7

An Experimental Music Theory?

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Aristotle knew his logic. He could ring the changes on premisses major and minor, true and false, universal and particular. Yet he still wrote the following:

> In man, the size of the trunk is proportionate to the lower portions. and as a man grows up it becomes much smaller in proportion. In infancy the reverse is found. . . . In other words, all children are dwarfs. . . . The whole groups of birds and fishes are dwarflike. . . . This is why all animals are less intelligent than man. . . . And the reason, as aforesaid, is that in very many of them the principle of the soul is sluggish and corporeal. And if the heat which raises the organism up wanes still further while the earthy matter waxes, then the animals' bodies wane, and they will be many-footed; and finally they lose their feet altogether and lie full length on the ground. Proceeding a little further in this way, they actually have their principal part down below, and finally the part which answers to a head comes to have neither motion nor sensation; at this stage the creature becomes a plant.[1]

This fine bit of nonsense took root in fertile commonplaces. Any Attic fool knew that there were four elements in the cosmos and four associated humours in all living things. Slight variations in the balance of these humours affected an organism's moods. while gross variations affected its very nature. Aristotle's experience of the world, filtered through these four-square verities, reinforced the apparent rightness of the theory. Feedback between theory and observation assimilated anomaly. Data that ought to have invalidated the theory became reinterpreted as its triumph. Even the most recalcitrant facts only forced a grudging accommodation that, like Ptolemaic epicycles, complexified but did not challenge the received dogma. Aristotle's mastery of logic was no defence against untested or untestable premisses.

The theory of four elements and humours, though surely 'sluggish and corporeal', nevertheless had legs. Much late medieval art testifies that children remained conceptualized as dwarfs for a long, long time. Depictions of children gained verisimilitude only when the new men of the Renaissance, men like Dürer in the north and da Vinci in the south. forced themselves to separate knowing from seeing by introducing objective measurement. When Dürer gazed at a

1 Aristotle. De partibus amimalium. 686b6–34.

subject through a grid of wire or string, his act of measurement corrected the distortions introduced by the knowledge-driven, highly interpreted perception that characterizes so many of the transactions between the human mind and its environment. Measurement changed seeing, and led to a new knowing.

Today, whenever I attend a meeting of music theorists. I am struck by the conviction with which old beliefs are invoked as eternal verities. 'Tonality', like Aristotle's 'principle of the soul', is asserted as an agent in the world. 'Voice-leading'. like Aristotle's 'heat'. is given causal force as an explanation of why musical things are the way they are. The waxing and waning of these principles seemingly create music history, govern style. and. 'proceeding a little further in this way', determine hearing itself. Recent attempts to 'problematize' these verities have resulted in complexified dogma. The basic terms of the debate. however, remain unchanged. As a result, music-theoretical discourse has become largely music-exegetical in content. The self-stabilizing, corroborating effect of interdependent premisses precludes fundamental revisions, major discoveries. or even accidental breakthroughs.

From this state of affairs one might conclude that music theorists would have little interest in psychological experiments directed toward an objective understanding of music perception. Nothing could be further from the truth. Having presented the work of experimental psychologists to music theorists on many occasions, I can report that music theorists have a passionate interest in this work. The musical illusions, ambiguous musical figures. and artificially modified sounds that are used as stimuli in such experiments have their most fascinated—and perhaps most discerning—audience among music theorists. Why, then, does this considerable interest and fascination have little noticeable effect on the discipline?

It is not. I would argue, because musicians mistrust experimentalists or the notion of experiment as impartial arbiter of conflicting hypotheses. Musicians routinely conduct informal experiments when they evaluate alternative modes of performance. A concert-mistress may test several bowings, comparing each to a learned ideal of Romantic phrasing, or a studio guitarist may ask an arranger which of several voicings he prefers for an upcoming recording session. Even teachers of aural skills conduct batteries of informal experiments in music perception. In college and university classrooms each day, thousands of students give millions of responses to written, sung, played, or recorded musical stimuli.

Although music theory endorses experiment. and grants the presumption that experiments are skilfully performed and accurately reported, the interpretation of experimental results takes place in a no man's land between disciplines with very different histories, mores. central subject-matters, and professional goals. Take, for example, a hypothetical experiment in melodic perception. The psychologist who sets up the experiment may be seeking correlates in the auditory system for some well-studied phenomena in the visual system. The history of that prior research in vision will dictate the outlines of the proposed study in music, and experimental protocols will be employed based on their utility within, and comparability to, a larger body of research in, say, mental representations. For the psychologist. the core of the article reporting the eventual experiment will be the 'results' section, where statistical proofs are adduced to support or refute the relevant hypotheses. Music theorists, by contrast, will probably skip the recondite 'results' section and concentrate instead on the narrative 'discussion' section. There. where the psychologist is permitted licence to speculate, the music theorist will subject to intense scrutiny words often intended as mere musical tokens for general psychological phenomena. Moreover, should the melodic stimuli imply (to the theorist) certain harmonic progressions, the 'laws' of harmony will be brought to bear in criticizing the 'lack of reality' in the experiment. Because the psychologist sought to avoid musical material too tied to a particular place, time, social class, and system of belief, and because he or she failed to frame concepts within guild-sanctioned modes of discourse, music theorists are likely to dismiss the entire experiment as failing to address real music. And they may go on to ask, Why don't psychologists study *real* musical issues? Why. for example, can't they measure how long a tonic can be prolonged?

The measurement of things musical is frequently problematic. For instance. if a music student sings doh–me–soh in response to a written doh–ray–me, how many mistakes should the teacher record? On the one hand, the teacher might have an atomistic view of music cognition and performance in which the student is theorized to have made three independent judgements of pitch (doh, ray, and me), two of which were performed in error. On the other hand. perhaps in the spirit of Deutsch and Feroe,[2] the teacher might have a structuralist view, according to which the student is theorized to have chosen the wrong alphabet ('triad' rather than 'diatonic scale'), three successive tones of which were none the less performed correctly. The number of errors 'observed' thus depends on the theory assumed. For this task, the 'scientific' measurement of error according to, say, cycles per second is no advance, because it engages only the epiphenomena of hidden mental processes.

Psychologists know the pitfalls associated with trying to measure a mental state or process. Their training in experimental method has sensitized them to how easily an attempt to measure x may turn out to be a measurement of y, z, or some combination of still other factors. Just as musicians learn to respect examples of flawless part-writing, so experimental psychologists learn to value classic experiments that have met high standards of design, procedure, and statistical analysis. They know that such experiments are fiendishly difficult to conceive and both laborious and expensive to carry out. Psychologists, reviewing an

2 D. Deutsch and J. Feroe, 'The Internal Representation of Pitch Sequences in Tonal Music', *Psychological Review*, 88 (1981). 503–22.

experiment proposed by a music theorist, will probably spot the methodological equivalent of parallel fifths, tritones. cross-relations, and odd doublings. They may go on to wonder, Why don't they do a *real* experiment?

To give some specificity to the interpretative rift between music theory and music psychology, let us examine an experiment on the perception of large-scale tonal closure by Nicholas Cook.[3] Cook selected six nineteenth-century compositions. and altered them so that each makes a tonal detour to end in a key other than the tonic. He played the altered and unaltered pieces pairwise to music students, and asked them to rate which of each pair they preferred in terms of four separate descriptors: pleasure, expressiveness, coherence, and sense of completion. The results of these ratings were interpreted to show that the perceptual influence of large-scale tonal closure is 'relatively weak and restricted to fairly short time spans'.[4]

Here music theorists may recognize one of their own, who directly tackled the question. How long can a tonic be prolonged? Real music was used to study a real musical issue. Old dogmas of tonal unity were held up to objective measurement, and apparently found wanting. Moreover. Cook appears to have demonstrated statistically that the effect of large-scale tonal closure is perceptually weak if perceptible at alL a conclusion I personally find persuasive. Psychologists, however, would argue that nothing of the kind was proved or disproved by the experiment. It suffered from problems both of conception and of execution. Let me treat conception first.

Proving the non-existence of a mental state or process is never easy. In evaluating an experiment, psychologists begin with a 'null hypothesis', and then disprove it statistically. That is, they take as a baseline assumption the absence of an effect, and then demonstrate that their data are in fact distributed in a way that is highly unlikely to occur if the null hypothesis is true. If the data instead show no strong reason to reject the null hypothesis, one does not then claim that the null hypothesis is true. In other words, one can only disprove the null hypothesis. Thus, in preference ratings for 'expressiveness', the absence of a signiilcant effect of unaltered over altered versions of live piano performances tells us nothing specifically about the existence or non-existence of large-scale tonal closure. 'Pleasure' is equally uninformative. The apparent co-variance of 'coherence' and 'sense of completion' with the first two factors suggests that something else was being measured than large-scale tonal closure. Indeed, as Cook freely admits, the consistent effect shown by the ratings was a slight preference for the second performance of each piece, regardless of whether it was the altered version or the original.

The problem of the order of presentation is a problem of execution. Cook responded to it by conducting a second experiment in which various subgroups

3 N. Cook. 'The Perception of Large-Scale Tonal Closure', Music Perception. 5 (1987), 197–205. ,
4 Ibid. 197.

of students heard the pieces played in different orders. But he selected only the two shortest pieces for this revised experiment. And of these, the sole statistically significant result was that the 'coherence' of Brahms's own version of the St. Anthony chorale (*Haydn Variations*, bars 1–10) was rated higher than an altered version in which the key of the chorale suddenly leaps down a minor third following the half-cadence. From one rating of 'coherence' in one short piece, are we really to conclude that 'the influence of tonal closure over listeners' responses is restricted to a maximum time scale, possibly on the order of 1 min'?[5] The notion of a function relating the force of tonal closure to time span—a quite reasonable notion, I might add—came from the first experiment. But that experiment demonstrated only the effect of order of performance. Cook asserts the function; the experiments do not support it.

Cook's experiments reveal the manifest difficulties in attempting to apply rigorous methods to poorly defined, culturally contingent phenomena. The number of pieces tested, for instance, was far too small. All the pieces were of different lengths and styles. No tests were done to see if the students could reliably tell if the second performance was different from the first. Students from the first, flawed experiment participated in the second experiment. and were played pieces from the first experiment. The responses of 'no preference' were omitted from the statistics in the first experiment. A human performer, hopefully not the experimenter, executed both versions of each piece, ensuring that large-scale tonal closure was not the sole variable. And the surgeries required to alter each piece varied considerably in their aesthetic effect: in one piece the scar is cleverly concealed. in another it glowers hideously.

I note these shortcomings because Cook has caricatured the more circumspect studies undertaken by professional psychologists as pedestrian efforts based on banal music-theoretical concepts that lead only to a 'psychology of ear training'.[6] Even if this charge were warranted, which it is not, a pedestrian but rigorously substantiated demonstration of the psychological validity of some small facet of music-theoretical discourse would be extremely valuable. Such findings could do far more to create interdisciplinary understanding than unsubstantiated claims about the perceptual nature of an ill-defined tonal mode of listening.

Cook's experiments were well received, perhaps because many in the crowd were only too happy to have someone point out an embarrassing problem with the emperor's clothes. The crowd. of course, was more interested in the critique than the experimental method. In our rush toward fashionable criticism—and I presume no one would wish to be thought 'uncritical'—we must be careful not to let knowing once again outstrip seeing. When Cook[7] cites experiments by

5 Ibid. 103.

6 N. Cook. 'Perception: A Perspective from Music Theory'. in R. Aiello (ed.) *Musical Perceptions* (New York. 1994) 6.

7 Ibid. 72.

Clarke and Krumhansl[8] that tested the criteria by which listeners recognized sectional boundaries in one piece by Stockhausen and another by Mozart. his welcome critique of the idolatry of tonal structure goes beyond just emphasizing that changes of texture, dynamics, metre, and other non-tonal features were important cues to sectional boundaries in both compositions. He claims that

> what is strikingly absent from the criteria adopted in the Mozart is any sign of specifically tonal features, such as modulations, cadence points, or tonal closure, . . . The conclusion seems inescapable: if people (musically trained people) listen to tonal and atonal music in much the same way, and if atonal music is not very grammatical, then tonai music cannot be very grammatical either.[9]

I was surprised to read that listeners to Mozart seemed to pay no heed to tonal features, and when I referred to the original study, I was even more surprised to see tonal features listed prominently. Clarke and Krumhansl's table 2 has 'Change of key (minor to major)' as its first entry for 'Musical Characteristics Contributing to the Six Boundaries in Mozart's *Fantasie*'.[10] 'Change of key' appears twice more, and is joined by 'Change of harmony (cadence)'. In four of the six recognized sectional boundaries. some listeners specifically made mention of tonal features. The 'inescapable' conclusion to be drawn is not. however, that Mozart's music is thus 'grammatical' after all. but that criteria for selecting sectional boundaries neither prove nor disprove a music's grammaticality. Of course, Cook may have been using 'tonal features' in some special sense, restricting their semantic field to 'tonal features in the sense of Lerdahl and Jackendoff's hierarchical structures'. Nevertheless, vague, discipline-summarizing terms like 'tonal features' and 'grammaticality' simply do not constitute the appropriate objects for the confident manipulations of Aristotelian logic.

Experiments well done provide resistance to theories too enmeshed in networks of self-confirming premisses. Careful measurements of what is truly measurable can serve to correct the inevitable distortions of culturally contingent modes of evaluation. In surveying the history of music theory, a cynic might conclude that the discipline has often provided little more than a technical apparatus in support of the current aesthetic doctrine. Yet music theory can and should do more. A thoughtful confrontation between theory and the results of solid experiments fosters real progress in understanding. Rameau, the great eighteenth-century theorist, recast his explanation of harmony in response to the scientific work of Sauveur[11] and other pioneers of' acoustics.[12] Riemann, the nineteenth century's most brilliant theorist. engaged in a lifelong dialectic

8 E. Clarke and C. Krumhansl. 'Perceiving Musical Time', *Music Perception*, 7 (1990), 213–51.

9 N. Cook, 'Perception: A Perspective', 72.

10 Clarke and Krumhansl. 'Perceiving Musical Time·, 243.

11 J. Sauveur. 'Systeme general des intervalles des sons', *Mémoires de L'Académie royale des sciences* (Paris, 1701), passim.

12 J-Ph. Rameau, *Nouvenu Systèmc de Musique théorique* (Paris, 1726).

between Romantic musical practice and the findings of Helmholtz's experiments[13] on auditory sensation.[14] Many in this century—Leonard B. Meyer comes to mind[15]—have made real contributions through interpretations of the work of experimental psychologists. Experiments serve as important goads to refine or reformulate theory, and new theory in turn can provide the conceptual underpinnings for further experiments.

At no time has this idealized interplay between theory and experiment been closer to actual practice than today. A lively, international. interdisciplinary group of scholars and researchers is actively engaged in experiments directed toward questions of harmony, rhythm. metre, timbre, performance, contour, style, emotion, and a host of other topics that lie at the heart of music theory. For example, the music-theoretical work of Lerdahl and Jackendoff[16] has stimulated psychological experiments directed at testing its claims about segmentation[17] and tonal tension.[18] Similarly. the recent melodic theory of Narmour[19] is currently being tested by researchers at Cornell, in particular Carol Krumhansl. These and other studies are collaborative in nature. Theorists and experimentalists have pooled their expertise in the hope of producing results that meet the needs and standards of both disciplines.

The relevance to music theory of some experimental work has been obscured by arcane or newly minted terminology. Not every musician who reads the term 'auditory stream segregation'[20] will recognize that it refers to mental processes central to the experience of voice-leading.[21] Similarly, the musical relevance of 'virtual pitch sensations,'[22] is not immediately obvious. even though the concept may be fundamental to questions of perceived harmonic roots and progressions.[23] Yet terminology changes because theory changes. And in the two cases just cited, theory changed because the results of experiments in auditory perception indicated that more precise terms were required. The fact that such developments are occurring outside the traditional confines of music theory should give the discipline pause.

13 H. von Helmholtz, *Die Lehre von den Toncmpfindungn* (Brunswick, 1863).
14 H. Riemann, preface to *Musikqeschichte in Beispielen* (Leipzig. 1912).
15 L B. Meyer. *Emotion and Meaning in Music* (Chicago. 1956); idem, *Style and Music: Theory, History, and Ideology* (Philadelphia. 1989).
16 F. Lerdahl and R. Jackendoff, *A Generative Theory of Tonal Music* (Cambridge, Mass., 1983).
17 I. Deliege. 'Grouping Conditions in Listening to Music: An Approach to Lerdahl and Jackendoff's Grouping Preference Rules, *Music Perception*. 4 (1987), 35–60.
18 E. Bigand. 'Abstraction of Two Forms of Underlying Structure in a Tonal Melody', *Psychology of Music*, 18 (l990), 45–59.
19 E. Narmour, *The Analysis and Cognition of Basic Melodic Structures: The Implication-Realization modeI* (Chicago. 1990).
20 A. Bregman. Auditory Scene Analysis: The Perceptual Organization of Sound (Cambridge, Mass., 1990).
21 D. Huron, 'The Avoidance of Part-Crossing in Polyphonic Music: Perceptual Evidence and Musical Practice', *Music Perception*, 9 (1991). 93–104.
22 E. Terhardt, G. Stoll, and M. Seewan. 'Pitch of Complex Signals According to Virtual-Pitch Theory: Tests, Examples, and Predictions', J*ournal of the Acoustical Society of America*, 71 (1982), 671–8.
23 R. Parncutt. *Harmony: A Psychoacoustic Approach* (Berlin, 1989).

Beyond difficulties in terminology, the work of Bregman on auditory stream segregation and of Terhardt and colleagues on virtual pitch sensations can be difficult for music theorists to evaluate. because they imply a mental faculty capable of finding the 'best organization' inherent in a complex. noisy sensory environment. The analytical orientation of music theory favours firm primary objects (notes. durations. intervals), which can then be manipulated in a musical calculus. By contrast. the perception of an auditory stream—the recognition, for example, that the violas are playing a countermelody—is conditional, emergent. evanescent. and characterized by shades of grey rather than black-and-white certainty. How melodic, for instance, must a viola part be before a listener recognizes it as a countermelody? Must it be played louder? Must the melodic interest of the other parts be attenuated? A little reflection on these questions leads one to realize that a great deal of music perception is contingent, situational, and subject to biases of culture and experience. Can any systematic exploration be made of areas this complex and this resistant to Aristotelian logic?

One promising avenue of enquiry leads to the province of connectionism, or neural networks. Based loosely on the neural architecture of the human cortex. computer simulations of the behaviour of massively interconnected processing units exhibit many of the very qualities needed to find a 'best organization' in a complex environment. Neural networks can 'learn'; they can 'generalize'; they can 'fill in gaps'; they can form 'prototypes'; and they can arrive at global decisions based on an evaluation, weighted by 'experience', of the simultaneous input of hundreds of pieces of information. Take, for example. Bharucha's connectionist simulation of how Terhardt's virtual pitch sensations could be learned through experience with the tones typical of speech and music.[24] In the process of simulating such learning, Bharucha was able to show how the resulting neural system would share with human subjects a peculiar, but highly predictable. response to tones with specially mistuned upper partials. This response requires the system to find a global 'best organization' of stimuli that did not figure in the system's past experience. Likewise. my connectionist simulation of the perception of auditory streams demonstrates the same appearance and disappearance of perceived voices reported in classic psychological studies.[25] The simulation suggests that auditory stream segregation is necessarily multiplex, contingent, and linked to processes of attention.

As analogues of biophysical processes, such simulations neither prove nor disprove particular premisses. Other, quite different simulations might also emulate a particular facet of human behaviour. But these simulations do lead us to think about thinking in a new way. The mere existence of simulations that perform complex feats of pattern recognition without a rule-based master program makes it easier to imagine theories of music perception that replace

24 J. J. Bharucha, 'The Emergence of Auditory and Musical Cognition from Neural Nets Exposed to Environmental Constraints', paper presented at the Second Intcrnarional Conference on Music Perception and Cognition, Los Angeles, Feb. 1992.

25 R. Gjerdingcn, 'Apparent Motion in Music?', *Music Perception*, 11 (1994), 35–70,

the calculus of musical atoms with an emphasis on experience, training, and attention.

Music theory is unlikely to become an experimental science. Not only do its areas of interest have important historical and art-critical components. but, as alluded to earlier, its practitioners are often professionally untrained to meet the specific standards required of researchers in established experimental sciences. Rather than become an experimental science, music theory should embrace experimental science. Theorists should, as many now do, collaborate with psychologists, acousticians, cognitive scientists, neurologists, behavioural scientists, and others who want to join in exploring the many aspects of music. The premisses of discourse within the discipline of music theory should be capable of meeting the challenge of translation into domains where inexactitude is never mistaken for subtlety. Our conceptual children will look far less dwarfish if our theoretical gaze is sharpened by reference to the grid of experiment.

Appendix

As a service to those who might wish to visit the terrain wherc cxperiments in music perception receive extended discussion, I have provided the following short bibliographic Baedeker.

Journals

Three scholarly journals devoted to research in music perception and cognition are *Music Perception*, published by thc University of California Press, *Psychomusicology*, originally published by Stephen F. Austin State University but now published by Illinois State University at Normal, and *Psychology of Music*. published in the United Kingdom by the Society for Research in Psychology of Music and Music Education. These journals, as well as the many psychological and acoustical journals that publish occasional articles on music perception, can be searched through Psychological Abstracts. a large database available at many college and university libraries either on-line, in CD-ROM format, or in printed form. Those who have never ventured into this domain may be astonished by the sheer volume of work being done on topics of interest to musicians.

Books

Among recent English-language books reporting or summarizing experiments in music perception and cognition are the following:

Aiello, R., *Musical Perceptions* (New York, 1994).
Bamberger, J., *The Mind behind the Musical Ear: How Children Develop Musical*

lntelligence (Cambridge. Mass., 1991).

Bregman, A., *Auditory Scene Analysis: The Perceptual Organization of Sound* (Cambridge, Mass., 1990).

Butler, D., *The Musician's Guide to Perception and Cognition* (New York, 1992).

Deutsch, D. (ed.), *The Psychology of Music* (Orlando, Fla., 1982; rev. ed. in press).

Dowling, W., and Harwood. D., *Music Cognition* (Orlando. Fla., 1980).

Gabrielsson, A. (ed.), *Action and Perception in Rhythm and Music: Papers Given at a Symposium in the Third International Conference on Event Perception and Action* (Stockholm. 1987).

Handel. S., *Listening: An Introduction to the Perception oj Auditory Events* (Cambridge, Mass., 1989).

Hargreaves, D., *The Developmental Psychology ojfMusic* (Cambridge, 1986).

Howell. P., Cross. I., and West. R. (eds.), *Musical Structure and Cognition* (Orlando, Fla., 1985).

Jones. M., and Halleran. S. (eds.), *The Cogniiive Bases of Musical Communication* (Washington D. C., 1991).

Krumhansl, C., *CognitIve Foundations of Musical Pitch* (New York. 1990).

McAdams, S., and Bigand, E. (eds.), *Thinking in Sound: The Cognitive Psychology of Human Audition* (Oxford. 1993).

Serafine, M., *Music as Cognition: The Development of Thought in Sound* (New York. 1988).

Sloboda. J., *The Musical Mind: The Cognitive Psychology of Music* (Oxford. 1985).

Sloboda. J. (ed.), *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition* (Oxford. 1988).

Tighe, T., and Dowling, J. (eds.), *Psychology and Music: The Understanding of Melody and Rhythm* (Hillsdale, N. J., 1993).