Review article

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A. OCKELFORD. *Repetition in Music: Theoretical and Metatheoretical Perspectives*. Aldershot: Ashgate Press, 2005. 151 pp. ISBN 0–7546–3573–2 (hbk) $74.95/£37.50

Good ideas are often simple. When we meet one, we ask: why was this never proposed before? So it is with Ockelford's *zygonic* theory of music, presented in *Repetition in Music: Theoretical and Metatheoretical Perspectives*.[1] Its vivid diagrams and lucid writing cast new glows and shadows on familiar music and theory.

Reading the book, one is struck by the clarity of Ockelford's vision and the directness with which he pursues its goals. The theory goes like this: music is judged aesthetically pleasing to the extent it is perceived as orderly. It is perceived as orderly to the extent it seems to imitate itself; this impression of orderliness intensifies to the extent the imitation coordinates between several perceptual attributes simultaneously or occurs at multiple levels of structure. Analysis finds and depicts the orderliness.[2]

Once familiar with Ockelford's theory, one notices that the unflagging, inevitable terms 'repetition', 'equivalence', 'imitation', 'parallelism', and in some sense even 'development', 'similarity' and 'coherence' – though each has its own set of contexts where its use is traditionally deemed appropriate – can all be grouped under one rubric: *zygonicity*, which means perceived orderliness arising from the perception of matched pairs. A *zygon* is a matched pair: twins. Zygonicity varies in degree by categories (imperfect and perfect) or on a quantitative continuum.

Ockelford's theory applies so broadly that one initially wonders whether it leaves room for any other theories. Yet, alas, its schematic nature makes it as much a metatheory as a theory – hence 'metatheoretical' in the book's title. It builds on other theories because theories tend to model a specific perceptual attribute (pitch, contour, harmony, timbre, etc.), which may itself be a source of zygonicity.

With this schematic model the analyst works at the pan-theoretic level; the coherence of the music and the way the coherence arises are factored into separate roles in analysis.[3] To visualize this, Ockelford develops a simple but effective graphic notation.[4] Its flexibility allows it to serve the analyst as a pan-theoretic apparatus: it is used to depict any sort of zygonicity. Thus it is compatible with any theory, or common knowledge, that defines transformations or differentiates equivalence (or similarity) from non-equivalence (or dissimilarity).[5] One imagines zygonic theory could even be used in support of other theories and analyses – indeed, its ability to interact with other theories shows promise.

The book promotes a range of agendas. After a well-researched introductory chapter arguing for the pervasiveness and power of zygonicity, Chapter 2 starts with a critique of Lewin's work – of which more below – as a prelude to presenting zygonic theory, its graphic notation and its implications for cognition of aesthetic response to music. Chapter 3 analyzes Mozart's K. 333. Chapter 4 views Schoenberg's Op. 11, no. 1, critiquing Forte's pc set approach and Lewin's transformational network approach to analysis; also presented here are some innovative quantitative measures for atonal pc sets and a list of preference rules for a 'new model of music transformational networks'. (It varies Lewin's model to be more in line with a 'populist' mode of cognition and perception, which I explain later in this review.)

Zygonic analysis of Mozart and zygonicity in atonal music

The fire really starts crackling in Chapter 3, which asks: what makes a Mozart sonata great? Two angles are considered: how the style and genre are orderly and how Sonata K. 333 in particular is orderly. Here Ockelford makes bona fide contributions to the vocabulary of music discourse and to the technology of music analysis. With the graphing notation he illustrates zygonicity (orderliness arising from matched pairs of events or relationships) in 'harmonic rhythmic pattern' (HRP), 'relative metric location' (RML), 'melodic function in harmonic structure' (MF), 'inter-onset ratios' (IOR), and in the more usual suspects like timbre, tempo, loudness, melodic contour and harmony.

Some of the observations are the sort a theory instructor would make in the classroom to explain a parallel period or the development of a motive. Yet zygonic analysis adds vital clarity, precision and flexibility to the enterprise. The paper-and-pencil analyst should appreciate its visual clarity; the computational musicologist should appreciate the precision it affords, so that even the hardheaded music scientist should concede the role zygonicity must play in listeners' and composers' cognition. The flexibility helps in two ways: it permits systematic generalization of the passage, piece, genre and style, and it provides the analyst with tools to reveal and depict orderly interplay between features varying in subtlety from the mundane to the urbane. Ockelford even coins a handy term, 'syzygy', for the situation in which two perceptual attributes, such as rhythm and contour, coordinate to create parallelism: the phenomenon is ubiquitous in classical music; it is about time we had a name for it – though Hanninen (1996, 2001, 2003) already proposed 'coincidence' for the same phenomenon – and a corresponding graphic notation, which Ockelford also provides.

Ockelford's decisions do leave room for quibbling. The 'melodic function' of accented non-chord tones (passing tones, suspension, neighbors) should not always be called appoggiatura; if an umbrella category is needed, perhaps 'chord member status' is more suitable. Schenkerians will bark at Ockelford's neglect of voice-leading – and they would be half right – but zygonic analysis could accommodate voice-leading considerations without much fuss so that's no grave concern.

Chapter 4 ('Metatheory and Meta-analysis') contrasts sharply with previous chapters, partly because of the repertoire (Schoenberg) and partly because it critiques Forte's and Lewin's theories. Ockelford is quite effective here in explaining, sometimes with diagrams, the cognitive mechanisms entailed by Forte's pc set constructs such as complementation, aggregate completion and the R_1 similarity relation. His big target is the method and meaning of Forte's choice of pc sets in his analysis of the piano piece Op. 11, no. 1. Ockelford questions how – and indeed whether – a listener could make sense of its first 12 seconds (23 notes) by consciously or even subconsciously registering the 28 principal sets, often imbricated, from among the 79 possible options. He supports his point, cogently, with a graph of possible transitions between successive pitch events. If not aural, what significance do Forte's 28 principal sets hold? Ockelford builds a probabilistic argument, the thrust of which is that large pc sets in general possess so much orderliness automatically that finding orderliness by virtue of them – even in any random bunch of notes – is virtually guaranteed! So is pc set analysis just voodoo? No, but here is not the place to mount a defense of it. Let it be said, however, that Ockelford's is the most persuasive critique against Fortean pc set analysis this reader has ever encountered.[6] And it's no cheap shot: far from dodging the analysis of atonal music, Ockelford shows new ways of revealing its structure.

The zygonicity measures he introduces in Chapter 4 are novel and useful – one of the highlights of the book. These gauge various sorts of zygonicity relating to pitch. How they differ from traditional pc set similarity relations is not emphasized by Ockelford, but it is easy to articulate: (1) Four of the eight zygonicity measures gauge the internal orderliness of a set rather than the relation between sets; (2) the traditional similarity relations ignore pitch recurrences, whereas all of Ockelford's zygonicity measures consider each pitch event: for instance the zygonicity of {0014}, a multiset of four pitch events of which two are the same pitch, is higher than that of {014}, three pitch events lacking repetition – {0014} is more zygonic, more orderly (see note 8 on Morris's (1998, 2003) exposition of multisets in music). Traditional pc set similarity measures make no such distinction. An unexpected consequence is that zygonicity measures promote pairs of the most generic segments (repeated C♯s: <1111> and <111>) as having the optimum orderliness, both internally and in relation to each other, even though we might be inclined to ignore the relation between such segments as motivically insignificant and thus trivial. Zygonicity looks from a new angle, not to be confused with motivic significance or similarity. It is better to think of these measures as gauging *homogeneity*. Four of the zygonicity measures (zyg_1, zyg_1-seq, ZYG_1 and ZYG_1-SEQ) gauge *pitch* homogeneity; the other four (zyg_2, zyg_2-seq, ZYG_2 and ZYG_2-SEQ) gauge *intervallic* homogeneity.

Unfortunately, the presentation of this fascinating material presents some obstacles to the reader. The definitions of the zygonicity measures are not precise enough, requiring the reader to engage in too much educated guessing and testing. Also, instead of being presented in a cumulative order or in one place, too many of them are scattered through the book in a convoluted fashion. Variables are sometimes not identified; sometimes the purpose of the measure is not described; other times the purpose is described but the formula is not given. However, applying the basic principles of combinatorics, the formulas and purposes of all of them can be pieced together. So as a service to the reader, I present them in an appendix to this review.

Typos also impede comprehension. On p. 90 the primary ic vector for {0,0,0,0} should be [6.000000] instead of [4.000000], because there are six, not four, ways to choose pairs from four objects. In some of the formulas, dots occur at the text baseline, looking like decimals ('a.b' on p. 72 and '#X.#Y' on p. 85), where they should be raised ('a • b' and '#X • #Y') to indicate arithmetic multiplication.

In regard to atonal music theory, Ockelford could contextualize his work more. For instance: zyg_2 is, in purpose and operation, sufficiently distinct to stand on its own, but readers interested in advancing this research might appreciate knowing how zyg_2 relates closely to Lewin's probabilistic applications of his own EMB function.[7] Similarly, readers intrigued by Ockelford's 'zygonic meta-analysis' (p. 100) – a dual derivation: vertical and horizontal – might appreciate its affinities to Lewin's (1987: 204–6, 236) 'product network' model of parallel organum. The multiset aspect of Ockelford's zygonicity measures would be well served by reference to Morris's (1998, 2003) prior account of multisets in atonal voice-leading and 12-tone composition.[8] Though they originate independently, the resonance between Ockelford's 'zygonic' theory and Hanninen's (1996, 2001) 'associational' segmentation theory is loud enough to earn more than a footnote.[9]

Ockelford on Lewin, and approaches to cognition and perception

In relation to Lewin's work, the resonance rings more hollow. Like the traditional theorist–analyst, Ockelford relies on introspection as a means of verification, but he takes the cognitive–scientific approach by inviting empirical studies to test his model. Savvy to this distinction, he states that because set theory and (Lewinian) transformations 'present the widest divergence from the cognitive-scientific approach' they are chosen for interrogation (critique) by zygonic theory (p. 68). The trouble is that his zygonic theory is partly based on Lewin's; this leads him – in his critiques of Lewin throughout the book – to a soft regard for the true depth of Lewin's divergence.

Observe that Ockelford maintains four unstated assumptions about perception and cognition. When Ockelford segregates the 'physical musical spaces' from the 'perceived musical spaces' (p. 12) in Lewin's GIS theory, he assumes that the listener is not trained to perceive in terms of frequency ratio, sound wave shape, spectral components, attack envelopes or other physical attributes. This segregation is proposed as an improvement upon Lewin's theory assuming that because people without specialized musical training (non-specialists) far outnumber those with it (specialists), modeling the cognition and perception of non-specialists is better. The proposal assumes the primacy of non-specialists' perception.

When Ockelford suggests that analysis avoid complex transformations we can merely conceptualize in favor of structure we perceive when listening (pp. 116–17), he assumes a crisp boundary and status distinction between listening to music and other musical activities like playing, reading, improvising, composing, analyzing, audiating, contemplating. It implies that real-time listening has autonomy and primacy.

His statement (p. 138) that 'a system of prioritization is evidently essential to avoid mental overload, and it is proposed that this is achieved through the principle of "least processing effort"', which he earlier (p. 122) calls 'the principle of parsimony ("Ockham's razor"), whereby it will seek the simplest solution to make sense of incoming perceptual input', suggests that for any given piece or passage of music, there is a single way of hearing, listening or cognizing it that is possible or desirable. It assumes that there is an exclusive optimum hearing.

Ockelford also writes (p. 8) that 'Lewin provides . . . musical spaces where the relationship between intuition (based on perceptual experiences) and the intellectually driven logic of mathematical structures appears to be precarious to say the least'; therefore he then proposes 'relationship' instead of 'interval' because it is difficult to imagine intervals between such entities as durations. Here Ockelford assumes that our powers of perception and cognition of music are – and for purposes of theorizing they might as well remain – basically fixed, immutable, unable or unwilling to learn duration intervals. The cognitive–scientific approach may find comfort in these assumptions (the exclusive optimum hearing of an immutable non-specialist engaging only in real-time listening), but Lewin's approach does not.

Clarke (1989) warns us to 'mind the gap' between disciplinary approaches and Temperley (2001) urges that we distinguish between 'descriptive' and 'suggestive' theories and analyses. Certainly Ockelford proposes his theory and analyses as more 'descriptive' than 'suggestive'. I want to couch this distinction in a different way, one that emphasizes the cognitive–perceptual component of theory and analysis. It will, I hope, reframe and reorient Ockelford's critique of Lewin: let me propose that we regard the noted cognitive-scientific assumptions as 'populist', stressing uniformity, stability and accessibility.[10]

In reviewing Korsyn's *Decentering Music* (2004) for this journal, Margulis (2005) suggests this 'populist' tendency of music cognition:

> Music cognition tends to explore those aspects of musical experience that are relatively robust and shared across large populations (betraying a dependence on what Korsyn sees as the problematic construct of 'normalcy'), rather than those that are unique and more amenable to the committed introspection of a single listener . . . Music analysts who rely on introspection as a methodology might manifest a commitment to music as an individual experience, constructed as fully by the listener as by the composer and performer. This vision elevates the specialist, and promotes the importance of training. Researchers who rely on empirical methodologies might reveal a commitment to music as more of a shared experience, with invariant features that characterize the hearing of a neophyte as much as a person with decades of training. (pp. 334–5)

In *Rethinking Music* (1999), Dubiel's plea elaborates the music analyst-theorist side, suggesting its rationale:

> The crucial condition for any increase in musical knowledge is to keep yourself ready to be struck by aspects of sound that you aren't listening for, [so] the value of analyses will ultimately be their value as ear-openers. The value of theories will be in their facilitation of such analyses, and in their making explicit the range of possibilities for what might be heard and the openness of hearing to change. To make the point stick, I'll allow myself this flashy way of putting it: the reason to *do* theory is to protect yourself against believing too much in any *particular* theory. (p. 274)

Rather than 'populist', the approach to perception and cognition Dubiel endorses for the theorist–analyst is 'progressive'. The 'populist' approach asks: What modes of listening are universally shared? Whereas the 'progressive' approach asks: What modes of listening are possible?[11] In simplistic terms, the extremes are that the populist approach is more at home trying to explain how or why almost everyone enjoys listening to Mozart's music so much, whereas the progressive approach is comfortable cultivating uncharted regions of perception and cognition to enhance dedicated specialists' multifaceted interactions with knotty Schoenberg or Stockhausen works. The progressive approach implicitly rejects the assumptions, stated above, of the populist approach.

Now, consider how populist assumptions sway Ockelford's reading of Lewin. In a passage from GMIT, Lewin models the interval from C4 to F♯4 with frequency ratios. Ockelford takes him to task for attempting to combine abstract scientific concepts with psychological representations (p. 9). Lewin can be interpreted in a different way, however.[12] He is modeling the cognition of the musicians or music scholars who are in the know about matters quantitative. Lewin's cognoscenti understand that simpler ratios correspond to acoustical consonance whereas more complex ratios correspond to acoustical dissonance. It is in this spirit that he proposes a quantitative model for an intuited chain of intuitions relating F♯4 to C4 through G3, D3, and F♯3: $FQ(F\sharp4) = 2(\frac{5}{4})(\frac{3}{4})(\frac{3}{4})FQ(C4) = (\frac{45}{32})FQ(C4)$. That is, Lewin provides exactly the model needed if we wish to conceptualize the relationship between F♯4 and C4 in terms of acoustical consonance and dissonance. For Lewin's cognoscenti, the perceptual meaning of $(\frac{45}{32})$ is two-fold: (1) it is a relatively complex ratio, thus *not* acoustically consonant, and (2) it corresponds to an octave up (×2) from a major third up ($\times\frac{5}{4}$) from a perfect fourth down ($\times\frac{3}{4}$) from a perfect fourth down ($\times\frac{3}{4}$) from C4. Since this derivation is based on a chain of harmonic intervals, it proposes an entirely different way of conceptualizing int(C4, F♯4) than to say it is merely six semitones up. By formalizing it, Lewin earns validity for it as a listening option, so we're not chained to the popular semitone-counting option.

Later, when Ockelford critiques the intermingling of 'physical' and 'perceived' in Lewin's theory, he suggests that 'Generalized Interval Systems [GIS] often seem to be better suited to physical musical spaces than their perceptual corollaries' (p. 12). GIS theory, however, is mathematical, not physical; since we have grown more comfortable modeling physical spaces mathematically than we have perceptual spaces, the mathematical nature of GIS theory *seems* more germane to physical spaces. This distracts from appreciating the value of mathematical modeling: it can describe and influence the perception and cognition of trained composers, theorists, analysts, in ways that informal discourse cannot.

Ockelford's critique (p. 103) of Lewin's RICH (retrograde-inversion-chain) is too narrowly conceived.[13] He overlooks what we gain from Lewin's discovery of RICH in Mozart's symphony: when we notice RICHs in Webern's 12-tone works, we can relate these conceptually to the RICHs in Mozart – a lucrative inter-repertoire link that, incidentally, Ockelford's zygonic theory could model well. Abstractions like RICH push beyond the everyday experience of repertoire that the 'populist' approach often assumes.

Lewin's divergence widens around matters of ontology; even the broad base of Ockelford's theory just cannot straddle this divide. Ockelford asserts that timbre space cannot form the basis of a GIS, since there is not 'a unique t in S which lies the interval i [away] from s' (p. 15). A little bit of shoptalk shows the flaw in that reasoning: The definition of the specific GIS guarantees there is such a 'unique t'; every GIS must define 'int' as a function such that any ordered pair (s, t) maps to some i in IVLS (the mathematical group whose elements are asserted as the intervals for the given musical space). Thus it is by fiat, not by analogy with default perception, that the GIS asserts some of its timbre intervals. This is what bothers Ockelford, or ought to. Nevertheless, Slawson's (1985) vowel-based *sound color* theory, which Ockelford cites as a solution, actually suffers the same limitation: perceptually each of Slawson's timbre dimensions (openness, acuteness, laxness and smallness) is linear, but, to use the standard 12-tone operators (pitch-class transposition and inversion), Slawson (p. 73) wraps these linear dimensions into cyclic spaces which do not model our default modes of perceiving timbre.[14] Like Lewin's theory, it knowingly diverges from default perception. (Nevertheless, Slawson (2005) has meanwhile reconfigured his theory, entirely dispelling this concern.[15] Moreover, much of Ockelford's unease about GIS-style mathematical modeling of timbre is met head-on by Slawson in an extensive illuminating discussion of the differences and similarities between pitch and sound color, their perception, phenomenology and ontology in music and spoken language.)

Similarly, Ockelford underestimates the degree to which GIS theory relies on mathematical group theory for its consistency when he asserts that 'harmony space – like timbre space – does not pass the test for a GIS'. It is well known, mostly through the recent explosion of neo-Riemannian theory, that many triadic chord transformations form mathematical groups, such as PLR.[16] Take any such group, call it IVLS, and there you have your GIS. That is the only test a GIS must pass; it need not model perception at all.

The burden of perceptibility lies, rather, in the analytical application of a GIS. In practice, a GIS-based analysis explains how it models some aspect of our perception in the specific passage analyzed. Often GIS-based analysis tries to formalize not perception in general, but rather an *intuition about perception* that is specific to the individual passage analyzed. Thus it cultivates modes of perceiving or conceptualizing the musical passage that promote its individuality. This is particularly the case when an analysis makes use of a *non-commutative* GIS (one in which successive transpositions may produce different results when applied in a different order). Non-commutative GISs go unmentioned by Ockelford. Transpositions in a non-commutative GIS do not behave at all like transpositions we generally intuit. A good example is Lewin's (1995) analysis of Schoenberg's String Trio, m. 1, where the pitches of a G minor triad trill with those of a B major triad. Lewin wishes to capture two intuitions: (1) the relevant transformational action is *oscillation*, and (2) the connection of each instrument's trill to that in the next pair of triads (A minor and D♭ major) neither subordinates, nor is subordinated by, its (vertical) connection to the simultaneous trills in the other instruments.

To model the first intuition Lewin employs a GIS in which half of the transposition operations are oscillations (*involutions* in mathematical parlance). For instance X1(C) = C♯, but also X1(C♯) = C, thus X1(X1(C)) = C. This is not your garden-variety transposition. The GIS is non-commutative because for instance doing transposition X1 before doing transposition Y2 produces a different pitch than doing X1 *after* doing Y2; in particular Y2(X1(C)) = Y2(C♯) = B whereas, topsy-turvy, X1(Y2(C)) = X1(D) = D♯. Rather than modeling the perception of transposition in general, transposition operation X1 models perceptions arising from the idiosyncrasies of the passage – made of trills between pitches of triads. The oscillating transposition operations of the non-commutative GIS make sense of the passage in a way that conventional transposition operations do not.

To model the second intuition, Lewin employs a *dual-GIS product network*: a joint derivation (one vertical-harmonic, the other horizontal-melodic) that 'dehierarchizes' the two perspectives. The product network actually requires non-commutative GISs, so Lewin not only models each of the two intuitions but also models their interdependence – Lewin's analysis is perhaps fanciful, but without a doubt it is also insightful. The point is, analyses like this one use the idiosyncrasies of the piece of music as an opportunity to challenge us to expand our concept – and accordingly try to expand our perception – of what intervals, harmonies and melodies are, protecting us from the complacency of 'believing too much in any *particular* theory' of what they are. And all this is done to keep our powers of perception and cognition flexible, so they may even progress.

The potential progress of music perception and cognition is not the focus of Ockelford's book. Its final chapter ('Cognition and Metacognition'), however, certainly invites consideration of these thorny concerns, as it proposes continuums of perception, cognition, conceptualization and conscious versus subconscious processing. Ockelford shows how zygonic theory contributes to an impressively nuanced view of these. Perhaps the zygonic treatment of cognition and metacognition could accommodate *motion* along these continuums, corresponding to the progressive spirit of Lewin's theory and analyses. As for zygonic analysis, I find it hard to accept that it only applies in the 'populist' approach to perception and cognition. Why not in the 'progressive' approach as well? Lewin's GIS theory – though highly flexible – does not lean comfortably in the 'populist' direction; the schematic nature of zygonic theory's analytic apparatus, however, makes it compatible with both 'populist' and 'progressive' approaches to cognition and perception.

Critiques and counter-critiques aside, Ockelford's zygonic theory is a good idea, and original too. It provokes thought in myriad directions, which could stimulate research, both 'populist' and 'progressive'. Ockelford's *Repetition in Music* is recommended especially to the broad spectrum of theorist-analysts and cognitive-scientific researchers.

NOTES

1. Zygonic theory was previously presented by Ockelford (1991, 1999, 2004).
2. Ockelford's work comports well with several influential music theories including Schenker's theory of tonality, and Schoenberg's *Grundgestalt* and Developing Variation theories.

3. It is similar to Hanninen's (1996, 2001) approach.
4. Hanninen presents a notation for 'association graphs', but it is less schematic and thus somewhat less flexible than Ockelford's. Ockelford cites Lewin and Fauconnier as forerunners of his approach.
5. See note 2 regarding other theories.
6. This is not to say the critique dissuades me. Responding to Ockelford's critique, a defense of pc set analysis could go in one or both of two directions: (1) Forte's imbrication method of pc set segmentation may enhance exploratory non-real-time interactions with the music, which indirectly enhance real-time listening; (2) the power of pc set analysis is demonstrated by Hasty (1981), Hanninen (1996, 2001) and others, who have developed approaches to segmentation that are more flexible and listener-sensitive than Forte's imbrication method.
7. See Lewin (1987: 106–11). Morris (1987: 70, 328, ff21) presents a related multiplicity function (MUL) and discusses earlier related work by Lewin.
8. Morris (1998: 206–7) explains multisets as a way to formalize the regulation of pc doubling in atonal voice-leading networks. Morris (2003) surveys the diversity of non-ornamental pc duplication in traditional 12-tone music and in later developments such as *rotational arrays* (Stravinsky, Wuorinen), *cyclic sets* (Perle) and *super-* and *weighted-arrays* (Babbitt, Swift and Morris). He then develops a compositional model by defining equivalence classes of *dmosaics* (double mosaics) which are classes of partitions of a double aggregate of 2×12 pc instances.
9. Hanninen's theory of segmentation and associative organization employs sonic, structural and contextual criteria to choose phenosegments from among genosegments. (The terms 'sonic', 'structural' and 'contextual' have specific technical definitions in Hanninen's theory.) These three types of criteria play a role in Hanninen's theory similar to that played by 'perspects' in Ockelford's theory. Ockelford's model shares much with Hanninen's: both focus on identifying which repetitions, or parallelisms, are structurally significant, and to achieve this end both consider myriad facets. Those drawn to either Ockelford's or Haninnen's theory should seek out the other.
10. The reader is urged not to infer the motivations or connotations of political populism.
11. Margulis (p. 334) characterizes the listening modes this way.
12. Lewin (1969, 1986) thoroughly conveys his approach to analysis and perception.
13. On a technical note: Ockelford's assertion, in Figure 64, that 'any series of regularly transposed intervals incidentally forms a chain of retrograde inversions' is not true. The example given produces RICH only because the first and last intervals of the transposed series are the only intervals, since the transposed segment is only three notes long. RICH is not guaranteed if, for instance, a segment four notes long is transposed regularly.
14. Slawson does this by locating 12 vowel sounds (ee-eh-ae-aa-ah-aw-oo-uu-ue-oe-yy-ii-ee) in a circular formation on the two-dimensional plane created by the orthogonal arrangement of two of the linear timbre dimensions: open vs. closed and acute vs. grave. Thereby, the mathematical isomorphism of color-class intervals to pitch-class intervals is upheld by perception of near and far all the way around the color-class circle.
15. See Sandell (1990: 259) on this point.
16. See Cohn (1998) and the entire issue 42(2) of the *Journal of Music Theory* devoted to neo-Riemannian theory. For the PLR-group specifically, see Hyer (1995).

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Appendix

DEF 1: *Pairs*(*X*) = The unordered pairs of elements of *X*: $\{(x_1, x_2) \mid x_1 \in X \;\&\; x_2 \in X\}$

$$\#Pairs(X) = \text{cardinality (size) of } Pairs(X) = \binom{\#X}{2} = \frac{\#X!}{(2!)(\#X!-2!)}$$

DEF 2: *Z*(*X*) = The pairs of identical elements of *X*: $\{(x_1, x_2) \in Pairs(X) \mid x_1 = x_2\}$

DEF 3: function $Eq(x_1, x_2) = \begin{cases} 1 & x_1 = x_2 \\ 0 & x_1 \neq x_2 \end{cases}$

$$\#Z(X) = \text{The number of matching pairs in } X = \sum_{x_1,\, x_2 \in X} Eq(x_1,\ x_2)$$

DEF 4: $IC(x_1, x_2)$ = The interval class of pitch dyad (x_1, x_2)

INTERNAL ZYGONICITY MEASURES

Not order-sensitive:		Let *X* be an unordered multiset of pitches.
	Answers the question:	Formula:
zyg_1	For a set of pitch events, what are the chances that any two, chosen at random, will be the same pitch?	$\frac{\#Z(X)}{\#Pairs(X)}$
zyg_2	For a set of pitch events, what are the chances any pair of its dyads, chosen at random, will be interval class equivalent?	$\frac{\sum_{x_1,x_2,x_3,x_4 \in X} Eq(IC(x_1,x_2), IC(x_3,x_4))}{\#(Pairs(Pairs(X)))}$

Order-sensitive:		for $x_i \in X$, where *X* is an ordered pitch segment.
zyg_1-seq	For an ordered segment of pitch events, what are the chances that any two consecutive pitch events, chosen at random, will be the same pitch?	$\frac{\sum_{i=2}^{\#X} Eq(x_{i-1}, x_i)}{\#X-1}$
zyg_2-seq	For an ordered segment of pitch events, what are the chances that any consecutive (overlapping) pair of its consecutive-pitch dyads, chosen at random, will be interval class equivalent?	$\frac{\sum_{i=2}^{\#X-1} Eq(IC(x_{i-1}, x_i), IC(x_i, x_{i+1}))}{\#X-2}$

DEF 5: *Pairs*(*X,Y*) = The unordered pairs from *X* and *Y*: $\{(x, y) \mid x \in X \;\&\; y \in Y\}$

#*Pairs*(*X,Y*) = cardinality of *Pairs*(*X,Y*) = (#*X*)(#*Y*)

DEF 6: *Z*(*X,Y*) = The pairs of identical elements in *X* and *Y*: $\{(x, y) \in Pairs(X,Y) \mid x = y\}$

$$\#Z(X,Y) = \text{The number of matching pairs from } X \text{ and } Y = \sum_{x \in X, y \in Y} Eq(x,y)$$

RELATIONAL ZYGONICITY MEASURES

Not order-sensitive:		Let X and Y be unordered multisets of pitches.
ZYG_1	For two sets of pitch events, what are the chances that any two, chosen randomly one from each set, will be the same pitch?	$\frac{\# Z(X,Y)}{\# Pairs(X,Y)}$
ZYG_2	For two sets of pitch events, of all the pairs of dyads formed by pairing a dyad from one set with a dyad from the other set, what proportion of these pairs of dyads would be interval class equivalent?	$\frac{\sum_{x_1,x_2 \in X, y_1,y_2 \in Y} Eq(IC(x_1,x_2), IC(y_1,y_2))}{\#(Pairs(Pairs(X,Y)))}$
Order-sensitive:		for $x_i \in X$, $y_i \in Y$, where X and Y are ordered pitch segments the same length.
ZYG_1-SEQ	For two ordered pitch segments the same length, what proportion of order positions put identical pitches in both segments?	$\frac{\sum_{i=1}^{\#X} Eq(x_i, y_i)}{\# X}$
ZYG_2-SEQ	For two ordered pitch segments the same length, of all the pairs of consecutive-pitch dyads formed by pairing a consecutive-pitch dyad from one segment with a consecutive-pitch dyad spanning the same order positions in the other segment, what proportion of said pairs of dyads would be interval class equivalent?	$\frac{\sum_{i=2}^{\#X} Eq(IC(x_{i-1}, x_i), IC(y_{i-1}, y_i))}{\# X - 1}$

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