *Information Theory and Esthetic Perception*, Urbana/London: University of Illinois Press 1966.
Pierce, John R.: *An Introduction to Information Theory: Symbols, Signals and Noise*, New York: Dover 1980.
Pinkerton, Richard C.: *Information Theory and Melody*, in: Scientific American 194/2 (1956), pp. 77–86.
Potter, Keith / Wiggins, Geraint A. / Pearce, Marcus T.: *Toward a Greater Objectivity in Music Theory. Information-Dynamic Analysis of Minimalist Music*, in: Musicae Scientiae 11/2 (2007), pp. 295–324.
Schoenberg, Arnold: *Fundamentals of Musical Composition*, London: Faber and Faber 1967.
Shannon, Claude E.: *A Mathematical Theory of Communication* [1948], Urbana: University of Illinois Press 1964.
Snyder, John L.: *Entropy as a Measure of Musical Style. The Influence of a Priori Assumptions*, in: Music Theory Spectrum 12/1 (1990), pp. 121–160.
Youngblood, Joseph E.: *Style as Information*, in: Journal of Music Theory 2/1 (1958), pp. 24–35.

Canterbury Christ Church University

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