AN INVESTIGATION OF PERIODICITY IN MUSIC, with reference to three twentieth-century compositions:
BARTOK's Music for Strings, Percussion & Celesta
LUTOSLAWSKI's Concerto for Orchestra
LIGETI's Chamber Concerto

by

Rosemary Mountain
B. Mus., University of Western Ontario, 1980
M.Mus., University of Victoria, 1986

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in the School of Music

We accept this thesis as conforming to the required standard

Prof. M. Longton, Supervisor (School of Music)

Dr. H. Krebs, Departmental Member (School of Music)

Dr. J. Celona, Departmental Member (School of Music)

Dr. C. Porac, Outside Member (Department of Psychology)

Dr. J. Michelsen, Outside Member (Department of Philosophy)

Prof. O. Underhill, External Examiner

Music Sales Corporation
225 Park Avenue South. New York. NY 10003.
Telephone: 212 254 2100.
Telex: 429351. Fax: 212 254 2013

Date: 9-2-93

Rosemary Mountain
c/o School of Music
University of Victoria
Via fax # 604-721-6597

RE: "Concerto for orchestra" by Lutoslawski
Publisher: G. Schirmer Inc.

Dear Mrs. Mountain:

This letter is to confirm our agreement for the use of excerpts from the above-mentioned title in your master thesis/doctoral dissertation, subject to the following conditions:

1. The following copyright credit is to be listed on the page where the excerpts will be used or with the acknowledgments;

Copyright © by G. Schirmer, Inc. (ASCAP)
International Copyright Secured. All Rights Reserved.
Used by Permission.

2. Copies are for your personal use in connection with your thesis/dissertation, and may not be sold or further duplicated without our written consent. This in no way is meant to prevent your depositing a copy in an inter-library system, such as the microfilm collection of the university you attend, or with University Microfilms, Inc.

3. Permission is granted to the University Microfilms, Inc. to make single copies of your thesis/dissertation upon demand, subject to a fee of Twenty-five ($25.00) Dollars on a yearly basis.

4. If your thesis/dissertation is accepted for commercial publication, further written permission must be sought.

Your very truly,

Zoraya Mendez-De Cosmis
Print Licensing Manager

Music Sales Corporation (Distribution Center) PO Box 572. 5 Bellvale Road. Chester. NY10918.
Telephone 914 469 2271.
Telex 236113. Fax 914-469-7544

EUROPEAN AMERICAN MUSIC

PO BOX 850
VALLEY FORGE, PA 19482-0850

TELEPHONE (215) 648-0506
FACSIMILE (215) 889-0242

VIA FACSIMILE
5 PAGES TOTAL
011-429-222856

17 September 1993

Mrs. Rosemary Mountain
103 Elwick Road
Hartlepool, Cleveland
ENGLAND TS26 9BB

RE: Bartok MUSIC FOR STRINGS, PERCUSSION AND CELESTA

Dear Mrs. Mountain:

Thank you for your fax of 9 September 1993 concerning the use of excerpts from the above work in your Ph.D. thesis for the University of Victoria, Canada. Following is a copy of our license for this use for your reference. Please note that we are sending the originals by air mail today, kindly wait until they arrive, then sign and return them as indicated in the last paragraph of the license.

Please note that we are authorized to license this use in the territory of Canada, only. Before University Microfilms International in the United States can reproduce your dissertation, you need to contact the copyright owner in the United States, which is as follows:

Boosey and Hawkes, Inc.
24 East 21st Street
New York, NY 10010
phone (212) 228-3300
fax (212) 473-5730

With kind regards,

Caroline Kane
Copyright Department

EUROPEAN AMERICAN MUSIC

PO BOX 850
VALLEY FORGE, PA 19482-0850

TELEPHONE (215) 648-0506
FACSIMILE (215) 889-0242

17 September 1993

Mrs. Rosemary Mountain
105 Elwick Road
Hartlepool, Cleveland
ENGLAND TS26 9BB

RE: Bartok MUSIC FOR STRING INSTRUMENTS, PERCUSSION AND CELESTA, excerpts as listed on the attached Schedule A, only

Dear Mrs. Mountain:

In accordance with your request of 9 September 1993, which was forwarded to us by Universal Edition (London) Ltd., we hereby grant a non-exclusive license for you to use the above-mentioned excerpts in your doctoral dissertation, provided the conditions listed below are satisfied:

1. Under each excerpt, the following copyright information must appear:

   Bartok MUSIC FOR STRING INSTRUMENTS, PERCUSSION AND CELESTA
   Copyright 1937 by Universal Edition
   Copyright renewed
   All Rights Reserved
   Used in the territory of Canada by permission of European American Music Distributors Corporation, sole U.S. and Canadian agent for Universal Edition

2. Mention will be given us in the prefatory or appendix acknowledgements, if any.

3. This permission is valid providing your doctoral dissertation is completed within one (1) year of the date of this letter.

4. This usage is restricted to your doctoral dissertation, which is not to be sold or distributed in any manner whatsoever without the consent of the publisher, and is not to be reproduced except for the archives of the University of Victoria and the National Library of Canada.

5. This license is limited to distribution and usage in the territory of Canada.

6. In consideration for the foregoing, you agree to pay European American Music Distributors Corporation a license fee of Thirty-five United States Dollars ($35.00 U.S.) which shall be paid when signed copies of this letter are returned to us.

(continued)

7. One (1) copy of your dissertation is to be provided to the publisher, gratis, upon completion thereof.

Please signify your acceptance by signing and dating each copy of this letter where indicated below and returning both copies to us for countersignature. One fully executed document will then be mailed to you for your files.

Sincerely yours,

EUROPEAN AMERICAN MUSIC
DISTRIBUTORS CORPORATION

By:_____

Accepted and agreed to:

By:_____

Schedule A

103 Elwick Road
Hartlepool, Cleveland
England TS26 9BB
011-44-429-
Tel: 0429-880232
Fax: 0429-222866

Sept. 9, 1993

Deirdre Bates
Copyright Division
Universal Editions
Warwick House
9 Warwick
London W1R 5RA

Dear Ms. Bates,

As per your request of our telephone conversation today, I am writing to ask permission to include hand-copied examples extracted from Bartok's *Music for Strings, Percussion and Celesta* in my Ph.D. thesis for the University of Victoria, Canada. The thesis will be microfilmed and deposited in the National Library of Canada and at University Microfilms International in the U.S.A. Although single copies of the thesis will then be available for sale by request from interested researchers, this is not a commercial publication and I will not be receiving any moneys from such sales. Naturally, I would acknowledge Universal Editions in the preliminary pages of the thesis if you grant me permiasion to include these examples.

For your information, I enclose a list of the relevant examples. As the thesis concentrates on aspects of rhythmic periodicity, most of the examples are presented in condensed form, or display only a single melodic line or rhythmic pattern.

Ex. 4.1 Bartok II:199-203 (harp, Group II strings)
Ex. 4.7 Bartok I: 78 (celesta)
Ex. 4.8 Bartok III: 36 (cel./pno./hp./cb.)
Ex. 4.9 Bartok III: 65 (tutti, compressed - 5 staves)
Ex. 5.1 Bartok I: 16-22 (tutti)
Ex. 5.2 Bartok I: 29-33 (tutti, compressed - 5 staves)
Ex. 5.3 Bartok II: 310-338 (single stave - melody)
Ex. 5.4 Bartok I: 65-69 (tutti)
Ex. 5.5 Bartok II: 94-112 (tutti, compressed - 2-3 staves)
Ex. 5.6 Bartok II: 287-300 (tutti, compressed - 5-7 staves)
Ex. 5.7 Bartok II: 40-55 (tutti, compressed - 4 staves)
Ex. 5.8 Bartok III: 6-12 (vla.1,2 / vln.1,3,4 - 1-4 staves)

D. Bates -- copyright division -- Universal

Ex. 5.9 Bartok III: 50-63 (tutti, compressed - 4 staves)
Ex. 5.10 Bartok IV: 121-129 (tutti, compressed - 4-5 staves)
Ex. 6.1a Bartok I: 243-250 (tutti, compressed - 4 staves)
Ex. 6.1b Bartok I: 264-285 (single stave - melody)
Ex. 6.2a Bartok II: 1-7 (single stave - melody)
Ex. 6.2b Bartok II: 1-19 (composite rhythmic line)
Ex. 6.3 Bartok II: 69-76 (vln.1, vc.1)
Ex. 6.4 Bartok II: 373-377 (vln.1, timp.)
Ex. 6.5 Bartok IV: 5-9 (vln. 2 & 3 / vc. 1)
Ex. 6.6 Bartok IV: 15-16 (vln. 1 & 2)
Ex. 6.7 Bartok IV: 28-40 (pno./ vln. 1 / timp.)
Ex. 6.8 Bartok IV: 74-83 (pno./hp.)
Ex. 7.1 Bartok I: 78-79 (tutti, compressed - 4 staves)
Ex. 7.2 Bartok III: 36 (tutti, compressed - 8 staves)
Ex. 7.3a Bartok II: 113-120 (tutti, compressed - 3 staves)
Ex. 7.3b Bartok II: 123-127 (tutti, compressed - 3 staves)
Ex. 7.3c Bartok II: 149-155 (tutti, compressed - 3-4 staves
Ex. 7.4 Bartok II: 205-211 (tutti, compressed - 3 staves
Ex. 8.1 Bartok I:45-53 (mm.45-50 - vln.1 only; 51-53 - t 1)
Ex. 9.1a Bartok IV: 136-138 (gp. I strings compressed - 1 a)
Ex. 9.1b Bartok IV: 148-153 (vln.1, pno.)

I sincerely hope that there will be no problem in including these excerpts, as they help clarify several points I make in the thesis. I hope to incorporate some of the work from the thesis into articles and/or a book at a later date, and will contact you if any of these examples would be desired. I am submitting the thesis next week, and would therefore greatly appreciate your response as soon as is convenient. Thank you for your help.

Sincerely,

(Mrs.) Rosemary Mountain

London · Mainz · Madrid · New York · Paris · Tokyo · Toronto

29 August 1993.

Mrs Rosemary Mountain
c/o School of Music
University of Victoria
Victoria. B.C.
CANADA V8W 2Y2

Dear Rosemary,

Thank you for your letter dated 29th July.

You have our permission to use the extracts from Ligeti's *Chamber Concerto* in your dissertation as listed in your letter.

If we can be of any further assistance to you please do not hesitate to contact me.

Yours sincerely

Marc Warry
Contracts & Copyright Manager

Schott & Co. Ltd · Music Publishers · 48 Great Marlborough Street, London W1V 2BN England
Telephone: 071-437 1246 Fax: 071-437 0263
Hire Library Direct line: 071-434 3943

Directors: L. von Canstein (Chairman); J. S. Harper (Managing); Dr. P. Hanser-Strecker; R. Reisinger; N. D. Wildish
Company No. 196809 England. Registered Office: 48 Great Marlborough Street, London W1V 2BN England

Supervisor: Prof. M. Longton

ABSTRACT

An investigation into the nature and functions of periodicity is presented through analysis and discussion. Periodicity is established by the repetition of any musical event at regular intervals in time. The three works analyzed exhibit periodic elements in a variety of contexts and on different structural levels, thereby illustrating typical functions of periodicities in complex twentieth-century music. These functions include stratum delineation, textural definition, and metric-style organization. In some cases, the regularity of the periodicities is crucial to their function, while in others the periodicity of the elements simply provides a convenient model for study.

Reference is made to perceptual tendencies and thresholds including Gestalt principles of grouping, the phenomena of auditory streaming and fusion, and the temporal limits of the perceptual present. As our response to periodicities is affected by the specific rate of recurrence, a classification is made according to the rate of recurrence. The links between rate and function are discussed. Boundaries are suggested for three main divisions: very fast rates (less than 0.10"), medium (between 0.10" and 10"), and long (greater than 10"). An additional tripartite division of the medium range is proposed, incorporating the levels of pulse, sub-pulse, and super-pulse. The term "super-pulse" is introduced to emphasize the potency of the pulse-grouping level.

Relationships between levels of periodic events are described in terms of rhythmic consonance and dissonance. The analyses show that a contrast in the degree of rhythmic consonance is a typical means of indicating structural boundaries. They also suggest a link between the levels which produce a dissonance and the degree of harshness felt. Consonance on several levels adds significant coherence to a stratum, enhancing its recognition in complex textures or on later appearances.

Keywords:

PERIODICITY, RHYTHM, TEXTURE, POLYRHYTHM, AUDITORY STREAMING

Examiners:

Prof. M. Longton, Supervisor (School of Music)

Dr. H. Krebs, Departmental Member (School of Music)

Dr. J. Celona, Departmental Member (School of Music)

Dr. C. Porac, Outside Member (Department of Psychology)

Dr. J. Michelsen, Outside Member (Department of Philosophy)

Prof. O. Underhill, External Examiner

T A B L E O F C O N T E N T S

TITLE PAGE i
ABSTRACT ii
TABLE of CONTENTS iv
LIST of EXAMPLES and FIGURES v
ACKNOWLEDGEMENTS vii

INTRODUCTION 1

PART ONE — BACKGROUND

I. A CLARIFICATION of TEMPORAL ISSUES 13

II. A SUMMARY of PERCEPTUAL INFLUENCES 28

III. PERIODICITIES in MUSIC 45

PART TWO — ANALYSES

IV. TEXTURES and TEXTURAL STRANDS 88

V. CANONS 117

VI. ENHANCER of THEMATIC STRUCTURE 133

VII. DELINEATION of STRATA 145

VIII. PULSE and SUB-PULSE 166

IX. DELINEATION of STRUCTURE 181

X. CONCLUSIONS 208

EXAMPLES 227
ENDNOTES 288
BIBLIOGRAPHY 312

APPENDICES
A. Glossary of terms 324
B. Estimates of perceptual boundaries 333
C. Reasons for choice of works 335
D. Converting metronome mark to clock time 337
E. Examples of meter overrides 339

LIST OF EXAMPLES

Ex. 4.1	Bartok II:199-239	228
Ex. 4.2a	Lutoslawski III: 598-599	229
Ex. 4.2b	Lutoslawski III: 600-601	230
Ex. 4.2c	Lutoslawski III: 659-665	231
Ex. 4.3	Lutoslawski III: 593-595	232
Ex. 4.4a	Lutoslawski I: 41-45	232
Ex. 4.4b	Lutoslawski I: 64-66	233
Ex. 4.4c	Lutoslawski I: 103-108	234
Ex. 4.5	Lutoslawski III: 715-717	235
Ex. 4.6	Lutoslawski III: 802-807/822-829	236
Ex. 4.7	Bartok I: 78	237
Ex. 4.8	Bartok III: 36	237
Ex. 4.9	Bartok III: 65	238
Ex. 4.10	Ligeti III: all (1-66)	239
Ex. 4.11a	Ligeti III: texture "A" - pitch	240
Ex. 4.11b	Ligeti III: 4-5	240
Ex. 4.11c	Ligeti III: 9-11	240
Ex. 4.12	Ligeti III: 23-27	241
Ex. 4.13a	Ligeti III: 32-39	242
Ex. 4.13b	Ligeti III: 36-38	242
Ex. 4.14	Ligeti III: 46-48	243
Ex. 4.15	Ligeti I: 17-25	243
Ex. 4.16	Ligeti I: 22-23	244
Ex. 4.17	Ligeti I: 30-34	245
Ex. 5.1	Bartok I: 16-22	246
Ex. 5.2	Bartok I: 29-33	246
Ex. 5.3	Bartok II: 310-338	247
Ex. 5.4	Bartok I: 65-69	248
Ex. 5.5	Bartok II: 94-112	249
Ex. 5.6	Bartok II: 287-300	250
Ex. 5.7	Bartok II: 40-55	251
Ex. 5.8	Bartok III: 6-12	252
Ex. 5.9	Bartok III: 50-63	253
Ex. 5.10	Bartok IV: 121-129	254
Ex. 5.11a	Lutoslawski I: 1-43	255
Ex. 5.11b	Lutoslawski I: 36-40	255
Ex. 5.11c	Lutoslawski I: 160-172	256
Ex. 5.12a	Lutoslawski III: 614-617	257
Ex. 5.12b	Lutoslawski III: 620-623	257
Ex. 5.13	Lutoslawski III: 885-888	257
Ex. 5.14	Lutoslawski III: 888-890	258
Ex. 5.15	Lutoslawski III: 698-700	258
Ex. 5.16	Lutoslawski III: 766-770	258
Ex. 6.1a	Bartok II: 243-250	259
Ex. 6.1b	Bartok II: 264-285	259
Ex. 6.2a	Bartok II: 1-7	260
Ex. 6.2b	Bartok II: 1-19	260

Ex. 6.3	Bartok II: 69-76	261
Ex. 6.4	Bartok II: 373-377	262
Ex. 6.5	Bartok IV: 5-9	262
Ex. 6.6	Bartok IV: 15-16	262
Ex. 6.7	Bartok IV: 28-40	263
Ex. 6.8	Bartok IV: 74-83	264
Ex. 6.9a	Lutoslawski III: 426-433	265
Ex. 6.9b	Lutoslawski III: 570-578	265
Ex. 6.9c	Lutoslawski III: 802-809	266
Ex. 6.9d	Lutoslawski III: 852-857	266
Ex. 6.9e	Lutoslawski III: 876-877	266
Ex. 6.10	Lutoslawski II: 173-189	267
Ex. 6.11	Lutoslawski I: 2-34	268
Ex. 7.1	Bartok I: 78-79	269
Ex. 7.2	Bartok III: 38	269
Ex. 7.3a	Bartok II: 113-120	270
Ex. 7.3b	Bartok II: 123-127	270
Ex. 7.3c	Bartok II: 149-155	271
Ex. 7.4	Bartok II: 205-211	271
Ex. 7.5	Bartok IV: 25-43	272
Ex. 7.6	Bartok IV: 136-183	273
Ex. 7.7a	Lutoslawski II: 311-324	274
Ex. 7.7b	Lutoslawski II: 307-314	275
Ex. 7.7c	Lutoslawski II: 323-327	275
Ex. 7.8a	Lutoslawski III: 438-441	276
Ex. 7.8b	Lutoslawski III: 447-451	276
Ex. 7.8c	Lutoslawski III: 455-458	276
Ex. 7.8d	Lutoslawski III: 463-467	276
Ex. 7.8e	Lutoslawski III: 471-475	277
Ex. 7.8f	Lutoslawski III: 479-481	277
Ex. 7.8g	Lutoslawski III: 484-485	277
Ex. 7.8h	Lutoslawski III: 498-500	278
Ex. 7.8i	Lutoslawski III: 505-508	278
Ex. 7.8j	Lutoslawski III: 524-528	278
Ex. 7.8k	Lutoslawski III: 530-532	278
Ex. 7.9a	Lutoslawski III: 434-479	279
Ex. 7.9b	Lutoslawski III: 498-543	280
Ex. 7.10a	Ligeti I: 8-16	281
Ex. 7.10b	Ligeti I: 14-18	281
Ex. 7.11	Ligeti I: 19	282
Ex. 8.1	Bartok I:45-53	283
Ex. 8.2a	Lutoslawski II: 189-210	284
Ex. 8.2b	Lutoslawski II: 210-221	285
Ex. 8.3	Ligeti IV: 48-49	286
Ex. 9.1	Bartok IV: 136-138, 148-153	287
Ex. 9.2a	Lutoslawski I: 40-43	287
Ex. 9.2b	Lutoslawski III: 597-614	287

ACKNOWLEDGEMENTS

Excerpts from Bartok's MUSIC FOR STRING INSTRUMENTS, PERCUSSION AND CELESTA are copyright 1937 by Universal Edition. Copyright renewed. All Rights Reserved. Used in the territory of Canada by permission of European American Music Distributors Corporation, sole U.S. and Canadian agent for Universal Edition.

Excerpts from Ligeti's CHAMBER CONCERTO are used by kind permission of Schott & Co., Ltd.

Excerpts from Lutoslawski's CONCERTO FOR ORCHESTRA are copyright © by G. Schirmer, Inc. (ASCAP). International Copyright Secured. All Rights Reserved. Used by Permission. Thanks also to Eulenberg Edition and Polskie Wydawnictwo Muzyczne.

I N T R O D U C T I O N

The subject of rhythm has received a surge of interest in the last few decades. Speculations by theorists, composers, cognitive scientists, phenomenologists and others on our perception of rhythm have led to the formulation of various approaches to rhythmic analysis. However, many of the stimulating questions posed have not yet been investigated in much depth within musical contexts. Also, some of the proposed analytical models have been designed initially for tonal and/or monorhythmic structures.[1] Therefore, they remain inadequate for revealing the atonal rhythmic complexities which characterize much twentieth-century music. My investigation was prompted by a search for a perspective which would ease the study of polyrhythmic works, and which would incorporate the latest relevant research on rhythmic perception.

Most researchers agree that certain types of periodic elements such as pulse and meter can have a very strong influence on our perception of formal structure. There appear to be intrinsic properties of periodicities which make some of their functions unique, though they do complement other elements that contribute to accent and grouping.[2] Also, models of rhythmic complexes can be

designed from periodic components in a way analogous to the construction of complex tones from sine waves. These aspects, and the relative ease of extricating periodic elements from a musical score, suggested that an examination of periodicities would be a logical first step in the formulation of appropriate methods for rhythmic analysis. This dissertation therefore undertakes an exploration of the periodic aspects of rhythm.

Periodic elements can occur at different levels in music, from the rearticulation of a note in a tremolo figure to the recurrence of a chorus in a song. Both polyrhythmic structures and textural passages are easily modelled, and sometimes composed, by superimposing different layers of periodic events. Periodicities in the form of pulse, meter and parallel phrase structure played a significant rôle in most Western music of the previous few centuries, and still form an important component of compositional design in many contemporary works. The establishment of such periodic structures often provides a basis for elaborations or subsequent deviations.

The particular arrangement of pulses, their subdivisions and groupings has a profound influence on the listener's perception of patterns and phrasing. Periodicities often occur at several hierarchical levels

simultaneously, but create markedly different effects depending on whether or not the periods of the various levels are in alignment. The degree of contrast in periodic configurations from one section to the next influences the perception of larger-scale structure. Similarly, the perception of two or more simultaneously-presented layers often depends on a contrast in their respective periodicities. This dissertation sets out to discover the array of factors which contribute to our varied responses to periodic events, and to examine the typical functions and manifestations of periodicities in musical works.

Because periodic events occur at regular intervals in time, a study of periodicity needs to address issues relating to time and our perception of regularity. Therefore, Chapter I presents a summary of temporal issues. The reader is alerted to the difficulties of assessing equivalence of durations, and given a brief review of theories explaining how that assessment may be aided by mental processes and by musical structures. Then, the merits and limitations of clock-time measurements are explained. The limitations range from imprecise musical notation to false implications of objectivity; merits include the convenience of quantization, and a means of correlating information with

findings from psychology. The latter part of the chapter describes broader temporal issues. Our perception of time in general is explained in terms of the rates of change observed in various phenomena; our perception of musical time is then discussed within that framework.

As perceptual tendencies and thresholds have crucial ramifications for our perception of musical structure, a summary of relevant research from the cognitive sciences is presented in Chapter II. Although many factors which contribute to the particular effect of a periodic event relate to the specific musical context, others appear to be inherent in the nature of regularity itself, and related to the precise rates of recurrence. Our varied reactions to specific rates are found to be linked to perceptual processes appropriate for assessing a myriad of sonic data from the environment in general. Findings from the areas of perception, cognition, Gestalt psychology, and information theory have proven particularly useful to the current investigation.

The chapter describes several perceptual tendencies investigated in the psychoacoustic laboratories which appear to have relevance for the analyst. For example, a threshold at about 0.05 seconds defines a point below which the ear has difficulty distinguishing temporal order

and duration.[3] The size of the short-term memory buffer contributes another boundary, though more variable, beyond which the perception of rhythm demands memory codification and retrieval. Together, these two limits define quite a narrow band within which periodic events are perceived directly. This band is shown to correspond roughly to the rates of musical sub-pulse, pulse, and a grouping level I have labelled "super-pulse". Each region within the band is assigned specific temporal boundaries, drawing on evidence from the cognitive sciences and from the analyses herein. Another relevant perceptual threshold is the apparent inability of the ear to detect a difference of less than five to eight per cent between two durations.[4] Although tested mainly in the context of very short durational comparisons, it appears that such a tolerance may exist on a much larger scale. The ramifications of such a tendency on listening strategies and on analysis are discussed.

Chapter III describes typical manifestations of musical periodicities and identifies each with its typical rates of recurrence. The list of manifestations begins with the fundamental building blocks of pulse, sub-pulse, and meter, progresses to aggregates such as sequence and ostinato, and continues to larger-scale forms such as rondo before returning to the very fast rates associated

with ornamentation and texture. As characteristics of periodicities vary with different rates of recurrence, those characteristics are reviewed with reference to musical and perceptual influences. A similar review is made of the different effects produced by the number and type of components controlled by periodicity. The latter part of Chapter III discusses the various functions of periodic elements. These functions are often interrelated or even inseparable but can benefit from being viewed from a variety of perspectives. Therefore the discussion involves concepts from Gestalt theory, information theory, music theory, and research in psychology.

In the six subsequent chapters, specific musical examples incorporating periodicities are examined in more detail. The examples are all drawn from three twentieth-century works: Bartok's Music for Strings, Percussion, and Celesta, Lutoslawski's Concerto for Orchestra, and Ligeti's Chamber Concerto. These compositions were chosen because they contain periodicities in a variety of contexts, including textures and extended multi-strata passages.[5] The almost exclusive focus of the analyses on periodic elements demonstrates the ability of such an approach to reveal significant data about the formal structure of certain works.

The relationship between periodicities is often conveniently described in terms of rhythmic consonance and dissonance. These terms refer to the degree of alignment between periodicities. Layers of periodicities are consonant when their note attacks are related in a simple ratio (such as 2:1 or 3:1) and the initiation of groupings coincide. Dissonance arises when periodicities are not related in a simple ratio, or when the grouping initiations are out of alignment. A passage can display dissonance at the foreground level and consonance at a higher level, or vice versa.

The six analytical chapters are each devoted to one particular function of periodicity. These are arranged roughly in terms of scale, with manifestations at a local level preceding those which contribute to large-scale structure. Chapter IV begins with texture and textural strands which depend on quite fast rates of periodicity and are quickly recognizable at a foreground level. The construction of various textures appearing in the three works are discussed in terms of rhythmic dissonance and of auditory fusion (a perceptual phenomenon described in Chapter II). A distinction is made between different types of textures according to the degree of dissonance exhibited at a foreground level. Chapter V contains a discussion of canons, described in terms of their textural

aspects as well as their individual properties.

Chapter VI examines the rôle of periodic elements in reinforcing thematic structure. Internal rhythmic consonance, usually in the form of hierarchical metric-type structure, is shown to be a typical component of themes even in the context of generally irregular large-scale structures. The benefits of including periodicities in a theme are discussed mainly in terms of Gestalt psychology. It is shown that consonant hierarchical structures have a significant potential for making a specific configuration memorable, and hence for aiding recognition of that configuration in future recurrences.

The rôle of periodicities in the segregation of strata is described in Chapter VII. Rhythmic dissonance is often a significant factor in creating the distinction between different layers, while principles of Gestalt grouping contribute to the cohesiveness of each component layer. Research on the phenomenon of auditory streaming provides an invaluable perspective for the study of this area. Although the phenomenon is usually discussed only in the context of very fast rates, Bregman has suggested that the phenomenon indicates perceptual tendencies which can operate in broader contexts.[6] His proposal seems supported by the analyses, which demonstrate how the

effect of periodicity can parallel those of timbre and register in producing segregation or fusion of musical information in certain contexts. The results of the investigation suggest that the segregation or fusion of rhythmically dissonant layers is highly dependent on both the specific and the relative rates of periodicity involved. As rhythmic dissonance is also typical of textural passages, factors which lead us to differentiate between textural and multi-strata passages are examined.

Chapter VIII describes the potential rôle of pulse and sub-pulse in providing cohesiveness in longer passages. The constant sounding of a reiterated pulse is a typical occurrence of periodicity in additive structures, where variety is more often produced by irregularity at higher grouping levels. The interruption of a pulse continuum usually indicates a structural highlight or boundary. Chapter IX examines other ways in which periodicity contribute to the marking of structural boundaries. Most of the examples in that chapter show the delineation of structure as arising from contrast in periodicities at a very local level. The examples demonstrate a range in the type and degree of contrast. The rôle of periodicity in establishing contrast is examined both vertically and horizontally; that is, in terms of rhythmic consonance and dissonance, and in terms of difference in period lengths.

In the final chapter, broader conclusions are drawn concerning our perception of periodicities in music. The findings throughout the analyses confirm that different rates of recurrence have intrinsic qualities, and are linked for solid perceptual reasons to different musical functions: ornament/texture, pulse/phrase, and large-scale structure. The advantages of further delineations of the pulse/phrase region into bands of sub-pulse, pulse, super-pulse, and phrase are demonstrated. It is suggested that the super-pulse is often the most salient periodic level.

A major reason for concluding the significance of the super-pulse level is drawn from an examination of polyrhythmic structures. A comparison of various examples of rhythmic dissonance illustrates that the particular vertical configuration of periodic elements is a major contributor to the degree of harshness sensed in a polyrhythmic passage. Extending this concept, it is suggested that the harshness of a particular rhythmic dissonance may be most severe when on the level of the super-pulse. A ranking of dissonances is proposed, based on the alignment or non-alignment of periodicities of the various levels.

Specialized terms relevant to the investigation have

their particular usage defined in the glossary: Appendix A. Four other appendices expand certain aspects of the dissertation. Appendix B presents a sampling of estimates of the perceptual thresholds described in Chapters I and II, such as the temporal range of the perceptual present. Appendix C describes the reasons for choosing the specific works analyzed. Appendix D provides the interested analyst with a conversion chart of metronome markings to clock-time durations. Appendix E provides two quasi-musical examples composed to demonstrate the potential of metrical structure for obscuring isorhythmic construction and periodic pitch structure.

Although many twentieth-century works do not exhibit periodicities to the extent of those examined herein, the results indicate that even the fleeting presence of periodicities at certain rates will have an impact on the perception of musical structure. Therefore, a clear understanding of the properties of periodicity can ensure that such elements will not be overlooked in analysis. In addition, many of the observations contained herein may be relevant to non-periodic events which share the same <u>average</u> rate of recurrence, and thus share certain characteristics. The dissertation aims to clarify many of the issues relating to periodic aspects of rhythm, and to illustrate the relevance of studying perceptual

influences. It is hoped that the contents will provide a useful basis for future investigations into rhythmic structure in general.

Chapter I . . . . . .

A CLARIFICATION of TEMPORAL ISSUES

A study of periodic elements in music requires an appreciation of what constitutes regularity in time, and how we measure that regularity. Such temporal issues have been faced by many theorists while searching for viable approaches to rhythmic analysis. Although the subject of time provides a fascinating theme for reflection, it eludes the sort of clear definition with which we like to describe our world. The effect on music theory has been a proliferation of different perspectives, ranging from the stimulating to the confusing.[1] The most problematic aspect of such investigations for music is that the experience of duration appears to fluctuate, depending on the individual and on what is being experienced. Therefore, how can we possibly have a meaningful discussion of regular durations in music?

The fluctuating experience of duration is manifest in our feeling that not all five-minute segments of our lives are equal in duration. It is natural to conclude that the clock measurement which grants them equivalence is misleading. However, since we do not yet have precise

means of specifying duration as we actually feel it, the use of clock-time measurements persists. The conclusion, then, seems to be one of despair because we do not have a satisfactory measurement for experienced duration.

Ornstein proposed that experienced duration relates to the amount of information or density of events contained within the duration.[2] More recently, it has been proposed that the amount of mental processing involved affects the sense of duration.[3] Stockhausen, Clarke, and Tenney have stressed the importance of change in various musical parameters as constituting significant information.[4] There is evidence of internal body clocks, controlling the cardio-vascular and nervous systems. However, their relevance for music appears to be in the reproduction of rhythms, and therefore applies to the performer more than the listener.[5] A more accessible clock metaphor has been suggested by Benjamin, who points out that certain levels of periodicity such as pulse and meter can function as a built-in clock for the music.[6] The present study examines factors potentially relevant to questions of perceived duration. Those factors include the manifestation of periodicities, and changes in rates and densities of periodic activity. Therefore, the results may be able to contribute to further investigation of our sense of experienced duration in music.

There is increasing evidence that our reaction to certain rates of periodicity in music is fundamentally linked to motor activity and other physiological processes. All humans possess certain inner mechanisms which operate at very similar levels to those of other humans. Examples include breathing rates, heartbeats, muscle contractions and neuron activity.[7] The link between body mechanisms and our perception of musical rhythms appears to be based almost entirely within a small range of periods. We seem most confident in identifying rhythmic configurations which do not exceed the short period of time referred to as the perceptual present (generally estimated as no longer than ten seconds).[8] There is a lower boundary as well: our discrimination weakens considerably for durations under about one tenth of a second. The relative length of durations within this band of 0.10" to 10" can be sensed directly. They are probably imprinted as temporal patterns directly to memory, whereas our perception of longer durations is almost entirely dependent on our mental organization of the short components.[9] The processing required to apprehend longer durations depends on the experience, education, mood, and mental strategies of the individual. It is doubtless at this stage that the variety of experienced durations originates.

Clock-time measurements are employed extensively in this study for three reasons. Firstly, we seem to lack suitable alternatives. Secondly, the use of clock-time durations facilitates comparisons with research in the cognitive sciences, which are almost invariably expressed in such terms. Thirdly, and most importantly, at certain rates (roughly less than 10"), differences in clock-time measurements do seem able to convey useful and pertinent information. Clock time admittedly ignores the subtleties of personal experience, yet it can provide a useful and familiar reference. Significantly, clock time is used constantly by musicians for the interpretation of notated music. Metronome markings are direct references to clock time, indicating the number of beats per minute. Many scores of the last several decades indicate all or parts of the composition directly in terms of the number of minutes' and seconds' duration, although the absolute nature of such references is frequently tempered by the use of "circa" or "approximately".

At certain rates, periodicities are quite audible as regular events, so to discuss them as equal in clock-time seems reasonable. The use of discrete time units for reference has been criticized as ignoring the fluctuation of time and its subjective implications, thus falsifying

the data in a misleading way. However, as discussed above, this fluctuation is most likely to be significant for durations which exceed the level of six to ten seconds. Below that level, clock-time expressions of duration can be regarded as quantization for the purposes of discussion. For increasingly longer durations, the figures must be considered increasingly approximate. As research on this subject is only now being assimilated, and as it is rather beyond the scope of the current paper, I ask my readers to accept the clock-time references as an approximation, just as they must regard the corresponding metronome markings in the score (and in fact the durational values of the notes themselves). I have attempted to remind the reader of such discrepancies at various points during this paper where ignoring the fluctuation could cause significant misinterpretation.

Initially, we should be able to proceed with the familiar clock-time measurements without forgetting that such measurements are **not** an indicator of experienced duration. There is no more reason to resent the inability of clock time to describe the subtleties of musical experience than to resent the yardstick's inability to describe the surface textures of objects being measured. Both are indispensable for their particular form of measurement. Clock measurements of time are certainly

familiar. The idea of using clocks presumeably arose from the realization that, despite a constantly fluctuating sense of duration, there are external references to which we all have access. Even within an urban society we tend to be aware of the regularity of the day/night cycle, and it is this still-valid reference that produced the original concept of the clock.

One serious problem caused by the use of clock-time measurements for research in rhythm is that, despite appearances, there are far more tempo deviations in notation and performance than is convenient for a coldly analytic survey. Firstly, even though metronome markings are based on clocks in stating number of beats per minute, it is rumoured that many metronomes are inaccurate.[10] Such may be the case with Bartok's and Ligeti's, as their works exhibit quite substantial discrepancies in the score between the metronome markings and the cumulative durations given for the various movements or sections. Ligeti seems the more realistic of the two, as he stresses in his notes to the fourth movement of the Chamber Concerto that the proportion of the various sections must be kept intact after an initial tempo is settled.[11] Bartok is quite precise about metronome markings, stating even minor tempo differences quite carefully, but the total duration of movements stated at the end of his Music

for Strings differs substantially (in one case by 45") from that calculated by a tally of beats.[12]

Such discrepancies must be considered quite common, and emphasize how the musician's use of clock-time durations is considerably looser than that of the psychologist's. They also indicate the danger of implying a precision of timings or durations inappropriate to the context.[13] I have concluded that in the case of these particular analyses, discrepancies between measurements derived from the score (as mine are) and those heard in a performance are not usually critical, as some leeway is to be allowed in either direction. In other words, it is the relative proportions that are most important. The reader is reminded of the problem when the difference of a few milliseconds might affect perception.[14]

Another pertinent temporal issue is raised by Clarke and others, who have evidence that music is rarely if ever played exactly and consistently at the prescribed tempo.[15] Clarke has presented a startling but plausible hypothesis: bar-level periodicities in metric contexts may be the only ones which the performer produces with extreme accuracy. All lower periodicities, including those of the beat, are adjusted to fit the expression of the music (or in more theoretical terms, the grouping structures).[16] The

findings indicate that the four quarter-notes of a typical 4/4 bar, although representing equal values, are played unequally depending on where they occur within the context of the bar or musical phrase.

This hypothesis might suggest an insurmountable problem in discussing periodicities with reference to clock-time. However, a closer look at the findings suggest that we may continue to assume for the moment that the notes are heard as being regular. The preference is to relate all notes in the simplest ratios such as 2:1 or 3:1.[17] There appears to be a specific pattern associated with metric structure which leads to deviations involving a slowing down towards the end of each bar or similar type of group. Greater deviations match the endings of larger-scale structures. Therefore, the listener interprets such deviation precisely as deviation of an underlying regularity, and acting as carrier of the higher-level structural groupings. More extreme cases of the same phenomenon are found as accelerandi and ritardandi, where the listener interprets the fluctuation of tempo as a separate force acting upon the pulse level. We recognize this phenomenon easily because of its common occurence in our environment: most familiarly as a speeding up or slowing down of an activity such as walking/running, but equally evident in such things as the coming to rest of a

bouncing ball. These effects need only an established pulse as carrier.[18] Therefore even complex twentieth-century works which show virtually no metric-style organization can incorporate "expressive" deviation if the context is periodic on one level.[19]

For the purposes of this study, I conceive of time as referring directly to the rate at which change occurs. Since change occurs at different rates in different phenomena, the perception of time depends on the specific phenomenon being observed. A change of focus is probably a major factor contributing to the sense of fluctuation in our experience of duration. Such a change is as likely to involve a shift in a temporal or parametric focus as in a focus of scene.[20] Ordinarily, we have multiple references available to our consciousness as we are surrounded by many phenomena, each changing at its own rate. Everything in our environment evolves or exists at a rate or tempo according to its own nature; each has its own internal rate of growth and decay. Through interaction with the environment, we learn to distinguish different phenomena from each other according to their rate of change. This strategy leads us to apprehend (and to some extent, predict) the behaviour of various things. The more periodic and the slower-evolving things are the easiest to apprehend.[21]

Though most phenomena do not exhibit a strict periodicity, many possess a usual range of movement. Ocean waves arrive at the shore at a slower or faster speed depending on constants such as land formation, and variables such as weather and tides. However, they always arrive at the shore within certain limits: they are never as slow as one every ten minutes or as fast as one every second. A walking pace is similarly variable but occurs within limits dictated by the configuration of the hip, length of leg, muscle tone, coördination, etc. The startling and often comical effect of watching time-lapse photography clearly illustrates our knowledge of these limits by showing events which change at excessively fast rates. Familiar phenomena thus become measures by which one can judge the movement or degree of change in other things. Therefore our perception of things involves a sense of relative temporalities. In addition, most of us have at some time or another measured our familiar experiences by clock time. The neutrality of the clock thus provides an indication of the relative rate of change of disparate events. In music, however, we usually ignore references outside the performance itself. In electronic music, even the physical actions of performance are often no longer available as references.

We recognize a table as being a stable object in our vision because each time the room is scanned, the table image remains unchanged. Minsky has presented a very plausible explanation of one aspect of our musical perception by drawing a parallel with this visual strategy. He suggests that certain levels of periodicity in music can create the feeling of the persistence of a musical "object". The figure being repeated corresponds to an image, and the sameness of that figure at each pass confirms its stability.[22] This analogy is easiest to confirm with ostinato figures, but seems applicable to many instances of repetitions in music. For example, a phrase is often followed by another which starts off in the same way but ends differently. The listener can quickly compare the differences by mentally placing the profile of the second phrase on top of the first.

Discussions of music by composers such as Varèse often incorporate the idea of "spatial" images in music.[23] Structures such as ostinati (which rely on periodic components) create the impression of "objects" which remain static in time. Such a compositional aim is quite different to the more organic growth of musical ideas typical of earlier centuries, when the music was designed to change at rates more attuned to the fluctuation of human emotions. It is a characteristically 20th-century

idea to create sonic shapes that do not cater to the human audience with its traditional modes of listening and anticipation. The sounds simply exist in aural space, available to be heard by anyone who is within listening distance at the time. In addition, the lack of directed motion contradicts the intention usually implicit in beginnings and endings, and such passages can imply an indefinite duration extending beyond the work itself.

Epstein's suggestion that "music <u>structures</u> time"[24] seems compatible with the concept of time described above. By granting each musical composition an identity comparable to other more tangible events, the listener can perceive time as demonstrated through its particular rate of change. The extreme flexibility and unpredictability of change in music explains the great diversity in temporal durations experienced while listening. In some modern polyphonic compositions (including those studied below) the listener can perceive the coexistence of two or more musical "forms" which develop at independent rates and portray independent characteristics. This aspect is the fundamental difference between true multi-strata works and a more stylized polyphony which was common within traditional pieces. In the latter, the interwoven lines are generally understood as being parts of the same material. The impact of many twentieth-century works is

due to their unabashed presentations of disparate events; in some cases the works are designed specifically to depict multi-faceted environments.[25]

Returning to the question of experienced duration, it may be seen that differing perceptions of duration result from a combination of factors. The rate at which time unfolds within the phenomenon being perceived is affected by the manner and degree in which the perceiver is following, anticipating, or participating in that unfolding. In addition, the specific rate at which the phenomenon is unfolding will be perceived relative to the reference rates of the perceiver. In day-to-day life, an individual is usually aware of more than one phenomenon at a time. The profound effect of music on an individual's sense of experienced duration may well be due to the tendency for a listener to ignore outside references and give full concentration to that one experience.

Because there are no physical objects involved to suggest familiar rates of motion by size, weight, character, etc., the range of motion is much less predictable in music than in most other types of phenomena. In fact, the non-physicality of music makes it an ideal place to represent or evoke the temporal aspects of any and all kinds of phenomena, whether human emotions,

pastoral images, chaos, or the growth and decay of an imagined organism. Music is bewildering to analyze in terms of time precisely because temporal characteristics are presented in the absence of a tangible phenomenon. With almost everything else, time can be understood as the way in which that particular phenomenon unfolds, whereas in music, it might be said that there is nothing but the unfolding itself. A parallel could be found in human emotions, which also have no tangible presence. This parallel may explain the suitability of music for portraying and even inducing emotion in humans.

The importance of clock-time measurement of periodicities is stressed in order to emphasize how different rates affect our listening in different ways. The specific rate is fundamental to our perception and should therefore be included in any attempt to discuss our perception of periodicities and rhythm. However, once these aspects are understood, there are other far more interesting facets of periodic events to study, such as the specific interrelations and juxtapositions of periodic events in a musical work. The different effect of different rates is so fundamental that the issue seems to have been generally overlooked in the context of music theory. Therefore, an articulation of the obvious appeared to be necessary, and may help in the development

of flexible tools for rhythmic analysis.

For many of us, part of music's appeal is that we can forget the relentless pace of time defined by our working schedule. The composer presents a more unpredictable pace of events which maintains our interest by its variety. It would be a daunting task to define, or even describe to universal satisfaction, the sensed duration of each musical phrase in a work. However, the current study may permit the interested reader to understand some of the factors which differentiate one five-minute segment from another.

Chapter II . . . . . .

A SUMMARY of
PERCEPTUAL INFLUENCES

Periodicity in music occurs on various temporal levels, from that of the sub-pulse to large-scale formal structure. At certain rates, regular recurrence of elements is one of the most immediately discernible properties of a work. It can influence our sense of grouping and contribute to our discrimination of formal structure. Research in the cognitive sciences has demonstrated the existence of perceptual tendencies which operate in our discrimination of grouping and segregation in musical contexts. It has also established the existence of perceptual boundaries which affect our interpretation of musical phenomena. This chapter summarizes the pertinent issues and suggests how they may affect our perception of musical structure.

Relevant perceptual influences fall into the main areas of memory processing, Gestalt psychology, auditory streaming and fusion, perception of polyrhythms, and associative links and limiting perceptual thresholds which affect our reaction to specific rates of periodicities. One relevant threshold determines our ability to

discriminate between similar periods, while others help define the regions of pulse and ornamentation.

Perceptual thresholds and associative links

The pulse level is grasped on a very direct level; Clynes and Walker use the term "involuntary".[1] The specific pulse, tempo, and metrical organization (if any) tend to induce conscious or subconscious reference to a familiar body activity such as walking, dancing, or playing an instrument.[2] The natural association of excitement or tension with a fast pulse derives from its physical connotations; more energy is required to walk quickly or to play an instrument vigourously. The effect of a change to a faster pulse, whether gradual or sudden, is thus a strong factor in portraying an increase of tension.[3] The pulse range seems generally confined to 40-120 beats per minute, or one every 1.5" (one and a half seconds) to one every 0.5" (half-second); this range can be expressed in musical notation as quarter note beats in tempi from ♩=40 to ♩=120. The listener will tend to subdivide or double any beat outside this range unless the context is carefully designed to compensate.[4]

The threshold relating to our discrimination between durations, sometimes referred to as the just-noticeable

difference (JND), has been calculated according to the Weber fraction. Research in this area is still limited, but it has been estimated that two durations must differ by more than eight per cent before their inequality is perceived.[5] This threshold explains certain discrepancies between intention and result in some serial music, as early attempts to serialize rhythm treated each of several notated durations as though it were perceptually unique. However, a duration of ten thirty-seconds, for example, is virtually impossible to distinguish from one of eleven thirty-seconds when the tempo is ♩=88.[6] This fact might suggest a sloppiness in our perception, but its benefit is that it allows us to hear a series of notes as being periodic despite minor fluctuations in duration. As mentioned in the previous chapter, minor fluctuations seem to play a rôle in conveying expression. The factors which produce the effect of similarity between slightly-deviating durations thus enable us to perceive many configurations in terms of low-integer ratios (2:1, 3:1, 2:3, etc.).

Associations with motor movement and natural phenomena may contribute to the phenomenon of subtle deviation on the pulse level. Clarke's research indicates that in metrical contexts there is "a graduated tempo decrease towards the group boundary."[7] Therefore, the relative

deviations of near-equal durations can reveal the specific position of each note within the larger period. The same phenomenon may be imagined in terms of the "metric wave" proposed by Zuckerkandl,[8] and by an explanation of motor movements described by Clynes and Walker.[9] Zuckerkandl's model suggests a wave of motion away from one impulse (the downbeat of one bar) and moving towards the next (the downbeat of the next bar). Clynes and Walker explain how, by physically tracing an arc repeatedly with the arm, one can readily perceive both the regularity of each completed movement and the variation in speed depending on the specific position of the arc. The energy required to initiate the movement is released in the downward swing, which in turn gives momentum for a return to the higher position. Thus the most natural and efficient way to make the movement incorporates a regular fluctuation of speed.

The ornamental level, which I determine as being approximately 0.10" and less, is the region where the perception of rhythm weakens. At approximately 20 notes per second (periods of about 0.05") temporal order becomes difficult to distinguish and articulations of a single pitch begin to fuse into continuous sound.[10] At fast rates of recurrence such as in tremolo figures, periodicity is most likely to be perceived as a statistical parameter, as is timbre.[11] Very short

durations are common in ornamental flourishes and trills which serve to accent and embellish a structural pitch. When varied short durations are assigned to several instruments simultaneously, a high density of note attacks is produced. The effect, often described as a thickening of the texture, needs very little time to be grasped, making textural thickening a very convenient technique for providing contrast between passages. Such textures and ornamentations contribute significantly to the specific mood or character of a passage.

Memory processing

The perceptual boundaries of periods greater than 6"-10" relate to memory processing. The region of pulse and meter coincides largely with that of the perceptual present. The short-term memory, which determines the length of the perceptual present, has two limits: one is temporal, and the other contextual. The contextual limit refers to the number of chunks of data received. It is generally estimated that only five to nine chunks can be retained in the short-term memory; this total includes any chunks of data which may be retrieved from the long-term memory for review. The temporal upper limit of the perceptual present has been estimated differently by many people; a sampling of the range of these estimations is

given in Appendix C. For the purposes of this study, I have tentatively accepted a relatively high limit of approximately 10 seconds. These boundaries are not absolute but do serve to indicate the tendency for a specific periodicity to function in a way appropriate to its rate. Composers tend to avoid boundary areas unless deliberately playing with the perceptual ambiguities.

The recognition of regularity, though immediate and fundamental at the levels of the pulse, sub-pulse, and super-pulse, depends on the specific content when the regularity occurs at a temporal distance of six to ten seconds or more. Longer periods exceed our short-term memory capacity, and therefore depend on memory codification for a perception of regularity. Regular audible subdivisions of the type provided by metric organization enable longer periods to be understood as multiples of shorter ones; in other cases the perception of regularity depends on the listener's ability to compare the melodic/rhythmic patterning for durational equivalence. Conversely, the recognition of equal duration of long periods can easily be thwarted by the intervention of dissonant material: anything which implies a contradictory pulse or grouping structure. Thus the processing of information at the level of the pulse and super-pulse is essential to the perception of duration at

higher levels. The subdivisions of the longer periods can be periodic themselves, or simply recognizable through their specific melodic/rhythmic components.[12]

The mind tries to make sense of data as quickly as possible. To achieve this end, it looks for patterning of any kind. Such patterning helps the mind to encode the numerous bits of information into fewer "chunks" for memory storage. There is a constant search for reasonable ways of ordering and codifying to facilitate memory storage and retrieval. Some of these ways may be suggested by the specific musical context, while others will be strategies learned by the listener. Difficulties arise when the listener is confronted by a high density of unexpected combinations and sequences of sounds. An overload occurs, typically in the short-term memory buffer which is the place where data is processed and codified for storage and future recall.

In order to avoid such an overload, most composers control the input of new data either by employing a slower rate of presentation, or by incorporating redundancy. The latter is achieved by injecting a measure of predictability, usually through repetition, expectation of continued motion, usage of familiar formulae, etc.[13] Periodicity contributes significantly to such redundancy

by creating strong expectations of continuity and predictable accent patterns; it is often produced by means of repetition.

Periodicity has a quality of creating expectations so that the perceiver can anticipate future events. By expecting that a note is more likely to appear at some specific point in time, the listener is able to prepare for new data to be received at that point. This tendency has been shown to operate in the pitch domain as well: once a pitch range is established by the music, it is more difficult to hear a pitch outside that range, and detail about it may be lost.[14] These two tendencies combine when pitch and rhythm are combined into patterns. The purest form of such pattern is found in the ostinato, where the exact pitch and rhythm configuration is repeated exactly, and constantly. Once such a pattern is grasped, the listener does not have to pay much more attention to know that it is still there. The same principles which operate in the construction of ostinato govern much pattern repetition. A limited number of pitches, a repeated contour, and especially a repetition of rhythmic patterns all contribute to redundancy and hence to the efficient encoding of information. Because of this attribute, periodic elements are quite common in one or more layers of a multi-strata passage, facilitating a distinction

between layers. When the first layer is introduced in isolation, the listener learns to identify its profile and range of variation. Then, when the next layer is introduced, only a minimal amount of attention is needed to confirm that it is evolving as expected.

Gestalt psychology

Recognition of a pattern recurrence implies that the listener can perceive a similarity between two (or more) occurrences of an event, and can therefore compare them for identity. Such comparison involves pitch, contour, dynamics, duration, timbre, and rhythmic configuration. Studies indicate that contour and rhythmic configuration are among the most salient characteristics. Periodic components of the pattern ease recognition. Conversely, multiple repetitions of a pattern (as in ostinato or sequence) can convey a strong sense of periodic rhythm. The identification of a pattern or figure as an entity is often discussed in terms of Gestalt psychology. Although much of the original theory in this branch of psychology has become outmoded, there are a few principles of pattern recognition which remain very useful in both the visual and the musical realms.[15]

The three most useful guidelines for the perception of

Gestalten in music are those of similarity, proximity, and "common fate" or "good continuation". The existence of such structures at a foreground level and their influence on grouping seems clearly established.[16] Analysis can therefore benefit from an understanding of the principles involved. Their effect on perception is also being studied in such contexts as auditory streaming (discussed below). The factors of similarity, proximity, and common fate each contribute to the tendencies for elements to be grouped together by the listener.

Similarity in a musical context can operate in any musical parameter, though the context will usually influence the prominence of one or two parameters over others. Pitch, register, and timbre are most frequently involved.[17] The factor of proximity, in musical terms, usually refers to temporal proximity. It can be expressed as the tendency for notes sounding the closest together in time to be grouped together, or conversely, for those notes which are separated by the longest silences to be perceived as belonging to separate groups. As Benjamin points out,[18] this tendency can be overridden by a contradictory periodic structure.

Common direction involves the tendency for a perceived line of movement to continue. In visual terms, this

phenomenon is often illustrated by the tendency of an arc to suggest continuation of a circular motion. In music, an analogy might be that of a descending stepwise melodic line tending to continue downwards. On a rhythmic level, it operates in the tendency for a series of regular pitches to continue. It could as easily relate to the tendency for an accelerando or ritardando to continue. Tenney and Polansky devised an interesting experiment to test the effect of these factors by a simple application to three twentieth-century monophonic works.[19] The results were surprisingly reflective of a more musical analysis and support claims that such criteria may have a "universal" nature.

One other extremely useful concept donated by the Gestalt school is that of the figure/ground phenomenon. The term refers to the perception of one sonic image as distinct from other sounds present in the music. The sonic image is more prominent, and the other material is understood as background texture. A song with melody and accompaniment is a clear example. Obviously, some contexts are far less clear. The perception of a layer as textural implies a certain degree of invariance in one or more components. When there is sufficient ambiguity, considerable concentration may be required in order to maintain the contrast between the two. Ambiguity can

arise from the lack of strong identity in the figure, and/or from prominent activity in the ground which rivals that of the figure in claiming attention. The establishment of a clear identity (Gestalt) is therefore crucial to effective separation between figure and ground.[20] As will be seen through the analyses, the establishment of Gestalt can be approached in a variety of ways. It should not be assumed that a figure/ground separation is always desirable, or that such separation was the intent of the composer. All the works studied herein demonstrate some exploration of that boundary.

Monahan et al., who have been investigating rhythm from the perspective of psychoacoustics, warn:

> composers who ignore the Gestalt principles of grouping, in the domain either of frequency (pitch) or of time, run the risk of writing music that is difficult to code or to remember easily in the short term.[21]

Some composers might feel offended at this directive, arguing that listeners should develop their coding abilities, or learn to enjoy the sounds in themselves. However, as there are limits to the amount of apparent chaos most listeners will tolerate, many composers may wish to increase their sensitivity to such issues.

auditory streaming and fusion

The perceptual phenomenon of auditory streaming is generally associated with very fast rates of presentation. This phenomenon (sometimes referred to as melodic fission) has been receiving increasing study in the last decade.[22] It arises when the listener segregates different tones of a fast series into two distinct lines. Factors producing the segregation include register, periodicity, and timbre. Even when the listener is deliberately trying to hear the notes as part of a single stream, the effect of fission may be too strong to resist. This case seems to arise specifically when the rate of presentation is around 0.10" or faster, and the distance between pitches is greater than 15% (roughly three semitones in mid-range).[23] Although the phenomenon weakens when there is a greater temporal distance between the pitches, it seems clear that the same perceptual processes can be induced at periods much greater than those stated. Composers have availed themselves of this potential for centuries: works by Corelli, Bach, and contemporaries are full of illustrations.[24] The most relevant aspect of the phenomenon for analysis is the insight it provides into the mind's readiness to segregate information into different strata as seems appropriate. It indicates a tendency to hear two simple lines over one complex line.

This concept lends support to the findings in the analyses herein, where strata are often differentiated by contrasts in periodic organization.[25]

The phenomenon of auditory fusion can be understood as the converse of auditory streaming. It relates to the tendency in certain conditions to hear two or more separate lines as being part of one greater line. It is thought to be an extension of the process by which the brain fuses the various components of a complex sound such as a clarinet tone into one timbre. Factors which contribute to such fusion include the initiation of two lines at the same time, and the simultaneous dynamic and/or frequency modulation of those lines. Conversely, the lack of simultaneous attacks, or asynchrony, can cause segregation even when the attacks are separated by as little as 30 milliseconds.[26]

Both auditory fusion and auditory streaming are understood as a logical response to the diversity of sounds in our environment. Assigning sounds to their respective sources is clearly a valuable strategy for extracting order from a multitude of data. The mind assumes, for instance, that one sound does not stop just because another one has begun. Experiments have shown this assumption to be so strong that listeners could

"hear" a continuing line of music underneath the interruption of extraneous sounds, when in fact the line had stopped temporarily.[27] The mind assumes that each component has its proper place, and tries for the best fit. As a result, it tends to allocate a component to one group or the other, but not both. An interesting result of this perceptual tendency is that a component which fits two streams can be "captured" by the more prominent one.[28] Prominence in music can involve a higher degree of movement (change of pitch, temporal proximity) or a preconditioning by the listener's familiarity with the prominent gesture, as in ostinato.

perception of polyrhythms

Research on the perception of polyrhythms is beginning to surface in the psychoacoustic field. Typically the focus is on short durations, such as in the study by Pitt & Monahan who set note density at approximately one attack every 0.225". This particular rate was determined in order that the density would fall "within the time boundaries in which rhythm is perceived".[29] Interestingly, they found that the listener tracked the slower of two pulses when they were presented at fast rates, and the faster pulse at slow rates. At the very fastest rates, the period articulated by the coinciding of the two pulses

was tracked.[30] This evidence supports the concept of pulse being restricted to a specific range of durations. We might therefore hypothesize that in a polyrhythmic musical context there will be a tendency for one pulse to be used as a reference. Such a tendency can however be easily thwarted or reinforced by other means such as prominence of a specific rhythmic pattern or consonance with the prevailing metric scheme. The success of compositions such as the ones examined herein may depend partly on the composer's intuition to maximize such tendencies. The third movement of Ligeti's Chamber Concerto provides an opportunity to study strictly periodic polyrhythms at fast rates, and in a musical context.

CONCLUSIONS

An understanding of the perceptual result of various musical configurations is fundamental to any composer's ability to express musical ideas successfully. A composer who wishes to take full advantage of the new potential in sounds and structures will benefit from a grasp of the various perceptual tendencies employed by the listener. Interpreters of music can also benefit from understanding the potential variety of interpretations in order to emphasize the preferred one. Given the relevance of much

of the research in perception to the hearing of complex works, it seems essential that analysis begins to incorporate such issues as well. I hope that the present investigation will demonstrate the extent to which such perceptual phenomena contribute to our aural interpretation of music. If the approach is found to be valid, it will emphasize the benefits of closer contact between analysts and those involved in cognitive studies.

Chapter III . . . . . .

PERIODICITIES in MUSIC:

CHARACTERISTICS and FUNCTIONS

Periodicity is a strict form of repetition, and repetition has probably been an integral part of music since its inception. Physical work which involves repetition of movement (rowing, pounding of grain, stretching of wool, chopping of wood) becomes easier if performed rhythmically, enabling more efficient muscle coördination. Music with repetition is also beneficial to achieving coördination between humans involved in such activity. Dances are often dependent on repetition, not only for coördination but also for ease of memorization of steps. The potency of repeated musical rhythms has long been recognized as a means of heightening or even inducing specific moods. The music of certain African healing rituals, for instance, is designed to put the patient into a trance. Lullabies designed to calm an infant often reinforce a rocking movement. Faster pounding rhythms are a common ingredient of ritual tribal dances where the function is to heighten the prevailing mood of concentration and rising excitement.

When music exists as an abstract art form or a vehicle for personal expression, separated from the functions of dance, ritual, or work, there is tolerance for more variety of mood and rhythm within a single work. However, repetition still has a very important rôle in communicating the message, mood, or sonic image to the listener. It conveys the rate at which the musical event is unfolding.[1] The composer uses repetition to regulate the amount and rate of information being conveyed to the listener. Repetition can provide internal references for mental comparisons of various aspects of the music with other sections, in the form of templates or, less strictly, recognition of similarities in tempo, density, hierarchical ordering, etc. Conversely, different rates of repetition can provide contrast between sections. Such contrast can be achieved by a simple change in the pulse or sub-pulse rate, by a change in the number of elements controlled by repetition, or by a change in the number of levels which exhibit consonant periods. A significant difference between sections can be produced by varying the degree of rhythmic consonance exhibited. These means of delineating structure are all common in the works examined below.

Exact repetition has been a part of music for centuries, but the manner in which repetition occurs seems

to be changing considerably. For example, repetition of the exposition of a sonata or half a minuet was very common in the past, but one rarely finds immediate and exact repetition of a similar length of material in a modern work. This change in style may be encouraged in part by music technology, which allows us to listen to exact repetitions of entire performances at will. On the other hand, it seems that exact repetition of short motives is more frequently used in modern music than in the past. In older music, short passages of repeated material would often be subject to a slight variation such as transposition. The exact repetition of short patterns was more likely to be restricted to accompaniment figures. The reason for their incorporation in traditional accompaniment patterns relates to a typical function of periodicity in 20th-century works. In terms of information theory, this function can be described in terms of redundancy. By repeating many parts of the musical texture, the composer restricts the amount of new data being received within a short period of time. Incorporating repetition into an accompaniment figure allows the listener time to process the information from the more rapidly changing melody. As modern compositions are often designed with more than one layer of material sounding at a time, there is a danger of confusion for the listener. The confusion can be alleviated by the careful

use of repetition in one or more of the layers. Such a technique encourages focus on another layer, or on the interplay of layers.

Other factors also contributed to the increase of exact repetition on a local level. These relate to the weakening of tonal functions, the subsequent disappearance of the need for harmonic change, and a general desire for new approaches to formal structures. Although the dissatisfaction with old methods led to a marked reduction in periodicity of the type associated with metric organization, other forms of periodicity have been incorporated. In addition, an increasing awareness of other cultures' music suggested means of incorporating repetition in dramatically different ways to those of traditional Western traditions. For example, central African and Indonesian traditions both aim for trance-like effects in some of their ritual music, and so incorporate drones and ostinati. Such effects have been imitated by Western composers. At the other extreme, East Indian music is noted for its highly-developed traditions of intricate rhythmic structure usually based on additive methods of construction; these often rely on the repetition of very short modules and have likewise been imitated. Another source of inspiration for novel uses of repetition in early 20th-century music was a desire to imitate machines.

This desire is explicit in the Futurist manifesto and in such works as Villa-Lobos's Little Train of the Caipira. Ligeti takes this fascination one step further to portray "machines gone mad".[2]

Electronic music has also influenced the use of repetition by providing the means to repeat any material exactly, no matter how complex. One of the most striking effects grew out of an unpredictable malfunction in this process when Steve Reich was first composing with the aid of tape loops. When he played the loops back on two machines that were not synchronized exactly, they produced a slow phase-shifting effect that he then exploited to its full in subsequent works.[3]

DESCRIPTION of PERIODICITIES

Typical occurrences of periodicity in music can be grouped conveniently by rate. Those of the immediately perceptible foreground include sub-pulse, pulse, super-pulse, phrase, sequence, ostinato, etc. Larger-scale forms include passacaglia, rondo, and theme & variations. At the other extreme are the very fast, almost imperceptible, periods of embellishment such as tremolo and trills. Descriptions of the general categories follow

below, with their usual rate of periodicity.

As periodicity is established by the recognition of recurrence, different types of events will define periodicity at different rates. At the fastest levels, a regularity of note attacks produces periodicity. At slightly slower levels, periodicity may arise from recurrence of a specific pitch or gesture, recurrence of a pattern, oscillation between timbre groups, etc. The listener also searches for evidence of reasonable subdivisions of longer periods. (A listener will usually try to subdivide a pattern of six eighths in length, for example, into two groups of three or three groups of two, according to the musical context and the performance itself). The performer frequently accentuates a periodicity by very slight durational adjustments and dynamic shading. Once a foreground periodicity is established, it no longer needs definite cues from the music. Unless strong contradictory patterns are established, the periodicity will be assumed to continue, accenting whatever musical event occurs at the predicted point of recurrence. The situation changes at higher levels, where a sense of periodicity is not easily sustainable unless supported by audible partitioning. As at the foreground level, periodicity can be established by the recurrence of recognized sonorities or patterns.

However, such patterns or sonorities usually incorporate a more complex structure (such as is found in a theme) so that they can be clearly distinguished from the intervening sounds.

pulse

Pulse is generally considered the most basic periodic unit, and is perhaps the last periodic element to disappear in avant-garde music. Pulse is usually between 40-120 cycles per minute (or about 0.5" to 1.5" long). Faster periodicities tend to be grouped (usually by 2's, 3's or 4's) and slower ones tend to be subdivided, so that the resultant falls in the above range. There has been some discussion of the difference between pulse and beat. Beat has been defined as the strict point on the time-grid of meter, and thus refers to the anticipated point of emphasis, whereas pulse refers to an overt emphasis in the actual music.[4] Clarke's research indicates that performers subtly adjust beats for expressive reasons while maintaining a stricter clock-time periodicity for bar-length (super-pulse) time divisions.[5] To attribute an idealized periodicity to the abstract beat and then reserve the word "pulse" for the real event implies a potential conflict between them. However, my research indicates that any sense of beat is not long

maintained in the presence of contradictory emphasis in the music. To avoid confusion, I use the word "beat" only in the most unambiguous sense of a notated component of meter ("four beats in a bar") and "pulse" for all other discussion.

sub-pulse

Pulses are almost always subdivided at some point in a musical passage. The division of pulses into duple or triple determines simple or compound time when time signatures are used. Periodicity on the sub-pulse level arises most commonly when the subdivisions are all articulated (e.g. in constant sixteenth-note texture). However, they can also arise when a pattern is clearly based on the repetition of smaller units (e.g. dotted eighth, sixteenth). Division of pulses into 5, 7, 9 or more has become more common in the last several decades. Prior to this century such figures would be used only occasionally, usually in the context of an ornamental flourish or a written-out accelerando. Works by Ives, Cowell, Crawford, Carter, Stockhausen and Ligeti all contain passages of regular subdivisions of pulses into unconventional numbers.[6]

meter

Meter refers to the grouping of pulses according to a specific and regular pattern. Traditionally, it has been an exceptionally strong contributor of periodicity in music. The number of beats per bar would be indicated by means of a time signature at the beginning of the bar or series of bars, and the normally-accented beat would be placed directly following a bar line. Regular grouping of equal pulses into two, three, or four was very common in Western European music between the seventeeth and twentieth centuries. The same grouping usually persisted throughout an entire movement, with any deviations understood to be local and expressive. Such groupings seem to follow cultural preferences. Dance forms in Eastern Europe, for example, have many more instances of "irregular" meters such as 5/8, 7/8, and mixtures of two or more meters. This influence cannot be overemphasized as a factor in the irregular patterns of Bartok and Lutoslawski, both of whom were involved in the collection of folk tunes in the years immediately prior to the compositions analyzed below. Ives, Cowell, and Carter, on the other hand, seem to have derived their irregular meters from more abstract intellectual explorations.[7]

Meter refers to the grouping of the basic pulse by a

super-pulse.[8] Therefore, it is expressible only through the relationship of one level to a hierarchically-adjacent one.[9] Meter is quite rate-dependent; the super-pulse level tends to be around 1.5 to 4.5 seconds.[10] Because of perceptual tendencies and traditions, we seem particularly alert to regularity in this range. Often, a mere two bars seems sufficient to create expectations of a continuing metric structure.[11] However, a metric sense which was quickly established can also be quickly eradicated.

phrase

The length of a musical phrase, like that of the phrase in speech, is extremely variable. The ability to sustain a long phrase successfully is one indicator of talent in both composers and performers. In the Western European tradition of the nineteenth century, flexibility of phrase length contributed to the development of lyrical and dramatic expression. However, in Renaissance, Baroque, and Classical periods, it was quite typical for phrases to conform to a fixed length, especially that of four bars. Much of this conformity arose from the association with dance. Dance forms naturally benefit from a regular phrase structure, in order that the same or similar movements can be performed repeatedly. The elongation, elision, or truncation of phrases in more

complex music often depends on the expectation of a regular length for the deviation to be appreciated. Schachter suggests that most consequent phrases are the same length as their antecedents.[12] Irregular phrase lengths are more common in some other cultures, especially where additive structure is used (e.g. African, Indian). Even in the case of irregular phrase lengths, however, the phrases may often be grouped together and repeated so that at the next hierarchical level their composite length is regular. Ravel's Bolero is a good example of regular phrase structure taken to an extreme.

sequence

Sequence refers to the immediate repetition of a set of notes, transposed in pitch but retaining contour and rhythm. Sequences, common in both traditional and modern music, give a strong sense of periodicity even when it is in conflict with the established meter, since a pitch/rhythm pattern has a clear, recognizable identity. The term sequence is generally reserved for a relatively short segment. This restriction is presumably related to the perception of sequence within the duration of the perceptual present. When a large-scale sequence does occur, it is more aptly described as a parallel structure.

ostinato

An ostinato is formed by the exact, immediate, and continuous repetition of a musical fragment. The term ostinato, like sequence, implies the repetition of a short segment of music. If it can be contained entirely within the span of short-term memory, its form can be grasped directly. The ostinato is a very powerful device, as it encourages the attention to focus elsewhere while contributing a specific colour or mood. Its presence can be monitored easily, and thus it contributes a sense of stability. It represents something which either does not change at all, or else changes much more slowly than other elements in the music. Therefore, it can provide an appropriate means for representing various natural phenomena (e.g. flowing water) within a musical context. It can establish mood, and can be made to inject a sense of the grotesque by means of its obstinacy. When coördinated with the prevailing meter in a consonant passage, it emphasizes that consonance very strongly; when uncoördinated, it becomes perceived as a discrete element. Wright & Bregman state that in their experiments with ostinato, "segregation effects increased with the number of repetition of the pattern...thereby...'capturing' its notes from vertical integration."[13] The device thereby encourages horizontal listening.

drone

A drone usually refers to a continuously-sounding pitch. However, in some cases, the pitch is articulated by a steady pulse. In such cases, the static quality of the pitch is echoed by the static quality of the rhythmic aspect. Drones are found in many different cultural traditions but were generally abandoned in Western music for a few centuries because of their conflict with the development of harmonic motion. With the waning of harmony as a necessary element in music, drones have again become prominent. The first movement of Lutoslawski's Concerto for Orchestra contains an example of an articulated drone.

LARGE-SCALE FORMS

The perception of periodicity in long-term durations in music weakens with an increase in the time-span.[14] Our perception of duration relies heavily on the nature of that which is apprehended. Durations greater than ten seconds or so involve codification of short-term data into chunks suitable for long-term memory storage. Let us assume that three equal periods must elapse before periodicity is clearly determined. Even at periods just outside the limits of the perceptual present, three

periods of ten seconds would require half a minute of time. It is unlikely, from a compositional point of view, that there would be no fluctuation in the degree of activity in the intervening material. If there is fluctuation, however, the accuracy of duration estimates is likely to be affected. Thus the sense of periodicity would remain at a vague level, quite different from that of periodicities at the level of the pulse and bar.

passacaglia

A passacaglia involves the continuous repetition of one phrase. It is usually a simple melody with strong harmonic foundations, providing a background for variations which embellish or complement it. Traditionally, the repeating phrase is subject to various harmonizations and orchestrations. A ground is a sub-set of the passacaglia, in which the repeated theme remains in the bass. A passacaglia theme usually remains unchanged and basically audible throughout, so the sense of recurrence is quite clear and contributes to a feeling of periodicity. When a speeding up or slowing down is involved, the fluctuation will be readily grasped as a separate function of tempo change affecting a periodic event. Chaconne is a closely-related form, though often more closely associated with a specific (3/4) meter.

theme and variations

A theme and variations form is similar in some ways to a passacaglia. In this form, however, the theme is subsumed into the variations and transformed by texture, orchestration, pitch embellishment, etc. The composer often chooses a theme already in existence. Typically, the rhythmic/metric structure of the theme itself is quite simple, to allow for more variety of subsequent treatment. It is often in rounded binary form and played with repeats, so large-scale periodicities are sensed through the constant reiteration of the same length of phrases. The form is often designed to display virtuosity, and variations become increasingly ornate. These variations typically involve higher density of textures, with shorter durations produced by smaller subdivisions of the pulse. Contrast of periodicities therefore operates mainly at a sub-pulse level.

rondo

A rondo can be periodic, but will be perceived as such only if the various sections are readily comparable. An ABABA rondo will be clearly periodic, as in a typical song form with verse and chorus, if the identity of each

section is easily recognized. However, in a rondo of a form such as ABACADABA, the differences between the B, C, and D sections will usually pre-empt a comparison of durations. Therefore, periodicity will not be apparent, though a sense of recurrence will naturally remain very strong.

canon

Canons may exhibit periodicities on the pulse and bar level, but also incorporate them through the intervals between entries when they are regular. If these intervals are quite long (e.g. more than a bar or two) the periodicity is likely to be recognized by context rather than by a sense of the specific clock-time duration. The correspondence between the entry of the second voice and the musical configuration of the first creates a cue. Expectation increases when the second voice reaches that same point in its melodic statement (see further discussion in Chapter VI).

isorhythm

The technique of isorhythm involves the repetition of two constant but unequal series: one of pitches and one of durations. If, for example, 5 notes are chosen as the

pitch sequence and 7 durations for the rhythmic series, the correspondence of pitch to duration will shift until the cycle (5 x 7) is complete. In most cases, the repetition of each element does not appear to be very audible, although the restricted number of pitches and durations will usually produce the effect of a statistical field and contribute to redundancy. If the passage extends through two or more full cycles, then another level of periodicity will be formed. Its audibility depends on the context, as the period length will most likely exceed that of the perceptual present. The fascination of isorhythmic technique for composers may be due to the ease of construction coupled with the subtlety of effect.[15]

ORNAMENTATION

Trills and tremolo exhibit periodicity: trills involve periodic frequency modulation while tremolos involve a type of periodic amplitude modulation, sometimes coupled with frequency alternation as well.[16]. There are rare cases in modern music where the speed of modulation itself is specified as changing (usually in a linear manner, creating a simple speeding up or slowing down). It is increasingly evident from psychological investigation that periodicity on the ornamentation level is of a slightly

different kind from the level of pulse, and substantially different from that of longer durations. With a predilection for exploring boundaries of perception, 20th-century composers have experimented with using these very fast periodicities in new ways. Examples can be found in the three works analyzed below. The theme of Lutoslawski's Arioso, for example, has a curious quality arising from a boundary-crossing. It sounds slightly like a tape played at the wrong speed, due to the fast tempo and and the high register employed. It moves at a rate typically reserved for ornamentation and texture, but cannot be heard as either because it has the pitch and rhythmic contour of a melody. The effect focusses attention, as the listener must concentrate in order to decipher the information. Ligeti also enjoys playing with the boundaries of perception, as he reveals while discussing Continuuum:

> I...remembered that a harpsichord was most typically an instrument with a non-continuous sound.... I thought to myself, what about composing a piece of music that would be a paradoxically continuous sound...that would have to consist of innumerable thin slices of salami? A harpsichord has an easy touch; it can be played very fast, almost fast enough to reach the level of continuum, but not quite (it takes about eighteen separate sounds per second to reach the threshold where you can no longer make out individual notes and the limit set by the mechanism of the harpsichord is about fifteen to sixteen notes a second)....The entire process is a series of sound impulses in rapid succession which create the impression of continuous sound.[17]

Several instances in the Chamber Concerto exhibit similar types of experiments, as will be seen in the analyses.

The fast rates of ornamentation are also found in the context of textures. The effect produced is that of a layer of sound with a characteristic pitch and density, but containing surface fluctuation provided by quick movements between elements. Periodicities are sometimes involved in one or more component strands, and often such periodicities create rhythmic dissonance on the foreground level. Even when strict periodicities are not present, the range of durations may be sufficiently restricted that they can be usefully represented by an average rate of recurrence. In other words, periodicities can serve as a model for textural construction.

CHARACTERISTICS OF PERIODIC ELEMENTS

Each manifestation of periodicity is linked to a typical range of period lengths. Therefore, the listener may often depend on rate to infer which rôle is allocated to a given periodic event. Given the very fast rates at which the mind has to organize incoming data, such a strategy is generally quite sensible. A high proportion of musical works reinforces this relationship between rate and function. It is only in cases like the Arioso theme

of Lutoslawski's mentioned above that the mind has to reject the first interpretation and reconsider.[18]

The pulse is usually associated with some form of body rate. Although the word implies a connection with the heartbeat, a musical pulse is easier to relate to the more overt motor activities of the legs: walking, running, skipping, dancing. Such activites incorporate a wider range of fluctuation than that of the heartbeat, and are often more audible. The breathing rate is another familiar event within the slower end of the same range. Although its periodicity is less strict, it is also more perceptible than heartbeat, and is more readily altered by emotions and events (gasping in amazement, holding the breath in anticipation, etc.). In general, a speeding up of any of these activities is associated with increased energy expenditure, and a slowing down indicates relaxation. These links of tempo with tension and relaxation are so fundamental to our being that they naturally retain the same associations in a musical context. Both dance and performance reinforce links between music and physical movement. The fast tempi and irregular accents of some of the rhythms of Bartok and Stravinsky, for example, imbue that music with a strong feeling of excitement conveyed at a very physical level.

The identification of a musical pulse with semi-conscious and conscious body activities helps explain our appreciation of minor fluctuations in basic pulse. That we are sensitive to even the minutest change in tempo is evidenced by the distaste many of us have for "drum machines" or other electronically-produced rhythms; they are too steady to be human, or expressive. Gabrielssen, Clarke and others have produced some very interesting evidence about the rubato effect in performance, and the listener's response to it.[19]

Sub-pulse is generally perceived as relating directly to the basic pulse by a simple ratio (usually 2:1, 3:1, or 4:1). It can therefore involve reasonably fast durations without creating the tension that would be caused by a faster pulse. However, the degree of tension can also be affected by the difficulty of the passage, the capabilities of the instrument and the skill of the performer. For example, a quick and difficult passage consuming considerable energy and requiring a high degree of coördination is unlikely to convey a feeling of calm.[20] Usually, the composer encourages natural associations by reserving such passages for moods of excitement and tension. Ligeti capitalizes on the phenomenon by instructing performers to play virtually impossible passages "as fast as possible", drawing on the

resulting frenzy as a dramatic ingredient.

Periodicities at the super-pulse level correspond to the range of the bar period of metric schemes. These periods are traditionally two, three, or four times the rate of the pulse. The downbeats of 4/4 bars at a fast tempo of ♩=120, for example, will form a super-pulse with a period of 2 seconds. The sense of recurrence will be well within the perceptual present boundary and thus sustainable even in the absence of a perceptible subdividing pulse. The downbeats of 4/4 bars at a slow tempo of o=40 would produce a super-pulse with a period of 6 seconds. As this duration is approaching the outer limits of the perceptual present, it may give a much vaguer sense of regularity if there is no pulse or a comparable patterning filling in the duration. Clearly, the importance of the foreground musical structure becomes crucial to the interpretation of periods even slightly longer than the basic pulse. The powerful effect of meter therefore rests on the combination of a pulse level and a grouping level. As consideration of longer periods is so dependent on context, further discussion will be reserved for the chapters involving the analyses of specific works.

The ornamental/textural rates are in the region in which discrete events recur so fast that they begin to

fuse into a single event. Therefore, two pitches sufficiently close in frequency and time are perceived as a trill.[21] Often such events involve very simple gestures, but occasionally much more ornate or complex figures are involved. Most of the research in the cognitive sciences focusses on events at fast rates such as these, and investigations of the phenomena of auditory fission and fusion have been virtually restricted to this range. As a result, considerable data is accumulating which probes the listening strategies and effects of various factors at such speeds.[22]

The listener grasps the specific rate of periods very quickly, and then proceeds to the more challenging task of trying to understand and appreciate the music. Likewise, the analyst can sort periodic events by rate and function, and then proceed to the more rewarding task of searching for essential structure. To understand the latter, it seems helpful to examine the relationship of periodicities between layers and adjacent textures. The results of such an examination express the contrasts of density, consonance, and dissonance, thus providing important clues to our perception of structural form. In short, while the clock-time rate generally indicates the function of the periodic event, the relationship between levels conveys more information about the specific musical structure.

COMPONENTS CONTROLLED BY PERIODIC TREATMENT

In the Western classical tradition, it is rare to have all elements of a musical work controlled by periodicity. The departure from periodicity is usually what conveys the expressive quality of a musical theme. However, total periodicity can easily arise for a short duration of time if, for example, an accompaniment pattern is being established and the theme has not yet entered. Another likely context would be during the neutralization of a theme, such as in a bridge passage, before a new and more dramatic section begins. In both cases, the effect creates a texture which invites contrast. A different situation is created when all events in a section are periodic, but of differing period lengths. Such an approach seems rare but can provide an interesting model for compositional design, evidenced by the third movement of Ligeti's Chamber Concerto.[23] Highly-periodic music can also be found in very different contexts in other cultures, where music is not always that of entertainment or expression but may aim rather at inducing a particular mood, such as trance.[24]

More commonly, all the elements of one particular layer may display periodicity. Such a design is a very effective means for the segregation of one layer from

others, as in the case of ostinato. Because the entire pattern of an ostinato can usually be grasped within the perceptual present, it creates the impression of a static object. A repeated ground, though similar, is likely to involve more internal progression. Therefore, the ground may be interpreted as the recurrence of a phenomenon rather than the persistence of one. A related situation is that of the intermittent periodic gesture or section, in which the effect can be almost identical to that of ostinato but in the sense of juxtaposition rather than concurrence. The advantage of periodicity in intermittent gestures, besides the evocation of a particular mood or character, is that of almost instant recognition. Its advantage over the ostinato the ear is given a rest from the obstinacy of the persistent auditory image.[25]

Most frequently, only a limited number of periodic elements will be incorporated into a segment or phrase, lending continuity and minimizing information while allowing for variety. This type of design is illustrated by the frequency of sequential treatment in many types of music, in which both rhythm and contour are periodic but the pitches change. Sequences seem easily grasped as a periodic phenomenon. Isorhythm, on the other hand, seems hardly perceptible as periodic at a foreground level.

Most examples of dynamic or timbral periodicity operating in isolation from other aspects have occurred in the context of minimal music. It is easy to illustrate that we can perceive dynamic fluctuation as periodic even when that fluctuation is superimposed on disparate musical material. If one takes a radio fixed on any station and turns the volume control slowly up and down in a regular cycle, the periodicity of the fluctuation is readily apparent, no matter what the musical material. Our mode of perception is adapted to interpreting our sonic environment, so it is logical that a regular fluctuation of sounds would suggest that those sounds all emanate from a single sound-producing source.[26]

The complexity of the context obviously affects our ability to recognize periodicity. Conversely, the rate and function of the periodicities affects our ability to appreciate complex structures. The number of strata and the degree and level of consonance exhibited are variables. Several combinations of these variables will be examined in the following chapters.

FUNCTIONS OF PERIODIC ELEMENTS

Periodic elements can have various functions in music. Some of these functions are inherent in the periodicities

themselves and have unavoidable influence; others are more latent and can be emphasized and reinforced by other elements, or contradicted and sublimated by the specific musical context. The functions which are exclusive to periodicity result from the establishment of a temporal framework with evenly-positioned structural points. This framework is essential in providing a means for tracking elapsed time and comparing durations, and the structure of some music depends on such awareness for full appreciation of its design. The presence of this type of framework also eases performance, aids the listener in chunking information, enhances the perception of grouping structures, creates expectations of continuity and closure, and contributes to the establishment of specific Gestalten. When there are no periodic aspects, these latter functions can be carried by non-periodic aspects alone, but when periodic elements exist within a passage, their influence is rarely able to be ignored.

The most familiar function of a regular framework of pulses is that of providing a background grid for a more organic melodic line. The irregularities of rhythm are highlighted by the existence of a stable base. The establishment of a hierarchical structure such as meter provides a sophisticated system of relative accents. Much rhythm depends on the extent to which the accents created

by melodic contour, dynamics, duration, timbre, etc. coincide with the accents of the basic framework. When the accents are aligned, they provide very strong cues for grouping structures. It is very common to have periodic accents aligned with grouping structure at least at the beginning of a section, as those accents have to be produced by musical events which are sufficiently prominent to establish regularity. Therefore, the grouping itself will often establish the framework.

tracking of time

The rôle of periodicities in tracking time has been compared to the function of a clock.[27] The establishment of a pulse contributes a reference by which time can be measured, and thus the comparative length of phrases, for example, can be established. When two phrases or phrase segments are equal in length, a certain stability is implied; conversely, the truncation of a phrase or segment can produce tension. Consonant hierarchical layers of periodicities, such as meter, produce a more sophisticated type of clock than does a single layer of pulsation. Every component level in a metrical structure usually receives an accent from the periods of the next higher layer every two, three, or four cycles. In such a context, an unaccented point will never be more than two

points away from an accent, and thus its position can be easily grasped and remembered.

A gradual change of tempo is generally noticeable only when a regular framework of pulses exists; otherwise only a change of activity density will be recognized. Once regularity is established, a gradual increase or decrease of periods can be perceived readily. Ease of perception increases with the rate of the periodicity; the fastest rate will have the clearest delineation of fluctuation, as it provides a higher "sampling rate". When several rhythmically consonant layers coexist hierarchically, they will all change together when an accelerando or ritardando is specified, and the effect can be quite forceful.

easing of performance

Performance is eased by periodicity by three main factors. The motor skills involved in playing instruments are facilitated by regular and repeated movement, when that movement corresponds to a normal physical action such as beating a drum or bowing a violin. In addition, the grouping of pulses into regular patterns (such as by meter), facilitates coördination between players. In fact, research suggests that even a single performer can benefit from metric structure, since it is on the level of

the super-pulse that the performer is likely to maintain regularity.[28] The advent of electronic music has contributed to a move away from periodic elements, as its freedom from the limitations of human performance allow it to exhibit an enormous range of complex rhythmic combinations.

Another performance-related aspect of periodicity is what Benjamin calls the "stability of reproduction".[29] This function depends on the periods being at the super-pulse level or lower, where they can be grasped directly. It appears that performers can retain a very precise memory of periodic rates, and therefore reproduce a work at the same tempo at will. The average listener is also able to sense whether or not a piece is being played at the "correct" tempo by comparing it to previous hearings of the same work. A sOphisticated listener may be able to determine the correctness of tempo even at a first hearing, but this ability requires other qualities such as an awareness of style and intended grouping structures.

chunking of time

A major function of periodicity is that of aiding in the assimilation of data for memory storage and retrieval. The brain seems eager to grasp onto anything which closely

resembles a periodic organization in order to make sense of incoming data. The recurrence of a basic pulse or pulse configuration contributes significantly to redundancy by creating and fulfilling expectations of events at particular intervals in time. It appears that at the level of pulse and super-pulse, even one immediate repetition of a musical event can initiate an expectation of continued recurrence in favourable conditions. Such conditions include a lack of competition from other pulses or dissonant grouping structures. Hierarchical periodic structures, such as meter, can contribute stronger expectations because of relative weightings of the various accent points when the music is designed as consonant to such a structure. There would be a strong expectation of a cadence at the end of the eighth bar, for example, if the first four bars ended in cadence and the next three exhibited parallel construction.[30] The establishment of a regular pattern of accents will encourage the listener to interpret musical structures in a certain way. Berry refers to this effect as "preconditioning".[31] The initiation and continuation of recurring pulse patterns thus contribute significantly to the perception of grouping structures, and hence to chunking.

Minsky's proposal (mentioned in Chapter I) provides a convenient analogy to explain why the listener remains so

alert for regularity at various levels.[32] His theory suggests that in music with parallel phrase and sub-phrase construction, one musical event heard within a periodic context may be used as a template, with the periodicities providing reference points so that the next fragment can be superimposed for comparison. A comparison of new information with previously-encountered data enables predictions to be made regarding information lost, missing, or not yet available. It can also facilitate a search for logical or familiar processes acting on the data. Such processes might include tempo fluctuation, ornamentation, transposition, and timbral or dynamic variation. The rate of repetition can be understood as functioning as a "scanning time", and although the visual equivalent is extremely fast, the musical version may easily correspond to a level as slow as the super-pulse.

encouraging Gestalt perception

Periodicity can be a significant factor contributing to the identification of the Gestalt of a particular fragment, phrase, or passage. The function of stability of reproduction, mentioned above with regard to the tempo of an entire work, applies equally to short fragments. The identification of a specific configuration is linked inexorably with its rate of unfolding. That unfolding is

often grasped with reference to the specific rates of the periodic components. Another significant factor in representing the specific identity of a passage is the presence or absence of rhythmic consonance or dissonance, and the precise relationship between the various coexisting layers of periodic elements.

The character or mood of a passage is intimately connected to the tempo at which the theme unfolds, or the speed with which the elements change. As mentioned above, periodicity is the standard indicator of tempo fluctuation. Research indicates that the "correct" tempo for a piece is likely to be fully integrated with the memory of the specific rhythms and notes involved, and is reproducible to a very exact level on demand.[33] Boulez comments:

> I think it was Schoenberg who pointed out that the 'themes' of the classical period were composed with a more or less precise speed in mind, certainly precise enough to need no other indication than their character: any overstepping of the limits determined by the given tempo could result only in the various elements of the music becoming meaningless, the harmony becoming confused, the rhythm incoherent and even the interval of the melody losing their proper relationship.[34]

When recalling a familiar piece, the specific tempo is one of the most reliable bits of data retrievable. Most of us are more likely to forget the exact sequence of notes in

the fourth bar, for example, or the exact starting pitch, than the correct tempo of a given example. Therefore, when a phrase reappears with an alteration of tempo, the degree of alteration is grasped as a significant element, conveying meaning.[35]

By contributing to the Gestalt of a musical image, periodicities gain structural functions. They enable the listener to recognize not only the recurrence of a gesture or theme, but also the distinction between it and the surrounding material. "Surrounding" can refer to juxtaposing or simultaneous material. Therefore, to the extent that periodicities contribute to the establishment of Gestalt and the contrast between sections, they enable the listener to distinguish some of the formal structure of a work.

The specific configurations of a passage can be grouped broadly into textural, metrical, or additive types. In the metrical and additive types, the very nature of periodicity will contribute a sense of order, coherence, and expectation to each type. The contrast between adjacent passages depends not only on the contrast between the specific configurations, but also on the length of time they have been sounding, and the length of time taken for the transition from one to the other.

Textural configurations refer to passages where melodic and rhythmic changes are sufficiently limited that the listener tends to hear a sustained "field" of sound, rather than a progression of individual melodic or rhythmic lines. Textures do not require an audible periodicity, but as they are often calculated and described in terms of their averages, periodic rates can figure as a type of statistical average determining the density (i.e. frequency of note attacks or events). Therefore, in a textural context, periodicity can function as "a coefficient of density". The construction of textures will be more fully explored in the following chapter.

Periodic structure which extends to several layers or hierarchical levels can create a sense of "depth". This sense can be emphasized by a fluctuation achieved through a change in the number of layers participating. For example, a texture that grows from an ungrouped pulse to a layering of two clearly-defined strata and then dissolves back into a single line expresses an increase and decrease of depth, thereby drawing the listener's attention to that parameter. Such manipulation can be mastered to produce extremely well-controlled balances of density, tension, etc., as illustrated by the works studied herein.

The presence of a pulse continuum as a unifying force in a passage usually indicates an additive approach to rhythmic construction. This method of composition is typical of many Eastern cultures and has been imported into Western music by various composers, including Bartok and Lutoslawski. It will be shown in Chapter VII that a continuously-articulated pulse figures prominently in Bartok's Music for Strings, Percussion and Celesta as a means of providing continuity. Even a brief interruption in such a continuum is quite noticeable, and can indicate a major structural point. Ostinati and drones are both structured by additive means, as they are formed by the continuous repetition of a basic unit.

delineating of contrast

In the absence of harmony, the delineation of formal structure is frequently achieved by contrast in various parameters, of which foreground rhythm is one of the most significant and quickly-apprehended. Such delineation through contrast can occur horizontally or vertically. In other words, differences in periodicities can distinguish one stratum from another, as well as indicating a change of pace from one section of music to a subsequent one.

The degree of contrast perceived between layers or juxtaposed passages depends on several factors. A sudden dramatic contrast in period length will clearly produce a noticeable structural boundary. However, a slow transition from one such passage to the other will have a very different effect, as memory processes will be involved. A change from a hierarchical structure to an additive one can be quite gentle, if the pulse of the latter retains a period incorporated in the former and the grouping structure is not jarringly dissonant. On the other hand, two consonant hierarchical structures may be highly contrasted even if they share one period, if that period happens to be at a different hierarchical level in each. Textures of very similar configurations may be perceptibly different because of our sensitivity to slight changes in density. A structural boundary can appear more marked if the preceding passage has continued for a long time, as the established periodicities will be more resistant to change.[36]

descriptive functions

In some cases, a specific rate of periodicity may be chosen to allude to an extra-musical phenomenon. These are referred to as descriptive functions, and contribute to the character or mood of a work. They range from

representative, rate-dependent imitations of birds to more abstract rôles such as indicators of permanence by means of an ostinato. Messiaen used bird-calls at all different rates, as in Chronochromie, but they are generally not recognizable unless close to the original rate.[37] On the other hand, the cuckoo call of Beethoven's 6th Symphony depends on a specific tempo for its significance. Similarly, it would be quite absurd even within the whimsical contexts of Carnival of the Animals and Jimbo's Lullaby if Saint-Saëns or Debussy had attempted to evoke the image of elephants with fast-moving music. All aural phenomena incorporate a specific range of tempi. If the music does not correspond to that range, they are unlikely to be evocative of the phenomenon.[38]

Such correspondence between musical rate and physical model applies to machinery as well as natural events. Villa-Lobos' Little Train of the Caipira, for example, depicts a train with sufficient accuracy that a listener familiar with train travel could well estimate the specific mile-per-hour speed of the train at a given point in the piece. Works such as Varèse's Offrandes and Ionisation suggest imaginary machines through ostinati and similar devices. As machines run at a variety of speeds, different rates suggest different types: slow rates are more reminiscent of early industrial-age factories, and

fast ones of sophisticated electrical devices. The most clear association is that of a prolonged static state, with an absence of tempo fluctuation. Some composers can even incorporate that aspect: Ligeti admits fascination with the image of machines going out of control.[39]

The use of metrical organization reminiscent of dance can also be considered a descriptive function. Specific dance meters themselves evolved because of the association of certain periodic rates with motor movement, generally of the feet, in specific patterns of repetition. The association has been reinforced over the centuries, and now a mere few bars of a march or gigue at the correct tempo can suggest the mood and even the era, as well as the particular pattern of steps. Lendvai suggests that there is an inherent difference between duple and triple meter in general: triple carrys a strong sense of circular or "rotary" motion, while duple expresses a clearer bipolar alternation.[40]

Some works evoke mood or atmosphere by association with our physical environment, through the use of specific references in temporal density.[41] Mood and atmosphere are difficult to describe without resorting to poetic imagery and other non-measureable allusions. However, the fact that specific combinations tend to evoke specific

reactions seems undeniable.[42] Passages which are faster, higher, louder, and denser are generally more tension-producing than their opposites.[43] Slow and sparse textures, though not in themselves indicative of serenity, for example, are nonetheless taken to be more appropriate in portraying this mood than fast and dense ones. Of course, slow tempi can evoke other moods such as mournfulness also; the difference between serenity and mournfulness would be communicated through other parameters such as melodic and harmonic profile. At the mention of tempo, it might be argued that we are discussing periodicities only at the pulse level and higher. Might not a slow peaceful work contain ornamental notes which move quite quickly? The answer to this question would have to be limited to a qualified "yes", for if the ornamental notes were not only very quick, but sounding constantly, they would give a hint of something more volatile.

These issues return us to the physiological basis of the faster periodicities. Tremolo, for instance, logically suggests a quivering, which is precisely how it would be conveyed by a string player (probably the most traditional producer of tremolo figures). Quivering implies a state of excitement or nervousness and therefore tends to imbue a slow-moving passage with a sense of

anticipation or anxiety. Traditionally, a distinction is preserved between the various levels (ornamental to phrase) which are then kept in a certain proportion. At a slow tempo, all are within a slower range than at a fast tempo. The pulse is the main indicator of the general mood, and its subdivision by sub-pulse and degree of filling-in by ornament give the specific character to the passage. A melody which is played first in one instrument and then in another may exhibit minute differences in timings, and significant differences in timbral content. However, we can still recognize the notes and rhythms. The addition of tremolo ornamentation to each note of a melody can be understood as a variation of the same principle, acting as a type of timbral enhancement without destroying the integrity of the melodic shape.

CONCLUSIONS

Periodicity is an extremely potent device with different effects and effectiveness at various levels. The musical material which establishes regularity encourages focus on other elements, while simultaneously contributing a specific character to the music. Many musical figures involve some periodicity at a pulse or sub-pulse level, and often these exist within a hierarchical structure. Certain periods, such as those of

a subdivided super-pulse, can help delineate a template which enables the listener to compare musical figures more easily when they exhibit parallel construction consonant with that level. As periodicities under three or four seconds are grasped directly, their incorporation into musical configurations helps recognition of future recurrences of those configurations. By maintaining a contrast in the periods of different coexisting layers of material, the composer can clarify the definition of each layer, thus making the interplay of the various layers more audible.

A basic and traditional structural function of periodicity is the establishing of a pulse framework. Traditionally, this framework was manifest as a metric hierarchy. In additive forms, increasingly common in contemporary works, a single pulse layer may be the only unifying force. In either type, the regularity is likely to provide a background grid for more irregular and expressive rhythms. In the case of metric-style hierarchical frameworks, the irregularities are freqeuntly at the foreground level, resulting from a variety of subdivisions of the pulse or super-pulse. In an additive framework, however, irregularities are typically at higher grouping levels, as a result of addition or multiplication of a pulse or sub-pulse.

Many works exhibit periodicity on a level higher than that of the super-pulse. Phrase repetition and parallel phrase structures alone are responsible for many of these occurrences. Such structures rely on the identification of comparable material and/or structures for perception of their equivalent durations. Parallel phrase structures may embody irregular sub-phrases, but through such aspects as similarity of contour and rhythmic profile, the comparison between the two phrases is usually clear. Hypermeter is dependent on an appreciation of periodic sub-elements and their rôle in forming a hierarchical rhythmic structure.

The number of layers exhibiting periodicity and the specific relation of the periods involved have a profound effect on our perception of the music's character. Contrasts are not restricted to a simple alternation between consonance and dissonance. They can incorporate different types and degrees of dissonance, and different speeds and methods for moving from one arrangement to the other. The variety of examples in the works analyzed below may provide some suggestions for future study.

Chapter IV

PERIODICITY as a COMPONENT of

TEXTURE & TEXTURAL STRANDS

Musical texture refers to the temporal and registral distribution of notes in a passage. In modern usage, the term is often restricted to describe passages or layers in which the listener's attention is focussed on the interplay of the components rather than on any individual part. When the overall sonic image is more prominent than individual lines, the term textural is therefore appropriate to describe the passage. When a melodic line emerges from a texture, its recognition as melody indicates that the remaining material has become background texture, if only temporarily.[1]

The perception of a passage as textural depends on several factors. In some cases, the listener may choose to listen "texturally". The option of making a choice indicates that the passage presents components which <u>can</u> be perceived individually, but that the listener prefers to focus instead on a longer-range level. Such a decision is usually derived from the context. For example, a high degree of redundancy within individual lines may indicate

that the interaction of the various lines will provide more interest. Sometimes, the opposite is true, and the redundancy of individual parts is so low that the listener cannot deal adequately with the excessive input of information. At such a point, a common strategy is to abandon the effort to follow the structural organization and focus instead on immediately-perceptible foreground aspects such as timbre, dynamics and density.

In other cases, a listener may have little option but to listen texturally. The design of a passage may prevent individual parts from being heard distinctly. A common factor of such a design is in registral and/or temporal intertwining. Registral intertwining results from frequent voice-crossing, which presents difficulties for the ear trying to distinguish one line from another. This effect can be maximized by similarity of timbre and dynamics. Temporal intertwining involves rhythmic dissonance on a low foreground level. The more complex the dissonance and the faster the rate of attacks, the more difficult it is to extricate the separate parts. A slow 2:3 will be quite easy to distinguish compared to a quick 7:8:9.[2]

The composition of textural passages was championed by composers such as Xenakis, Stockhausen, and Ligeti as they searched for new ways of organizing sonic material.

Stockhausen promoted the term "statistical field" to refer to the situation where characteristics such as timbre, duration, and register remained similar throughout a passage.[3] The term accompanied a new compositional approach whereby the composer would select the precise way in which specific properties would be distributed among various instruments.[4] The textural approach was a very appropriate one for many twentieth-century composers who wished to move beyond traditional uses of harmony and meter while retaining a degree of large-scale control. It permitted the composer to establish "global" properties for each texture and then to construct formal designs that would produce varying types and degrees of contrast. Contrasts in timbre, dynamic level, durations, register, etc. could be extended to higher levels. For example, a passage incorporating high contrasts in several parameters could be juxtaposed with one of low contrast. For composers such as Ligeti and Stockhausen, such an approach to composition proved conducive to fascinating designs.

Ligeti's ideas were influenced by his realization that attempts to serialize durations could result in an undifferentiated rhythmic shape.[5] When a series of durations are distributed with equal frequency over a given period of time, the resulting textures composed of the same mix of durations can produce a bland durational

profile. Because we employ a mode of listening that extends beyond adjacent pairs of notes, the effect of the contrast between two durations can be dulled by a lack of contrast between adjacent groups of durations. Choosing to listen to a passage texturally often requires a further broadening of the temporal focus. In such a case, the listener receives data from a longer time period before codifying it. Since non-codified data is retained only in the short-term memory buffer, that time period is restricted by the limit of the perceptual present. However, the composer can help the listener extend the time period by minimizing the rate of information presented by the music.

Ligeti was particularly interested in the perceptual boundary of ca. 0.05", below which the ear cannot perceive distinct order of pitches.[6] He followed Koenig's example by experimenting with this boundary, though Koenig worked with electronic sounds and techniques while Ligeti preferred the acoustic medium. The aim was to combine sounds at speeds faster than 0.05", thereby producing changes that would cause slow overall "transformations in the 'molecular state' of sound".[7] This observation gave rise to Ligeti's fondness for foreground dissonance in the textural/ornamental region. He explains:

> Since you cannot play an instrument fast enough to produce a succession of notes at a rate of twenty per second, I built the rhythmic shifts into the music. For instance, twenty-four violins would play the same tune but with a slight time-lag between them. The figurations were almost identical but not quite.[8]

In a textural passage, a particular state of densities and proportions is often maintained for a sufficiently long period of time that perceived changes can be understood as a modification of the basic state. Works such as Atmosphères were influential in their presentation in textural passages of unprecedented length. The minimal movement exemplified by the music of Steve Reich also had considerable influence in training listeners to listen "texturally". Certain other cultures, such as that of Indonesia, have long traditions of music which we would consider textural. Some early examples of texture in twentieth-century Western compositions were directly influenced by such music.[9]

Because of the prominence of extended textural passages, the modern concept of texture often conveys the notion that there is similarity in several parameters for a relatively long time-span. However, such similarity is not a prerequisite. Any complex sound will convey a sense of texture when the ear has difficulty in segregating the component parts. Lutoslawski's third movement contains a passage where the "textures" are separated by rests and

last for a few seconds only, producing a foreground rhythm by their pattern of occurrence.[10] Despite the brevity of these bursts of sound, the similarity of their construction to other more clearly textural passages earns them the description of texture. The similarity between the various fragments gives a clear impression of the existence of a longer textural fabric from which short pieces have been extracted.

Ligeti is one of the masters of maintaining and manipulating textures over extremely long periods of time, up to several minutes of a piece. The most striking examples of lengthy textures are found in works which precede his Chamber Concerto, but the latter work is particularly appropriate for the present study because of the design of its third movement. That movement presents several textures each constructed by the same means: multiple periodicities are overlaid in close and complex relations to each other. Although the movement is by no means static, it contains no discernable melodies (with the exception of a few sustained notes near the beginning). Instead, each voice functions as a component of one of the various textures. Attention is sustained by the interplay of the periodicities of the component layers, by pitch/registral movement throughout a specific texture, and on a larger scale by contrast between the

various textures involved.

I reserve the analyses of these textures for the end of this chapter, due to their complexities. Textural passages of simpler construction will be examined first. Those of Lutoslawski's and Bartok's works are frequently presented in the more traditional function of a backdrop to melodic material. These can be divided into two distinct types of textures, each creating a different perceptual effect. One type operates in rhythmic unison and produces the effect of texture through a continuous differentiation in pitch and timbre. The other type creates foreground dissonance through an overlay of different pulse subdivisions, or by more additive means such as the continuous repetition of a very short figure.

The most prolonged static texture of Bartok's work, forming around m.196 of Movement II, provides an example of the rhythmic unison type [**Ex. 4.1**]. All layers of the accompaniment move at a constant eighth-note rate. The texture is composed of several independent parts, each repeating a five-note segment derived from the preceding material. Despite the 5/8 implication of the pattern repetition, the passage is notated in 2/4. As the passage is preceded by material that operates within a 2/4 meter, Bartok may well have retained that notation merely for

convenience of performance, as the piano's melodic theme which forms the focus of the passage exhibits a highly irregular rhythmic structure. However, it seems more likely that the 2/4 barring is intended to de-emphasize the 5/8 period of the texture by providing another layer of subtly dissonant periodicity.

Even at ♩=144, the texture's eighth-note articulation (giving a periodicity of ca. 0.2") is relatively slow for a background effect[11] and the contrast in rate between theme and background is not as pronounced as usual. However, the prominence of the theme is ensured by its rhythmic profile, dynamics, articulation, and orchestration. The delineation between theme and texture is also enhanced by the constant regular movement and the restricted pitch content of the texture. The theme incorporates sufficient rests between chords to allow glimpses of the background, but no more than one cycle of the texture is ever heard between two note attacks of the theme. The theme and texture are aligned on the level of the eighth note, as is characteristic of this work.

Another set of textures which exhibit rhythmic consonance, and often rhythmic unison, occurs in the third movement of Lutoslawski's Concerto for Orchestra. The textures provide a complex background for a familiar theme

moving primarily in long notes.[12] They are of two types: sparse short segments of quarter-notes played by lower strings (pizzicato) and brass (except horns) [**Ex.4.2a**], and denser, longer segments played alternately by horns and woodwinds [**Ex. 4.2b**]. The denser textures exhibit an interesting construction, as each instrument plays only two pitches yet the composite effect produces two layers: one of repeated static chords and the other of a chordal line moving up and down.

The same set of textures returns in m.659 at a slightly faster tempo. This time, the melodic line is replaced by a line with similar profile but without the detail of the previous statement, encouraging the listener to focus more attention on the accompanying texture. The passage is much longer (24"), has more inner complexity, and incorporates some internal shifting of patterns. Initially, most instruments participate, but gradually the texture thins, though the eighth-note pulse is always articulated. The reduction of activity in the texture is compensated for by the transformation of a static pulse in the lower instruments into an ascending chromatic line [**Ex.4.2c**].

A passage of three bars' length in Lutoslawski's work seems textural despite its brevity and relatively long

durations, because it exhibits temporal symmetry. This symmetry indicates a closed system rather than a goal-directed passage, and the careful dovetailing of recognizable harmonic patterns conveys this characteristic to the alert listener. One layer of sustained notes in the horns is the background for three other layers. Together they produce a simple composite rhythm of a quarter-note articulation which aligns with the melodic material. Three groups of instruments play dissonant, internally symmetrical, duration patterns [**Ex. 4.3**]. The pitch patterns of each group form harmonies which, though internally consonant and beginning on a perfect fifth, also exhibit dissonance during the three bars; that relationship helps maintain their independence.

Textures constructed through a superpositioning of different subdivisions are considerably denser than those exhibiting rhythmic consonance on the foreground level such as those just described. Three related passages in the first movement of Lutoslawski's work present an interesting opportunity to study both types within a similar framework. In each case, they accompany the slow second theme of the movement. At ⑤, two layers of texture each move in eighth notes. Although the pivots in the scalar figures of the clarinet coincide with rests in the oboe figure, that relationship is obscured by accents

in the oboe line which precede those rests. As the pivot points provide the only plausible accent point in the clarinet line, a "Type B dissonance" results.[13] In combination with the relatively uncommon grouping length of five eighths, the (irregular) insertion of some shorter groups, and the difference in character of the contours, considerable irregularity is audible [Ex. 4.4a].

At the next statement of the same theme, a related but more complex accompanying texture is constructed [Ex. 4.4b]. Dissonance is extended to the foreground level by the simultaneous presentation of different subdivisions of the dotted quarter-note. On the other hand, the coinciding of those subdivisions emphasizes the pulse. The scalar pattern which appeared at (5) in eighth notes now appears in sixteenth notes. It maintains the same period of time between pivots, and thus covers a much greater distance in register. The other layer played by oboe at ⑤ now appears in canon. The two parts of the canon can be clearly heard as distinct layers, because the accents and the difference in pitch/registral level prevent them from fusing. Another figure in celli and bassoons emphasizes the dotted half duration by sequential pitch patterns. As this line moves mainly by step, it is similar to the clarinet line of the previous statement. Therefore, the changing of the clarinet movement from

eighths to sixteenths may have been a crucial move in maintaining segregation. The lyrical theme is easily distinguishable from the various textural layers by its tempo, its lyrical nature, and by its recognizability from the previous statement.

At the third statement ((11)), the shortest duration in the texture returns to the eighth note, so the only foreground dissonance is a 2:3 ratio of two divisions of the dotted quarter. This time the texture is very full, due to a lack of rests, parallel harmonies in the strings, and a slow sustained line in trombones in addition to the foreground dissonances [**Ex. 4.4c**]. The distinction between figure and ground tends to reverse in this passage, owing to an increase in activity in the ground and the familiarity of the theme itself. The different layers of the texture are individually modulated by dynamic shaping or harmonic thickening, thereby emphasizing their independence. Subsequently, the various lines are interrupted by an increase of attack density and a decrease in pitch movement. This interruption serves in part as an anacrusis to a major downbeat of the theme.

The chorale section in the third movement of the same work contains more examples of accompaniment texture characterized by foreground dissonance. The first full

statement of this texture is in mm.715ff. Celesta, harps, piano, and percussion all repeat patterns which each provide a different subdivision of the half note in the ratio 3:4:5 [**Ex. 4.5**]. The effect is a reinforcement of the half-note period and, with the aid of the percussion rolls, a thickening of the texture. The piano and celesta patterns also articulate the two-bar period through repetition. This grouping provides a subtle continuation of the two-bar period already established and thereby helps maintain the vibrancy of the hemiola effect of the chorale theme. The subdivisions are at quite a fast rate, falling within the textural/ornamental zone. Their function as texture is therefore easily grasped, as the density of note attacks is too high to perceive as rhythm in itself. In the preceding sections where piano and harp each played alone, they performed quintuplets rather than slower rates. The higher density thus helps establish the textural function from the first entry.

Fragmented texture occurs as accent to a variation of the passacaglia theme in the third movement [**Ex. 4.6**]. The passage first occurs at m.802, and is later repeated at m.822 with a slight change in the final bars. Texture is produced by the superpositioning of trills, tremolo, and fast-moving triplet figures. What makes this texture unusual is its short durations and its function as

ornament on a larger scale. The segments are separated by much sparser writing, so there is a considerable accent resulting from the initiation of each textural fragment. Since the component parts cannot be distinguished, however, the textural fragment is grasped as one single, if prolonged, anacrusis to the following beat. This effect is reinforced by a dramatic crescendo in the horns, and by the periodicity of the texture's recurrence.

Bartok's work also contains a few passages where a high density of note attacks and the overlaying of several parts create an opaque texture. The first such instance begins in m.78 of the first movement [**Ex. 4.7**], where a shimmering celesta sound presents a fluid backdrop to the fugal material in the strings. The celesta figure exhibits periodicity on two levels: foreground attack points and grouping by pattern repetition. As the theme's grouping is irregular, the periodic grouping of the celesta pattern creates a dissonance with it. The extremely short durations produce the effect of an articulated sound complex, although the pitches may be perceived as clustered into two groups through auditory streaming. Further blurring of the celesta micropulsation is provided by the tremolo in the strings, which is also periodic, but dissonant with the foreground attacks of the celesta. Given the tempo and notation, the tremolo will

differ from player to player (reflecting motor skills). The tremolo's coloration function is confirmed by its registral placement between the pitches of the two theme statements. There are strong echoes of this passage in Movement III [**Ex. 4.8** and **4.9**].

The third movement of Ligeti's Chamber Concerto is full of textural variety. Since the various textures are created through the superpositioning of differing periodicities, the movement provides an excellent model for analysis. It presents a series of textures, with overlaps between a few of them. Each texture involves several instruments each playing a pitch repeated at a certain periodic rate. The pitch movement is very restricted, either remaining on one pitch or moving in a single direction by small intervals or through glissandi. The textures are contrasted by several means: the specific instruments, pitches, pitch movement, and dynamic levels involved; the rate of reiteration; and the relationship of the periods produced. Ligeti describes the resulting textures as:

> the type labelled 'like a precision mechanism' ... characterized by a specific rhythmical configuration: a state ... represented in terms, not of a 'smooth', but of a 'fine-ground' continuity, so that the music is seen as if through a number of superimposed lattices.[14]

The nine distinguishable textures in the movement are listed in **Ex. 4.10** and named alphabetically. The second, eighth, and ninth are special cases; the others are described in the figure with the range of periods employed on a foreground level. Despite the central rôle of periodicities in the formation of the textures, there is no visible periodic relationship between the overall durations of the various sections.

The first 47" of the movement (up to m.12) can be considered as presenting one distinct texture, though it contains three distinguishable sub-layers due to variations in timbre and durations. Each instrument presents a series of pitches [**Ex. 4.11a**]; each pitch is reiterated a variable number of times but always quickly, and initiated by an accent. Each instrument starts independently and exhibits different grouping rhythms. The overall texture is modified by progressive widening of the pitch, timbre, and duration choices.

Initially, timbre is restricted to woodwinds, pitch to a unison E, and durations to thirty-second notes (0.125"). The overall effect is of a fine-grained texture with irregular punctuation from the pattern of accents.[15] Gradually a cluster is produced as each instrument moves to the next note of the series. A "rhythmic cluster" is

also produced, as the new durations are initially either 7 or 9 notes per second, temporally "adjacent" to the 8-notes-per-second rate of the original subdivisions [Ex. 4.11b].

Piano, strings, and harpsichord enter soon afterwards. Though linked to the woodwind layer by pitch and duration, they are differentiated by timbre and by much briefer pauses between groups of notes. Piano and harpsichord maintain the fast reiterations while the strings introduce slightly slower durations. The sharing of the same pitches links the three layers; however, perceptual fusion is thwarted by the fading out of the woodwinds.

After ca. 26", the double bass creeps in with a sustained D played as a harmonic. The remaining pitches of the series which follow the D are similarly introduced as sustained notes in clarinets and flute. Together they produce a cluster which continues sounding until the end of the passage. Although these notes are obviously contrasted from the rapid reiterations of the rest of the texture, their durations are so long that they considerably exceed the perceptual present. Therefore, within a few seconds they tend to fade into the background, adding colour to the texture, rather than movement or contrast. More significant are the slightly

longer durations introduced by the strings which effectively slow the pace. In mm.8-11, the longer durations combine with repetition to enable the listener to hear the 5:4:3 dissonance of the string patterns. The patterns coincide every beat, initially articulating a 1-second period and delineating a tempo change by coinciding ten times throughout a rallentando before dying away [Ex. 4.11c].

Texture C has a structure similar in many respects to the preceding passage, but results in quite a different effect. All instruments (except double bass) start simultaneously, the subdivision durations are shortened, the registral range widened, and the rests omitted. All instruments play slow descending and/or ascending chromatic lines [Ex. 4.12]. During the passage, the number of instruments changing pitch at any one time gradually increases. The wide registral span is defined immediately by octave displacements of the starting pitch. Each instrument moves to its next note at an independent time, but the change of pitch is not accented as it was in Texture A. Uniformly soft dynamics, medium durations, and similar articulations increase the tendency for the various parts to fuse. As the precise rate of reiteration is chosen by the individual performer, a subtle dissonance of attacks produces what the composer describes as "a

'granulated' continuum". A striking characteristic of this texture is the incorporation of glissandi. The string glissandi are quite slow, taking up to 3" to move the distance of a semitone. By contrast, the trombone remains on its first pitch for almost one and a half minutes, then takes only 5" for a glissando covering a major sixth. Both are quite audible, but the trombone glissando is more prominent due to its speed.

Texture C continues for almost a full minute, although about 20" before the end, Texture D begins [**Ex. 4.13a**]. The new layer is quite distinct, as it is introduced by the double bass fortissimo at the significantly slower rate of 3 per second (0.33"). The other strings abandon their participation in the previous texture and join in, also at fortissimo, exhibiting a variety of articulations including the sharp attack of the "Bartok-pizz.". Each group of notes in this texture is assigned a different but relatively slow rate of recurrence, varying from periods of ca. 0.2" to 0.67" [**Ex. 4.13b**]. Ligeti notates the various rhythms in different tempi as well as by different subdivisions. This strategy produces an extremely complex relationship between the instruments, with virtually no coinciding of attacks.

Texture E begins with staccatissimo, molto secco

reiterated chords in harpsichord and then piano. The periods of their durations mediate between those of the woodwinds and the strings; their attacks create a 5:6 dissonance coinciding every beat (ca. 0.91"). The similarity of their durations, articulation, and pitch aggregates contribute to their fusion and to their segregation from the other instruments. Texture F represents another instance of a "granulated continuum". It consists of string pizzicato chords played softly but "as rapidly as possible", creating a frenzied effect which cannot (should not) be dissociated from the actual state of tension in the performer.[16] The incorporation of slow glissandi on the middle note of each chord is reminiscent of Texture B.

Texture G begins at m.42, as several instruments present a much slower reiteration of very short notes, all on the same low pitch. A rather comical effect is produced by the contrast of the low register and slow articulation with the preceding frenzied texture in the strings. The sense of texture is challenged by the (relatively) long periods, which tend to make the notes sound as distinct entities rather than as grains in a continuum. It is therefore possible to perceive an irregular rhythmic line resulting from the composite pattern of notes. The durations are outside the

textural/ornamental region, so to hear them as fused into one layer involves a considerable stretching of temporal focus. A focus on one specific timbre will enhance the listener's ability to hear the lines as independent and periodic.

After 14", five more voices join in simultaneously. Together with two notes added to the piano part, they produce a cluster in a high register. The new entries present periods slightly faster than those of the lower layer, but slow enough to suggest a connection. This interpretation is reinforced by the piano link, which plays its high notes in the same rhythm as its low ones. The registral gap creates an odd effect, stretching the fusion/fission boundary [**Ex. 4.14**]. After a few seconds, some instruments begin to slow down while the others maintain their original pace. The effect is quite startling, creating a slight perceptual dizziness and causing a segregation of layers. The instruments which slow down theoretically do so together, but since they are playing intricate subdivisions at different rates, there is ample opportunity for minor variations which can cause further perceptual blurring.[17] In addition, the first rallentando coincides with the final glissandi in the viola and cello as they finish the previous passage.

At m.50, violins enter at ff possible (pizzicato) and ca. 13" later, viola and cello similarly; all play notes of the high cluster already sounding. Such a beginning is reminiscent of Texture B, with an exchange of registers. Violins I & II should theoretically be consonant with trombone and horn, as those instruments are at the same tempo, and playing multiples of the same subdivisions. However, there is no insurance that they will start in phase, and in fact as the brass are maintaining their own tempi, it is likely that there will be some discrepancy. Ligeti is naturally aware of this tendency, and instructs:

> The players left by the conductor on their own keep as accurately as possible to their individual tempo... however, since they cannot measure the tempo, but only estimate it, tempo fluctuations may occur. Synchronization of the (non-conducted) parts is not to be striven for; in fact, slight shifts in the metre are welcome.[18]

Again, theoretically only, cello and piccolo have the same periodicity. More likely to be perceptible is the relation of attacks in harpsichord and piano: when harpsichord reaches ♩=40 they should be in a 1:1 proportion.[19] This alignment should become audible because no matter how inaccurately the parts are aligned, the parts will converge momentarily. Such an approaching unison can easily attract attention.

The last section of the movement consists of trills

and sharp attacks which together form a slightly uneven pattern of pulses on the same high pair of pitches (D♭/E♭). There are two possible interpretations. On one hand, the irregularity links this passage to the irregular accents of the first texture of the movement, and thus contributes to a sense of closure. In a different context, this interpretation would likely be the only plausible one. However, the context of the movement suggests that these few notes are delineating another (very sparse) texture produced by overlapping periodicities. The passage may therefore be interpreted as several layers of periodicity moving quite slowly and out of phase. Despite the fact that the intervals between attacks in the same timbre are not strictly periodic, they are easily interpretable as slowing down. The composite pattern is not regular, but can be sensed as increasing the durations between attacks. In either interpretation, the sparseness of the texture conveys a dispersal of energy appropriate to the end of a movement.

T E X T U R A L S T R A N D S

There are numerous instances in Ligeti's work where two or more lines are easily perceived as forming one distinct layer; these passages share some properties with

the types of texture already examined. However, in many cases the resultant textures are confined to a narrow pitch band, and exhibit a collective modulation in shape, note density, dynamics, etc. Therefore they exist in a state somewhere between texture and melody and can be more easily thought of as "textural strands". When such strands coexist, their interplay can produce a resemblance to contrapuntal design. An examination of these strands provides an interesting survey of perceptual effects, especially those involving fusion and fission. Even confining ourselves to a study of those which exhibit some periodicity gives a variety of examples for perusal.

In the middle of m.19 of the first movement, for example, harpsichord and piano enter simultaneously with a pp "cadenza" figure played as fast as possible. The motor skills of the performers and the differing actions of the two instrument ensure that they will not be in rhythmic unison. Nevertheless, the simultaneous entries, the similarity of the figures and the sharing of the same pitch range and dynamic level ensure that they can be heard as two twisted strands of the same layer. Subsequent pairs of entries in the strings playing very similar lines form a type of canon [**Ex. 4.15**]. Similar passages occur later in the movement such as at m.29 when all strings except double bass play Prestissimo, senza

tempo, in a very narrow pitch band. There, all four begin simultaneously and move together to sul ponticello, then ordinario, then sul tasto; the timbral shifts fuse the four together firmly.

Forming a contrast to the "canonic entry" in the strings is a textural strand presented by the woodwinds [Ex. 4.16]. Although the woodwinds' layer incorporates dynamics, pitches, and short durations similar to those of the strings, it is readily perceptible as a distinct stratum. The factors which contribute to the sense of fission include a more measured rhythmic notation which removes the franticness of performance associated with the directive "as fast as possible". In addition, a legato articulation contributes to the difference in character. Most noticeably, the woodwinds begin simultaneously and continue in rhythmic unison, presenting a strongly unified texture.[20] The rhythmic unison is especially striking as it involves very subtle variations of a general regularity; the number of subdivisions per beat differs by only one from the neighbouring beats. As the duration of the notes is altered from one beat to the next by less than 0.02", the effect could be considered comparable to microtonal shifts in pitch. The fact that three instruments exhibit identical fluctuation links them even more firmly than if they were playing a more rigid

periodicity. It implies a common modulator, and is thus similar to the effect of the timbral shifts in the string passage described above.

The effect of slight rhythmic variations in a horizontal context is fundamentally different from slight variations in vertical arrangements. The latter applies to situations in which simultaneous subdivisions of a beat differ by only one from each other. The effect was discussed with reference to Texture A of the third movement in terms of a "rhythmic cluster". A slight variation in the horizontal realm produces a rubato effect and blurs a sense of beat, while slight vertical deviations subtly articulate the pulse but blur the rhythm. In the latter case, the number of attacks per beat increases. Such an increase in note density changes the texture to an opaque one, while the coinciding of attacks at the beginning of each beat can subtly emphasize that period.

At m.31 of the first movement, woodwinds enter simultaneously on a sustained note [**Ex.4.17**]. When they do begin moving they are in rhythmic unison for one beat, before diverging slightly. The beginning unison strengthens their fusion, which is otherwise slightly weak because the rate of movement is slow. The difference

between a quintuplet subdivision and a sextuplet at ♩=60 is ca. 0.03", and the density of attacks is a mere 10-16 per beat (and per second). The listener may therefore be able to perceive the specific rhythm of the 5:6 and 5:6:7 ratios. Further fusion is provided by a brief unison pause, as well as by a common dynamic shaping.

In m.39 of the second movement, a high-pitched cluster suddenly appears at ff in six instruments. The instruments are tightly fused, moving quite erratically with an alternation of very fast movement and sustained notes, all accented and con fuoco. As the line continues, the activity increases until the sustained notes are dropped altogether and the movement becomes relentless in regular durations of ca. 0.11". Gradually the volume decreases and durations lengthen until they are almost 1.5". The passage is approximately 1'30" in its entirety, with the slowing down beginning halfway through. The effect of the regularity and the absence of dissonance between mm.50-58 is quite striking in the context of the overall arhythmic nature of this work. The passage is followed by a very brief episode of further periodicity, contrasted by speed: the four upper strings play very fast notes (ca. 0.09" duration) in rhythmic unison.

CONCLUSIONS

The perception of textures has been shown to depend on the fusion of the separate components of the musical passage or layer. The chance of such fusion occurring is near 100% in some cases, due to the constructs of our listening patterns. Factors which promote fusion include high density of attacks, and a shared registral, timbral, and dynamic range. In other cases, the musical context, the composer's intentions, the performer's interpretation and the listener's mode of hearing may all influence the result. Textures are often categorized in terms of dense and sparse: these terms refer to the density of events and as such reflect one of the most immediately salient characteristics of a passage. In addition, a useful distinction can be made between textures which move in rhythmic unison and those which exhibit rhythmic dissonance. The latter can be further subdivided into simple, lower-order rhythmic dissonances, and those of a much higher complexity. Examples of types of rhythmic dissonance can be found juxtaposed in the third movement of Ligeti's Chamber Concerto.

Textures can occur as background to a contrasting melody, or can provide a steady-state or slowly-changing sonic image as the focus of a passage. In some works, a

type of polyphony is achieved by the interweaving of textural strands. A strand exhibits properties of texture but the components remain within close registral distance of each other. The works by Bartok and Lutoslawski analyzed herein seem to demarcate the textures carefully, to maintain contrast between textures and other coexisting or juxtaposed layers. The presence of trills or tremolo accompanying many rhythmically-dissonant textures helps blur rhythmic complexities. They reinforce the opaque nature of the texture, and focus attention away from the harshness of the dissonant rhythms. Textures which exhibit rhythmic unison or consonance are usually confined to similar timbres, simple rhythms, and a reduction of melodic change. These factors help to maintain the fusion which is essential to perception of a texture as a single sonic image.

Chapter V

CANONS

Canons are the result of careful design on the part of the composer. They carry strong overtones of tradition because of their popularity in earlier centuries. The perception of canons depends on the ability to identify the basic theme or figure, hence the tradition of introducing the melody first in isolation, or clearly contrasted from the background. The first few notes of the melody are the most crucial, as they are normally the signal which alerts the listener to a new entrance. For similar reasons, activity is traditionally reduced in the continuing voice at the point where the new voice enters. Registral separation is a great advantage in distinguishing the independence of the various canonic voices, so that they will not fuse into textural strands. Timbral separation, though it would seem useful, seems to be rare. This rarity may be due simply to the development of canons within homogenous timbral ensembles (choirs, string quartets, piano). Also, the similarity between voices could be jarred by the appearance of the same melody in radically different orchestrations. Whether a cause or an effect, the similarity of timbre present in many canons creates a tendency for canons to fuse into

texture. As with textures themselves, this mode of listening can be encouraged by the musical context, the performance, and the listener's approach.

Canons figure in the three works analyzed, but are especially prominent in Bartok's Music for Strings, Percussion and Celesta. The fugue of the first movement could be thought of as spawning all other canonic passages in the work, but the difference in its scale makes it quite distinct in character. Later passages use canonic technique for momentum, textural considerations, means of increasing dissonance, changing of pulse length, etc. The first movement, on the other hand, uses canonic technique as its large-scale structure. The length of imitated phrase considerably exceeds that of the "perceptual present", so our recognition of fugal structure depends on memory processes.

The interval between the first five canonic entries in Bartok's fugue is approximately 18". This duration is 35 times as long as the other main period of the movement, defined by the eighth-note sub-pulse. In the absence of any mediating periods, the listener must therefore rely on the point of entry of the second voice to predict when subsequent voices are due to enter. At the fifth canonic entry, moments of rhythmic unison weaken the polyphonic

sense and longer durations become increasingly frequent. [Ex. 5.1]. In the subsequent bars (mm.22-26) a return to rhythmic independence is accompanied by a high degree of pitch repetition within each voice. The rhythms do not repeat exactly, but each voice (except double bass) incorporates a progressive shortening of durations. Because of the amount of change in the overall structure, the sixth entry is not particularly anticipated. However, at the appropriate place after the seventh entry, the absence of an expected entry is noticeable. Whereas the delay of the sixth entry was camouflaged by internal repetition and lengthening durations, this time there are no comparable distractions. Moreover, the lack of entry is highlighted by a clarity of texture created by the two inner voices moving to rhythmic unison in the preceding bar [Ex. 5.2]. The 35-eighths interval appears only once more in the movement, forming the distance between two violin entries of the theme.

The second movement (mm.310ff.) provides an interesting chance to study the extent of our reliance on contextual evidence for predicting fugal entries. An illusion of periodicity is conveyed by the recognition of fugal structure, but due to subtle shortening of phrases, the distance between entries is altered to progressively shorter durations. This sleight-of-hand benefits from

changing meters and sixteenth-note movement, which both help inhibit a counting procedure more easily deduced from a strong metric and hypermetric patterning. The listener may well be aware of the shortening, but that awareness is probably derived more from an awareness of the truncation on the level of the two-bar phrase [Ex. 5.3].

There are instances in the first movement where shorter delays between entries contribute to momentum and otherwise create interesting textures. With one exception, these occur after the climax. The exception is in m.27 when the outer voices introduce the sixth and seventh entries two octaves and a tritone apart at a delay of only three eighths. This stretto helps compensate for the lateness of the sixth entry and infuses more momentum into a passage that has incorporated substantial repetitions of pitch and rhythm.

An example of a quasi-canonic passage that does not imbue momentum is found in m.65 of the first movement. Although as usual the eighth-note sub-pulse is maintained, and the delays between entries are a mere three-eighths in duration, there is a feeling of calm owing to the sparse texture [Ex. 5.4]. The descent in register also contributes to a release of tension. The following passages build up the texture again with two voices in

canon (at two eighths' delay) and a third voice in counterpoint. This texture changes to a freer imitative style in four voices. A final phrase in canon, at six eighths' delay, leads into the new section at m.78.

The common eighth-note base of almost all the other canonic or imitative passages throughout the second and fourth movements emphasizes the presence of dissonance at a higher level. A typical example is that of mm.94-110 in the second movement [**Ex. 5.5**]. Initially, two layers moving in eighth notes state a two-bar fragment at a delay of one bar, creating a relationship of 1:4:8 between the three periodicities. The fragments are subsequently shortened to a one-bar, and finally a three-eighths', length with a corresponding shortening of the delay interval. With the entry of another layer and the freezing of pitch levels, a static texture is produced, emphasized by the presence of accents on each eighth note of the composite rhythm. This section is unique in not resolving into consonance.[1]

A cascading texture whose melodic simplicity disguises rhythmic complexity is produced by scales in canon in mm.287ff. [**Ex. 5.6**]. Five voices each present a four-octave descending scalar figure in eighths; the entries are at five eighths' delays. The octave recurrences form

a dissonant period of seven eighths, thus producing a clear 5:7 ratio. The harp emphasizes the five eighths' period with a descending perfect fourth figure. The passage "dissolves" into consonance simply by a reduction of voices. When only one voice is left in the texture, the harp drops an eighth rest from its pattern, creating an interval of four eighths' duration. That period prepares the listener for the next section, which presents the third statement of the theme in a 2/4 meter.

A particularly well-crafted example incorporating canon on two hierarchical levels is found at m.40 of the second movement [**Ex. 5.7**]. The canonic entries are each accompanied by imitative phrases which combine to form a composite rhythm of constant eighth notes. The phrase itself articulates the bar, and the imitative entries stress the half-bar, producing a consonant 1:2:4 ratio. The second and third phrases continue this consonance by entering at the delay of four bars (eight quarters). However, the end of the second phrase is truncated (by two eighths), and signals an increase in tension. Subsequent phrases are truncated or early. In later phrases, the accompanying voices also increase tension by offsetting their entries by one eighth, thereby creating dissonance with all other periods by placing an upbeat note on the downbeat of the bar. The process continues, developing

into an active passage.

Even the seemingly free section of the third movement involves canon. In m.10, a second voice enters in imitation of the first. At that point, the first voice shifts its accents by one quarter, still maintaining the same half-note period but stressing the independence of the two voices through a mild "type B" dissonance. [Ex. 5.8].[2] The composite rhythm articulates the quarter-note period, whose regularity is more easily grasped than that of the half-note due to the slow tempo. The delay of four bars between the first and second voices is confirmed as a period by the third entry in m.14. In addition, the xylophone/timpani dialogue presents an almost identical pattern in the bars preceding both the second and third entries. However, as this period is 24" long, it may not be readily perceived.

The middle section of the third movement presents a five-note group which sets up a periodicity of the quarter-note and the 5/4 bar. However, the regularity is disrupted after four bars by an insertion of the same figure in diminution. Subsequently, that eighth-note version is imitated at the delay of a quarter, then followed by a more complex canon of the quarter-note version. Had this been a five-voice canon, a constant

quarter-note motion would have resulted in a textural quality. Since the five-note figure is imitated in only four voices, however, it is possible to perceive the imitation as such. The period is emphasized by contour (each figure beginning with a high note), and by dynamic tapering [**Ex. 5.9**].

The relative regularity exhibited in the fourth movement extends to the canonic passages, as exhibited in mm.121-135 [**Ex. 5.10**]. Here the cascading entries of the first three bars are somewhat reminiscent of the second movement passage of mm.287ff., being mainly of eighth-note movement imitating at exact pitch. The texture is considerably more dense, however, due to delays of only one quarter note (ca. 0.25"), and to a slightly more differentiated rhythmic pattern (1-1-1-1-1-1-2). The bar period is emphasized by accented Bb's in violin I instead of the A of all other voices. The descending one-bar pattern is soon replaced by a two-bar figure incorporating a repeated one-bar rhythmic pattern. Initially, the new figure moves primarily in quarter notes, with imitation also at a delay of a quarter note. The listener is likely to "track" only the first entry in the highest voice, hearing the others as subsidiary. This tendency, in combination with the bar-length period strongly articulated since m.121, would explain the dissonant

effect of the violin I entry in the middle of m.127. It enters with the same rhythmic pattern but a different contour; the dissonance is emphasized by dynamics and notated accents. The second phrase of violin I enters after six quarters instead of four. Although this entry further disrupts the regularity of bar- and two-bar figures, it does re-align the figure with the established meter. Imitation continues, but the dissonance is gradually neutralized by the repetition of the rhythmic figure 1-1-2 which fuses the voices into a more static texture, in preparation for the subsequent section.

Lutoslawski's work, like Bartok's, also begins with a type of fugue. Each A section of the ABA form of the first movement has five entries, separated by the distance of seven bars, or 21 dotted quarter pulses. In the first section, there is a change of texture and material exactly seven bars after the fifth entry, where a sixth entry might be expected [**Ex. 5.11a**]. This change leads quickly into the middle section of the movement [**Ex. 5.11b**]. In the second presentation of the A section, there is no change of texture nor entry of any material seven bars after the fifth entry. Instead, four beats after that point, the english horn plays the first phrase of the fugue. The latter part of that phrase is then echoed twice as the movement draws to a close [**Ex. 5.11c**]. As in

the Bartok fugue, the phrases are of uneven length, providing contrast to the periodicity of the formal structure.

The middle section of the same movement contains a two-voice canon, but within the context of the dense texture at (11) discussed in the previous chapter [**Ex. 4.4c**], so its canonic structure is somewhat obscured. There are several instances in the second and third movements where imitation is used, but the fragmentary nature of the passages would make the term canon inappropriate. However, familiarity with and anticipation of canonic structure are often involved in such passages. The second section of the third movement, for example, introduces an eighth-note version of the passacaglia theme. At m.614, a fragment of this theme is echoed at the distance of three half-notes. Another three half-notes later, the bassoon begins a fragment likewise in eighths, with the first pitch repeated. Therefore, the listener might initially believe it to be the same fragment in inversion. However, its pattern repetition clearly groups it in six, contrasting with the clear four of the theme [**Ex. 5.12a**]. The dissonance thus created is all the more striking because of the expectation of a canonic passage set up by the previous entry. A few bars later (m.620), there is another example of fragments of

the same theme being echoed. This time, the third entry does remain in imitation, unexpectedly conforming to a rejected expectation; to maintain the unexpected, however, it arrives "early" [Ex. 5.12b].

Textural thickening is produced by a mixture of quasi-canon and heterophony at m.885. It displays properties of a textural strand, as it is restricted to a narrow registral band with foreground dissonance. Although the delay of the canonic entry combined with the prominent oboe timbre creates the effect of imitation, the first five notes are in octave unison with the piccolo. Six beats later, the piccolo repeats the fragment, and this time it is echoed twice at delays of one beat, again with octave unisons at the beginning of each entry [Ex. 5.13].

Immediately following this passage, a simple scalar figure derived from the passacaglia theme appears in imitation, with entries clearly audible due to registral separation. The use of only one rhythmic module results in four separate entries producing rhythmic consonance. The half-note period articulated by the entries is emphasized by diverging contours and a fortissimo dynamic level. The delay of the fourth entry is emphasized by its being presented in the highest voice, and reinforced by a contrasting (flute) timbre [Ex. 5.14].

The secondary theme of the chorale section is treated canonically in some of its occurrences. The "tail" of the first phrase is composed of two pairs of major thirds producing a double binary grouping. The canonic entry is consonant with that grouping. However, the phrasing is by threes, and thus produces a counter-rhythm. That grouping is further reinforced by quasi-canonic entries at lower octaves [Ex. 5.15]. Later on, the double binary figure is turned into an ostinato, and turned into texture through canon. This time, the entries are at a delay of six quarters, thus dissonant with the double binary figure but holding the half-note unit in common [Ex. 5.16]. The particular design of the figure results in the even-numbered entries producing a mirror image, and the odd-numbered ones moving in parallel motion, so the general effect quickly merges into texture. The fifth and sixth entries are at half-note delays only, ensuring that the listener remains aware of the canonic structure by the presence of stretto.

Ligeti is known for his use of micropolyphony, a term referring to the creation of textures by means such as "inaudible canons" which move too quickly and/or in too dense a context to be perceived of as such. By the time of the Chamber Concerto, however, he was beginning to

explore different approaches and aim for slightly different results, involving more open textures with the occasional emergence of melodic fragments. He explains:

> The methods [of compositional technique] vary from piece to piece ...and also by degrees: experiences with one piece lead to modifications in technique ... [The] closely woven musical network which is characteristic of the second movement of Apparitions [1957].... was the origin of 'inaudible' polyphony, or micro-polyphony, in which each single part, though imperceptible by itself, contributes to the character of the polyphonic network as a whole. In other words, the individual parts and the musical configurations arising from these parts remain subliminal, but each part and each configuration is, in relation to the overall structure, transparent in the sense that all changes in detail lead to changes, however slight, in the total effect.... I began to thin out the dense polyphonic network ... even more radically in the works after 1968. The individual parts were still more or less subliminal, but now and again there emerged musical shapes at a level of the individually perceptible. Typical of this thinned-out micropolyphony -- now resembling the transparency of a drawing rather than the opaqueness of a painting...[is] the Chamber Concerto...[3]

This work often involves structures that are reminiscent of canon but are not quite that. At the beginning of the work, for example, flute and clarinet play the same pitches in the same sequence, but coupled with different durations; the same is true of cello and bass clarinet. Another passage later in the same movement (beginning in m.19) gives more of a sense of canon without maintaining the same sequence of notes. This effect is due to the similarity of the entries and the difficulty of hearing

the specific pitch order. The similarities are a very fast and even rate of note attacks ("as fast as possible"), a pairing of instruments (harpsichord and celesta, violins I and II, viola and cello) and a shared pitch band [Ex. 4.15].

A similar passage, in a much lower register, appears in m.31 of the fourth movement. A few bars later, staggered entries of single sustained notes in the woodwinds likewise give the impression of imitation. It would also be possible to interpret parts of the third movement as canonic, where the staggered entries of instruments playing repeated notes on fixed pitches are in fact in imitation. However, the lack of melodic shape makes such an interpretation less compelling than one of texture. Thus it is clear that, although Ligeti is familiar with canonic structure, in this particular work it does not figure prominently.

CONCLUSIONS

Canonic form typically establishes periodicity by a regular pattern of entries. Periodicity in the canons studied was usually present on two levels: that of the delay between entries, and that of the pulse or sub-pulse. In more traditional works, the presence of meter involves

periods at the super-pulse level as well. Bartok's and Lutoslawski's works both begin with fugues, which also exhibit periodicity through a regular pattern of entries. However, in the fugues, the delay between entries exceeds the duration of the perceptual present, and therefore depends more exclusively on mental processes and the conceptual awareness of fugal structure. The canonic passages, on the other hand, often establish periods at a level which is immediately perceptible. In many cases, the phrases are not sufficiently long to be true canons, but the periodic delay of identical or transposed entries makes the resemblance unavoidable.

Bartok often uses canonic treatment in developmental passages, where the thickening of the texture and a progressive shortening of the phrase length contributes to a mounting tension while stability is maintained through a common subpulse. Lutoslawski likewise employs canonic means for thickening a texture, although some of the references to canon are very brief. He also uses the regular pattern of entries to articulate a periodicity. Ligeti's work contains only a few vague allusions to canon, as the lack of melodic content is somewhat antithetical to canonic episodes. One examples of quasi-canonic structure substitutes textural strands for melody.

The strictness of form implied by canon is similarly at odds with the relative lack of harmonic structure and the flexibility of rhythms in Bartok's and Lutoslawski's works. This incompatibility explains the brevity of many of the allusions to canon in those works. All three works reflect not only the composers' familiarity with canon, but also the listener's. Canon is an artificial device; considerable skill is required to design a melody which can be interwoven into a satisfying whole. As such, the form of canon conveys a sense of order and implies a mastery on the part of the craftsman. The tradition of canon is so well-established that a couple of imitative entries can serve to interject the sense of order without demanding a full manifestation of the design.

C H A P T E R V I

ENHANCER of

T H E M A T I C S T R U C T U R E

Themes often exhibit alignment of several levels of periodicities. In works such as those analyzed here, hierarchical alignment is not an ingredient of a large proportion of the work, yet it is often found within thematic structures. This fact suggests that recognition of a theme may be derived in part from such organization, lending support to theories of the relevance of Gestalt psychology to recognition of musical patterns.[1] A theme usually recurs at least a few times in a work, and serves as a vehicle for development or unity. Therefore, its ability to be quickly identifiable can be necessary to its function. In works where harmonic structure is weak, rhythmic structure becomes a more crucial component. Moreover, in works where lack of rhythmic consonance is the norm, the alignment of two or more layers of periodicities can serve to identify a significant element. This chapter explores the rôle of periodicities in clarifying thematic structure in the works studied.

Ligeti's Chamber Concerto has very few melodic lines,

and those few do not function as themes. Bartok's and Lutoslawski's works, on the other hand, contain several themes each. Most of these rely on periodic components in delineation of their structure. In Bartok's work, the first presentation of a theme often exhibits consonance. Lutoslawski's themes show more irregularity in their hierarchical structuring, employing periodicity instead as a means of creating a high level of redundancy on the foreground level. Distinction between layers in Lutoslawski's work is therefore usually achieved by contrast between foreground structures. In many of the multi-strata passages, at least one component layer exhibits some degree of internal consonance, and often contains overt periodic components (see Chapter VIII). In both Bartok's and Lutoslawski's work, the super-pulse level frequently exhibits irregularity, while the pulse, sub-pulse, and phrase levels remain in alignment.

A passage in Bartok's second movement demonstrates to what extent rhythmic consonance is a prerequisite of theme recognition. At mm.264ff., various lines seem unrelated to each other and lack formal coherence [**Ex. 6.1a**]. Finally, a theme emerges from the fragments. Recognition of its identity seems to be a direct result of the repetition of regular groupings and pitch structures [**Ex. 6.1b**]. The particular theme is very regular in a 1:2

ratio on the phrase level, but irregular on the level of the pulse. Other voices aligned with the sub-pulse level are easily perceived as being secondary because of their lack of consonance and regularity on the phrase level.

The first instance of metric-type organization in Bartok's work is in the opening of the second movement, which provides contrast to the additive structures and long phrases of the fugal first movement. The vigorous theme has a clear and traditional structure, constructed by the nesting of periods in a 1:2 relationship [**Ex. 6.2**]. The periodicity of the eighth note, the 2/4 bar and the 2-bar pair are all emphasized, and the quarter-note period is implicit.[2] All lower levels of periodicity remain intact at least until m.20. As periodic units are organized on progressively higher levels in a 2:1 ratio, there is a strong expectation of that proportion extending to the 4-bar length.[3] Therefore, the arrival of the second phrase on the downbeat of m.8 is unexpected, being early in comparison to the anticipated point one bar later. A sense of balance is quickly restored because the third phrase parallels the second, and the listener may tentatively accept the three-bar duration as a potential period. This interpretation is thwarted by the extension of the fourth phrase, though bar-level and now two-bar groupings are clearly articulated.[4] With the exception of

the first two bars (which are clearly identical to each other but different from the subsequent pair), all the 2-bar pairs are delineated by the contour. The alternation between the two groups of strings further emphasizes the 2-bar division.[5]

Fragments and variations of this theme figure throughout the movement, usually initiating new sections. The new theme which enters in m.68 begins with a rhythm identical to that of the first theme. It likewise exhibits a high degree of consonance, incorporating 2:1 proportions from the level of the eighth note to that of the 16-bar length. Because of the similarity of rhythmic structures, this theme subtly reinforces the binary groupings of the first theme for future hearings [**Ex. 6.3**].

The two-bar period (whether of 2/4 or 3/8) is common throughout the second movement, in canonic sections as well as in the more consonant passages. This prevalence does not indicate the dominance of a specific duration, but rather an adherence to the binary structure of the theme. In other words, the theme incorporates repetition of a short unit and thus implies repetition of similar short units within development sections. This design explains the audibly logical though irregular-looking

design of mm.373ff., another passage derived from the first theme. There, the sequence of a 2/4, 3/8, and 5/8 bar is repeated and then answered by 3 repetitions of a 2 x 3/8-bar phrase [**Ex. 6.4**]. Similarly, a fragment played by Group I at m.114ff., although lasting for the initially unusual length of six quarter notes, is balanced by its immediate repetition.[6]

The opening theme of Bartok's fourth movement exhibits complex rhythmic structure unified by a strong pulse. The two irregular patterns of the theme and accompaniment combine to form a steady eighth-note pulse. They are irregular only on the immediate foreground level, forming a rhythmic pattern which repeats at the period of the 4/4 bar [**Ex. 6.5**]. A longer period of the four-bar phrase is articulated by the (mainly scalar) melodic material. In addition, the bowing creates a (consonant) two-bar period, as the slur on the last two notes of each bar results in alternate bowing for each bar-length pattern. The contour and upbeat beginning of the theme imply a downbeat on the third eighth of each bar, with another accent on the sixth eighth suggested by duration. However, as the accompaniment is easier to interpret as sounding on strong beats rather than off-beats, a dissonance may be felt despite the dovetailing of the two patterns.

The second four-bar phrase is answered by a two-bar phrase containing the same rhythms with the addition of an introductory figure. The chords disappear, but an accompanying figure in the strings maintains the steady eighth-note pulse. However, the disappearance of the opening eighth rest and a shift in the accompanying figure changes the 3+3+2 grouping into a 4+4 grouping [Ex. 6.6]. The whole-note super-pulse is maintained by repetition within the answering phrase itself.

This material is found in very similar form three more times throughout the movement.[7] The accompaniment changes slightly each time, but the degree of dissonance does not increase. This constant level is presumably due to the irregular pattern of the basic rhythm and its slightly dissonant accompaniment. Such foreground complexity does not lend itself easily to further dissonant treatment, whether by canonic design or simultaneous presentation with another melody.

The second theme of the fourth movement, entering first in m.28, is composed of a two-bar rhythm in quarters repeated four times on the piano. It exhibits layers of periodicity to the eight-bar level in a 1:2 ratio. The rhythm is closely related to that of the coexisting string part [Ex. 6.7].[8] The dissonance between piano and strings

is sustained by repetition in both layers. The strings present a simple up/down contour which helps emphasize their four-bar division. The second phrase begins with the same six pitches, though with an altered rhythm (to help avoid fusion of the two layers, perhaps). The piano's reiteration of the same single pitch readily identifies that as the beginning of its second four-bar phrase. The theme recurs at m.150, this time aligned with the notated meter but subject to much more severe dissonance later, explained in Chapter VIII.

Another fourth-movement theme reminiscent of the opening enters in m.74, exhibiting periodicity on the level of the half-note (by rhythmic figures and by off-beat harp octaves), the two-bar phrase (by contour) and four-bar phrase (by parallel construction) [**Ex. 6.8**]. The substitution of silence for two of the accompaniment chords in the second four-bar phrase introduces some tension, even though the remaining chords are consonant with the established periodicity and with the scalar passages. This tension is greatly heightened by a complete silence on the last two beats of the phrase. The vivid effect of that interruption is clearly aided by an initial establishment of periodicity. A <u>rallentando</u> through the two last bars also contributes to the dramatic effect. The silence then adds considerable emphasis to

the downbeat of the following bar, which states a fragment of the same phrase.

In Lutoslawski's work, several of the major themes of the work move quite slowly and have irregular phrase lengths. These themes are designed so that their identity can be retained despite a shortening or lengthening of the sustained durations and a variable number of repeats of the shorter fragments. As a result of such flexibility, there is usually an absence of hierarchical periodicities. Other themes and figures of the work are contrasted by their incorporation of more regular, short durations, but their phrase lengths are often as irregular as those of the slower themes. They tend to have a stronger rhythmic vitality, and are more apt to be fragmented and manipulated in a developmental style, as they maintain their identity despite changes.

The original presentation of the passacaglia theme in the third movement provides an example of complex metric structure, but of a more traditional style [**Ex. 6.9a**]. The eight-bar ground appears only in skeletal form at first, emphasizing the bar period and implying a duple meter by the binary division of the fourth and eighth bars. However, with the beginning of the second statement (m.426, (47)), quarter notes clarify the basic 3/4 metric

structure, against which the fourth and eighth bars create the effect of hemiola.[9] The eighth-note period is articulated often enough to exist as a distinct level. As the first two bars share the same rhythmic structure, they suggest a two-bar period. However, the pitch similarity between the first and fourth bars disrupts that period by implying a three-bar grouping. The similarity between those bars also interferes with the pairing of bars 3 and 4 with bars 5 and 6, despite the identity of bars 3 and 5. On the other hand, the hemiola construction that links bars 4 and 8 creates a four-bar period. Therefore the four-bar period is out of alignment with the beginning of each statement of the ground. This dissonance creates a slight inner tension which helps maintain the interest through numerous repetitions of the entire phrase.

After eighteen repetitions, the pitch structure of the passacaglia is sufficiently familiar that the composer can alter the rhythms without destroying recognition. The first occurrence of a variation on the theme combines the regularity of repeated eighths with irregular groupings, typical of the additive structure found in much of the work [**Ex. 6.9b**]. Redundancy is provided by repetitions of single or paired modules, while interest is injected by the unpredictable number of repetitions employed. The end of the phrase changes to a very different rhythm,

reminiscent of the second movement theme. The similarity results from the insertion of a few very quick notes between sustained ones.[10]

Repetition of modules within the phrase appears in other variations, and might be considered a characteristic of the passacaglia's transformations. For example, the device is found in another version appearing at m.802. There, the duple bars of the ground are transformed through an additive approach. Instead of the bar period being retained and the two pulses stretched to fit in the time of three (as it was in the original), the two duple bars are shrunk to 2/4 so that the pulse duration is retained [**Ex. 6.9c**]. Both that variation and the next, at m.852, abandon the durational contrast of the original and move in steady, quick durations. The contour is highlighted by a shrinking of each pair of 3/4 bars into 6/8 bar [**Ex. 6.9d**]. The version presented at m.876 is quite rollicking. The very fast tempo makes every second pitch sound like a grace note to the following one. Accents are thus given to the notes which have traditionally been weak beats. The effect therefore is of irregularity, though the rhythm itself is constant [**Ex. 6.9e**].

The Capriccio theme of Lutoslawski's second movement

has a slightly ethereal quality that is reminiscent of a passage in the final movement of the composer's string quartet.[11] It causes the listener to strain to catch the music. This effect is a result of the extreme speed, relatively high register, and very soft dynamics. The rate at which the theme moves is normally associated with more ornamental rôles such as embellishment. An interpretation of ornamental function is however prevented by the definite shape of the theme and the absence of any other activity. That shape is emphasized by the four repeated sixteenths at the beginning of each phrase, and thrown into greater relief by the sudden rests and irregular phrase lengths. Nevertheless, the listener may not grasp the structure for the first few phrases, due to the speed of presentation and its novelty. There is some compensation for this effect by the incorporation of a high degree of redundancy in each phrase and between phrases [**Ex. 6.10**]. Similar use of redundancy is found in the opening theme of the first movement [**Ex. 6.11**].

CONCLUSIONS

Hierarchical organization of periodicities is typical of thematic structure in Bartok's work, but significantly less so in Lutoslawski. One technique of variation employed frequently by Bartok is that of presenting the

same theme with different hierarchical structures. The second and fourth movements of that work exhibit a much greater degree of periodic organization than the first and third, providing large-scale contrast. Lutoslawski's themes are generally of two types: sustained notes interrupted by quick movements, and quick notes with a high degree of foreground redundancy and overt periodicity. Ligeti's work does not embody themes in the traditional manner, and depends on other means for providing continuity and contrast. The three approaches lead to quite different results on a large scale, as will be discussed in later chapters.

Chapter VII

DELINEATION of STRATA

One of the main purposes of this study was to investigate the interaction of strata in complex works. This chapter focusses on a few of the more striking examples of multiple strata, in order to examine the way in which the composers create an effect of separation between layers. The distinction between stratum, layer, and strand is not always clearly defined, but I reserve "strand" for one distinct component of a texture, and "stratum" for one of two or more distinct layers which retain a certain independence at several levels. A stratum is frequently comparable to a theme, and often exhibits a certain degree of inner complexity.

The phenomenon of auditory streaming can provide a useful model for indicating ways in which we may tend to perceive distinct strata. It indicates strategies used by the brain when trying to sort out an overload of data. Psycho-acousticians generally reserve their discussion of the phenomenon for very fast rates of presentation. However, the study of auditory streaming can also benefit an understanding of our modes of perception for larger-scale organizations. It emphasizes our tendency to group

sounds by their interconnectedness rather than by coexistence in time. We can easily adopt a "horizontal" listening approach when the context encourages it.[1] The development of harmony in Western music has focussed attention on vertical combinations; harmonic structure is a result of careful design which can override a more natural tendency to segregate component strands by registral segregation, dynamic variation, etc. Bregman suggests that the auditory system is designed to integrate sounds that probably arose from the same source.[2] The audibility of stratification on a larger scale depends on the success of the composer in creating and maintaining distinction between layers, and on the interpreters' ability to emphasize those distinctions as necessary.

Contrast at some level(s) is essential to the delineation of strata. It might therefore appear that the most efficient way of differentiating layers is to have them contrasted in as many ways as possible: by register, pitch collection, durations, articulation, dynamics, and timbre. Extremes of contrast in all parameters, however, would produce tedium. More typically, a few parameters are contrasted while others retain similarity. Registral separation is one of the key factors of delineation in auditory streaming, and figures prominently in many cases of stratification. Its rôle in stratification is simply

the converse of its rôle in textures, where the sharing of the same registral band enhances fusion. If there is alignment at the level of pulse and super-pulse, a contrast of density or note activity between component lines does not necessarily produce segregation. A melodic passage may exhibit an interlocking design in which some instruments are restricted to a reinforcement of important pitch and/or rhythmic structure of a melody, while others have a high density of notes in the form of embellishment. However, non-alignment at the levels of pulse and/or super-pulse becomes a significant factor in encouraging a stratified mode of hearing. The works examined here incorporate passages whose layers are differentiated by a variety of methods. In some cases, the distinction between layers is subtle, and becomes blurred at certain points. This attribute should not be interpreted as a failure to achieve stratification, but rather as a sophisticated way of providing variety and depth.

Bartok's work contains few truly stratified passages in the sense of presenting two or more disjunct layers. He is the most traditional of the three composers in maintaining integration between layers through careful design. Much of the rhythmic dissonance is of a mild sort as exhibited in his canonic and textural passages. However, some of the textures are components of a

figure/ground relationship, and create a sense of stratification because of their inner complexity. Several of these passages involve considerable density at the foreground level, through high-order subdivisions, trills and tremolos. They are thereby differentiated from the slower motion of the "figure", or theme.

The first example of a figure-ground relationship occurs in Movement I with the celesta entrance of mm.78 [**Ex. 7.1**]. The "figure", in the form of the theme and its inversion, is relatively distinct from the "ground" created by the celesta and strings' tremolo. It is presented in eighths and quarters, while the "ground" is a fusion of several very fast articulations. A very similar passage occurs in the third movement at m.63 [**Ex.4.9**]. The distinction is more blurred in a related passage earlier in Movement III. There, the "figure" is presented in tremolo, pianissimo, moves by step, and incorporates an ostinato. It tends to merge with the ground due to the similarity of periodicities and the static quality of the ostinato. A simultaneous crescendo and stringendo in both layers and the presence of a timpani roll reinforces the fusion of the two layers [**Ex.7.2**].

A clear separation between melody and accompaniment occurs around m.115 of the second movement [**Ex. 7.3a**]. The

background texture moves by step in constant sixteenths, while the melody, though introduced by a pair of sixteenths, is contrasted by the incorporation of leaps and a mixture of sustained notes and eighth-note motion. The background texture exhibits a high and fluctuating dynamic level which rivals the melody for attention. However, the higher register and slower, less regular movement of the melody contribute to its prominence. As the passage continues, the relationship is switched. The reduction of activity in the melody layer and an ascending scale with crescendo in the background layer focusses the listener's attention on the texture. At that point, the texture transforms into the melody [**Ex. 7.3b**]. Alternation of rôles continues, and the two layers gradually become more perceptibly interrelated, finally fusing into rhythmic consonance for the entry of the piano theme in m.155 [**Ex. 7.3c**].

The presence of two strata is pronounced at mm.199 ff. [**Ex. 7.4**]. Again, the "figure" is made prominent by its irregularity of rhythm and an apparent phrase structuring, contrasted with the regular five-note ostinato of the other strings [**Ex.4.1**]. Contrast is heightened by dynamics (background piano, "melody" forte) and by a sharper articulation for the chords of the theme. The contrast in durations is not very marked, since both strata share an

eighth-note sub-pulse and there are no shorter durations than that. However, the grouping of the theme's chords is mainly by two and three eighths, and there is further irregular grouping on higher levels, while the background texture presents a continuous flow of sound.

The fourth movement of Bartok's work contains a stratified passage which exhibits a strident dissonance. As this instance involves two adjacent layers of internally-consonant periodicities, it suggests that the consonance of each layer helps throw the dissonance into sharper relief. Possibly the most important factor contributing to the striking dissonance is that it exists only on a secondary grouping level. That is, the foreground rhythms of the sounding pitches are in alignment, and it is only an awareness of conflicting stress patterns which produces the dissonance.

The passage referred to is that of mm.151ff.; the theme involved first occurs in m.28 of the fourth movement [**Ex. 6.7**]. Its first appearance is dissonant with the established meter and with the accompanying pattern [**Ex. 7.5**]. The dissonance, which is quite audible, is on the level of the whole note; the quarter- and half-note periods are consonant both with the preceding passage and with the coexisting material in the strings. The period of

the half-note established by the opening theme remains intact throughout the imitative section of mm.19-25. The whole-note period, however, is not clear after that section, because of the truncation of fragments to half-note lengths and the abandoning of two-bar periods. Therefore, the factors that contribute to a sense of dissonance in m.28 are quite local. First, the dramatic cut-off with a fortissimo rhythm/pitch unison figure gives extra emphasis to the downbeat timpani entry in m.26. The timpani pattern implies a bar-length period by presenting a subdivided version of the "Bulgarian" rhythm from the opening of the movement: a 3+3+2 which is not consonant with the half-note period.[3] That figure contributes to a strong upbeat/downbeat interpretation of Group I's entry at the end of m.27. That the piano entry should sound dissonant is confirmed by the presence of dotted barlines (out of alignment with the other barlines) and an accent mark on the second note of the piano part.

As mentioned in the previous chapter, the piano theme exhibits internal consonance in a 1:2 ratio up to the eight-bar phrase level. Dissonance is created by the relationship between the piano and strings. The clear half-note delay at the start may initially suggest rhythmic imitation, but the insertion of a quarter rest in the string pattern of the following bar weakens that

interpretation. The downbeats of the piano pattern, marked with accents and reinforced by contrabass pizzicato, often coincide with rests in the strings. An exception is the rest in m.33, which is "off" by half a beat. This displacement maintains the independence of the two layers, which might otherwise have meshed into complementary patterns.

After the piano's binary divisions of its eight-bar phrase, the articulation of a three-quarters period by reiterated chords produces a striking dissonance. Strings simultaneously change to the same period, exchanging their vertical dissonance to support the piano's horizontal one (producing an indirect dissonance).[4] Only the timpani maintains the bar-length pattern which keeps the dissonance clearly audible. In the bars between the two presentations of the three-quarter period, the strings subdivide the time into half-note periods.

There is a brief allusion to this passage in mm.83ff., where piano II begins halfway through a bar after a strong bar periodicity has been established [**Ex. 6.8**]. This entry presents a quarter-note pattern with every second note accented, suggesting a dissonance that is confirmed by the entry of a new theme on a clear downbeat at m.85. The next full reference occurs in m.150 [**Ex. 7.6**]. Here

the downbeat of the piano part coincides with the downbeat of the prevailing meter. It is also consonant with a three-bar period which has been reinforced by very regular rhythms since m.136. The dissonance this time is created by the two-bar period articulated by the piano grouping; the three-bar period is immediately neutralized into a repeating one-bar pattern. Since the three-bar period continues in the listener's ear, this presents another example of indirect dissonance.

After one statement of the piano's eight-bar phrase, the strings enter with its repetition. A mere four beats later, however, the piano begins again, this time at forte (the strings statement is mezzoforte). The dissonance seems very harsh, and it is interesting to note that as the layers are aligned on the level of the quarter note and the bar, that dissonance is created entirely by a clash of periodicities on the level of the two-, four-, and eight-bar grouping levels. In another context, the second entry might be interpreted as a simple echo, and therefore not seem so harsh. However, this interpretation is contradicted by four factors: timbre, dynamics, tempo, and structure. Because the preceding statements of the theme have been in the piano, the second entry of the piano has a certain authority as being the main voice. This is reinforced by the dynamic marking of forte, one

increment louder than that of the strings. It is also difficult to interpret the strings' entry as being an imitation of the piano's first statement, since the piano has come to a stop and the first interpretation of the string entry sounds like a continuation of the theme with timbral change. The impression given by the piano entry in m.159 can appear as that of an entry at the "correct" place, as though setting a proper example to the incorrect and premature entry of the strings. The tension is increased by the lack of resolution of the dissonance.[5]

A clear stratification occurs in the second movement of Lutoslawski's work, at m.311 [**Ex. 7.7**]. The main theme is presented in the trumpets, cantando and quasi legato. It incoporates long sustained notes and a few short durations initially presented in a type of neighbour-note figure. The phrases are of irregular length, but have a common denominator of a dotted half duration, and an average length of five dotted halves. The figure is quite recognizable and easy to distinguish. Contrasting sharply with this theme is a bold angular fragment proceeding in short regular durations. It recurs periodically at first, but the period of recurrence is dissonant with the grouping levels of the theme. The two strata begin together, but within a couple of reiterations of the brass figure, it becomes apparent that there is no

correspondence between the two. Further dissonance occurs at subdivision levels as oboes and clarinets present a slowly-descending line. That line, clearly audible due to its stepwise movement, presents a duple division of the half-note period. Although the main theme is not periodic, its groupings seemed consonant with the triple subdivision earlier, and are unlikely to be reinterpreted. The complexities of this passage continue as the main theme is treated quasi-canonically and new layers also appear. Although the number of layers increases, the durations incorporated in the new figures are closely related to existing durations. Thus, they form links with the other layers on the level of pulse or super-pulse, presenting variety through grouping or subdivision levels.

The passacaglia in Mvt. III of the same work presents a fascinating example of an extended multi-strata section. The Passacaglia proper lasts for almost six minutes (to m.562), and is clearly separated from the next section of the movement. During this time, the ground of 8 bars' length is heard 18 times [**Ex. 6.9a**]. The passacaglia theme is presented in various orchestrations, incorporates a steady registral climb, and has a dynamic shape which rises to its highest levels on the tenth, fourteenth, and fifteenth statements, then decreases quickly in the end. The dynamic increase is not gradual, but stepped: each of

the first ten statements increases the dynamic level on the first beat of the first bar. This helps the listener maintain track of the passacaglia theme.

There is some variation in the tempo, and the changes do not coincide with the beginnings of ground statements. This is just one indication of the discrepancy between the ground and the other coexisting musical material. Although Stucky refers to these other themes as "variations", I feel that is a misleading term.[6] It implies a connection which seems antithetic to the nature of the passage. What is striking about this section is the refusal of the composer to weave the disparate elements together into a whole. Only the fact that we hear them simultaneously links them together. The term "variation" seems more suitable for later sections of the movement, where the ground theme itself is subject to variations in rhythm, articulation, etc. (See **Ex. 6.9.**)

The various fragments and melodies which appear during this section exhibit a wide variety of characteristics [**Ex.7.8**]. Periodicity rarely extends to a level beyond that of the super-pulse. Most of the fragments share the same pulse as that of the 3/4 meter of the passacaglia theme. This results in a 2:3 dissonance every time the theme reaches one of its duple bars (fourth and eighth).

More significant dissonance results from a lack of alignment between the grouping levels and/or subdivisions of the fragments with those of the passacaglia theme. An example is at m.498 [**Ex. 7.8h**], where a clearly-articulated half-note period is markedly dissonant with the dotted half periodicity of the theme. More frequently, irregular groupings of the fragments produce the dissonance with the regularity of the theme. The rôle of periodicity is often that of creating a specific foreground texture, as various fragments exhibit different subdivisions of the quarter note, from triplet eighths to sextuplet sixteenths and thirty-second notes.

Much of the dissonance of this section seems jarring precisely because there is continuous expectation of alignment. Such expectation is reinforced by pattern recurrence, which often suggests a periodic structure which does not then materialize, due to truncations, extensions, interruptions, or even abrupt change. (See **Exs. 7.8c,e.**) The expectation of alignment can also arise from a temporary alignment of accents or phrase structure between fragment and ground. For example, a line which finishes quietly on the downbeat of m.479 seems appropriate, and thus leaves the listener completely unprepared for a strident fluttertongue chord which arrives on the second beat of that bar [**Ex. 7.8f**]. When

the chord occurs again on the second beat of the next two bars, a listener may try to reinterpret it as relating to the ground's meter in an offbeat pattern. However, that interpretation has to be abandoned when the chord fails to appear again for several bars.

The lack of alignment between the initiation of the fragments with those of the ground statements seems particularly important in creating segregation. The only place where there seems to be alignment is at m.538, where the sixteenth statement of the passacaglia theme begins. The other stratum arrives at a super-pulse period on the downbeat, and the texture changes. However, dissonance is established immediately in the form of a dotted half pulse, and a strong downbeat arrives two bars later, which indicates the independence of the two strata.

Several of the fragments overlap with each other, and usually produce more dissonance by their lack of alignment. That dissonance is usually a result of irregular groupings, and any harshness is perceived more from their individual relationship to the ground. At m.530 [**Ex.7.8k**], however, two fragments present a harsh Type B dissonance. Each is grouped by four, and exhibits a displacement of one eighth rest. This relationship links them more closely to each other than to the theme, with

which they are both dissonant. A summary of the non-alignment patterns of the fragments and the theme can be seen in **Ex. 7.9**.

Ligeti's work could be characterized as a juxtaposition and layering of various types of texture, and as such incorporates numerous instances of multiple strata. Many of these are quite brief, but well-defined. Timbre and density are two of the most commonly contrasted parameters. The degree of contrast is often not very marked, and in some cases the blurring of distinction becomes a major element of the design. In the first movement, for instance, a texture which begins in the woodwinds in m.8 is passed to the strings and then provides a background to a horn phrase [**Ex. 7.10**]. The strings move in irregular durations ranging from a sixteenth to just over one quarter. The resultant density averages about six attacks per second. In m.18, trombone and celesta enter with very short bursts of notes "as fast as possible", while the woodwinds play slightly longer bursts a bit more slowly. In the following bar, the density of the woodwind texture increases due to an increase in subdivisions and more overlap of voices [**Ex. 7.11**]. In the middle of that bar, piano and harpsichord begin very fast cadenzas, echoed by two groups of strings in the canon effect described in Chapter V.

The woodwinds, which stopped playing in m.20, begin again in m.22 with another texture, at similar speeds to those they left but much more unified, as they begin together and play in rhythmic unison [**Ex.4.16**]. The fact that many of these textures are closely-knit (i.e. temporally dense and confined to a narrow registral band) defines them quite clearly, and allows the listener to perceive the interplay of textures. In addition, the durations of the textures themselves help delineate the various strata. In the passage just mentioned, the woodwind/string texture continues for 48" while the trombone/celesta and short woodwind fragments last for a mere 8". It might be more difficult to maintain the separation between the layers if they were both present for the full 48". The effect of simultaneous initiation, which has a fusing tendency, is likewise conducive to the distinguishing of one layer from another: the woodwind entry at m.22 is sufficiently unified that it does not readily tolerate merging with another existing texture.

CONCLUSIONS

In order for a musical passage to appear stratified, there must be a clear distinction between at least two layers of musical material. The distinction between stratification and other types of polyphony is to some

extent simply a question of degree. However, a traditional polyphonic passage usually exhibits a balance of parts on a relatively low level (i.e. close to the foreground). This balance is generally achieved in two ways: each strand is of similar weight, and each has similar lengths of phrases, grouping structures, etc. A stratified passage, on the other hand, often involves a contrast in both areas. Thus a temporally and registrally dense texture may be contrasted with a sparse one, and the dense texture may last for a much longer period of time. The presence of any layer which can be called textural suggests a stratification, as the internal coherence of that layer implies a resistance to its fusion with other material. Effective stratification thus involves a simultaneous control of factors which enhance fusion and those which enhance segregation.

Ligeti's work is composed mainly from the manipulation of textures and textural strands. One suspects that each layer is composed first, and only afterwards are they superimposed and juxtaposed. Although some layers exhibit timbral modulation and others exhibit an internal fluctuation of density, there is little sense of one layer influencing a change in another. Most of the layers exhibit a relatively high rate of activity on the pulse level or lower. Due to a specific and limited range of

that activity, each layer is characterized by a relatively unique rate of motion. In addition, the restricting of other parameters in each layer, especially registral breadth, helps create a dense texture which is therefore more resistant to fusion with other layers. The synchronized attack of several voices also contributes to a perception of their belonging together. The converse of such an effect, asynchrony, is said to be a significant factor in auditory fission; this effect is extended to a large scale by Ligeti. He helps differentiate between strata by the simple technique of having one texture begin several seconds after another one, so that they seem quite unrelated, especially if the second one lasts only a brief time before disappearing again.

Bartok's work also exhibits stratified passages where one texture is extremely dense and therefore easily differentiated from the other. Several passages, similarly constructed with a high degree of foreground dissonance on the ornamental/textural level, illustrate varying degrees of contrast. When the "figure" moves in slow durations and outlines a familiar melodic contour, it is easily differentiated from the "ground", but when it is subject to an increase in attacks and a reduction in pitch movement, the distinction between figure and ground is blurred. In another type of stratification, such as at

m.199 of the second movement, the contrast in durations between figure and ground is reduced. The prominence of the theme is retained due to a higher contrast in grouping organization, and through timbral and articulation accent. The most striking stratification in the work occurs in the fourth movement, where a theme introduced on the piano appears out of alignment with itself when echoed by the strings. The segregation of the two layers is maintained through a relatively high grouping level, with a slight contribution from timbral and dynamic contrast. The two layers have virtually the same material, and it is the lack of alignment that prevents them from fusing.

Lutoslawski's stratified passages exhibit the most contrast in several parameters, and this design allows him to employ less dense textures. In the second movement, for instance, neither the theme nor the secondary layer have durations shorter than the eighth note, and neither employ ostinato or are particularly restricted in pitch movement. He relies more on grouping structures at the level of the bar, and on articulation and contour. In his passacaglia section, he takes advantage of the same segregation technique as Ligeti by maintaining one very redundant stratum for several minutes (the ground) while superimposing a variety of unrelated, shorter layers. These layers are not always dense, but are generally

dissonant on several levels, including those of the sub-pulse, pulse, and bar.

In most cases studied here, the clarity of strata delineation depends on contrast in several parameters. Contrast in the temporal realm seems very common, both on the level of individual note durations and on higher grouping levels; usually both are combined. The difficulty involved in distinguishing one stratum from another seems to contribute to the degree of harshness sensed. A periodically-organized dense texture contrasted with a slow-moving irregular melody seems easy to interpret as stratification, especially when heightened by registral and timbral separation. Therefore, the resulting composite may not evoke a sense of harsh dissonance, if other factors of intensity are low. On the other hand, two strata which are related in some close way, such as by the sharing of melodic and rhythmic contour, but which are not quite aligned, can appear very harshly dissonant.

A careful study of these phenomena suggests several factors relevant to the perception of multiple strata and textures in a musical work. The perception of distinct strata seems enhanced by contrast between the periodicities of coexisting levels. That is, when two or

more levels have the same rate of periodicity, the awareness of their polyphonic qualities is likely to be submerged by the resultant texture, unless they are carefully segregated by other means such as registral separation. Although canonic and fugal passages may seem to disprove this observation, the various strands of a canon can be difficult to discern after they have made their individual entries. It is primarily the audible echoes of patterns between parts that convinces us of the stratification. In cases where canons do appear to lapse into textures, this may in fact be the composer's intention.

A prominent and distinct kind of stratification is evident in many 20th-century works. Passages such as those found in the third movement of Lutoslawski's Concerto for Orchestra reveal highly contrasted periods at higher structural levels. In these cases, the emphasis is on maintaining independence of parts rather than on weaving parts together into an harmonious whole. Polytonality, registral separation, timbral differentiation, and poly-rhythm may all be employed to this end. The distinction between texture and independent multiple layers is often subtle, as both commonly employ rhythmic dissonance. Ligeti's Chamber Concerto provides a fascinating exploration of that perceptual boundary.

Chapter VIII

PULSE and SUB-PULSE

Pulse and sub-pulse are present throughout most of the works analyzed. This chapter discusses significant and long-term manifestations of audible pulse which have not otherwise been covered in discussions of thematic structure, texture, and multi-strata passages. These manifestations usually arise from the composite rhythm of several layers which form a rhythmic consonance on the level of pulse or sub-pulse.

Music for Strings, Percussion & Celesta

Pulse has an extremely important rôle in delineating structure in Bartok's work, as befits a work which exhibits additive construction. Although additive rhythmic structures were not common in the eighteenth and nineteenth centuries of the Western musical tradition, they form an integral part of Eastern European folk music as well as much of Indian and African folk and art music. Their presence in Bartok's music is a natural reflection of his immersion in the study of Hungarian and Romanian musical structures. In several passages in his work, structures are clarified by the establishment of an overt

pulse or sub-pulse throughout long sections. A break in the sounding of that pulse is then a signal of a major structural point. The most dramatic example of this technique occurs in the first movement.

The phrases of the first movement's fugal theme exhibit additive construction, with the eighth note as the common unit. Combinations of durations, mostly eighths and quarters, produce subgrouping by two, three, four, or five eighths. Although the duration of three eighths is predominant, it is not sufficiently constant to establish a periodicity at that level. Likewise, there is a marked absence of periodicity on a higher structural level, as the subgroups are themselves grouped into phrases of irregular length (generally between six and eleven eighths). The combination of varied grouping lengths and phrase lengths is doubtless a major contributing factor to the organic quality of the theme. There is, however, one periodicity in the form of the eighth-note sub-pulse: the common denominator to all groupings. With the second entry, the eighth-note becomes an audible, if subtle, constant as a result of the composite rhythm. It thus provides stability for the interweaving of parts, and is essential to the fluidity of the unfolding theme.

According to a pitch analysis, the climax of Movement

I arrives in m.56 where the E♭'s mark the limit of a slowly-expanding pitch structure. However, there is a very compelling moment a few bars earlier at the downbeat of m.52 which has justifiably been considered the beginning of the climax section.[1] Several factors contribute to a sense of culmination in m.52; the chief ones are in the domain of pitch and pulse. Leading up to that bar, the top voice (violin I) plays a progressively shorter series of notes each beginning with the pitches D♯-E-G. After 9 repetitions of this pattern, the downbeat of m.52 presents the retrograde: G-E-D♯. Simultaneously, and perhaps even more noticeably, the lower voices reach the climax of their ascending line in a relatively high register. After the first note of m.52 they begin their own retrograde descent, though at a slightly different rate from that of violin I [**Ex. 8.1**].

The moment of pivot for the pitch contours is emphasized by a suspension of motion at the downbeat of m.52. The first note of that bar is sustained for three eighths' duration by violin I and five eighths' duration by all others. The pause in movement lasts for ca. 1.5" in the violin (ca. 2.5" in the other instruments). Although this may seem very brief, it is quite noticeable due to the fact that the sub-pulse (of ca. 0.5" duration) has been constantly articulated for three and a half minutes.

terms of ratio, the held note of m.52 is three times as long as the subpulse duration, and provides the first interruption after 387 reiterations.[2] Later in the movement (mm.78-81), when the original theme and its inversion are presented simultaneously, each is slightly modified rhythmically, presumeably in order to maintain an overt eighth-note sub-pulse.

In the second movement, the eighth note is again maintained throughout long passages; the interruptions coincide with structural highlights. In two of these instances (mm.186 and 298), the points of rest are literal references to the opening theme of the movement, occurring as the specific rests which form a critical part of the opening gesture [Ex.5.6]. At the initial (and prevailing) tempo of ♩=138-144, the eighth's short duration ($_{ca}$ 0.2") is conducive to extreme flexibility; Bartok uses this to great advantage in the many passages where melodic material is fragmented and overlapped into increasingly short segments. As well as emphasizing dissonance at a higher level, the overt sounding of the sub-pulse gives energy and continuity to these sections.

The continuous sounding of the eighth note is a result of careful design, as it is often the composite rhythm of several layers which produces a steady pulse. (See for

instance Ex. 5.7.) In other passages, the larger periods by which the eighth notes are grouped frequently shift from the basic 2/4 and 2-bar period to 3/8, 5/8, and changing lengths. In these situations the eighth note provides a stable foundation on which other more irregular rhythms may be constructed. An interesting example is the passage beginning in m.242, where the constant pulse provides continuity and momentum for the seemingly erratic arrangement of scalar fragments of varying lengths [Ex. 6.1]. Gradually another level of periodicity makes itself felt, as a rhythmic pattern of nine eighths' duration is repeated and formed into a melody where further levels of periodicity become manifest. When in m.284 there is at last a change in that pattern, a new section is signalled.

In the first and last sections of Movement III, a much slower pulse has a more subtle effect in balancing a freer rhythmic design. Despite an apparent absence of rhythmic regularity emphasized through a marked contrast of sustained notes with very short durations, there is a strong slow pulse presented in the melody. The movement begins in an unmetered way with a notated accelerando / ritardando figure on the xylophone.[3] The subsequent introduction of ornate embellishment figures is likely to focus attention on the level of very quick

durations. However, in the first eight bars of the melody (mm.6-13), the half-note period (ca. 3") is constantly articulated and, in all but two cases, accented as well [Ex. 5.8]. As there are no intermediating subdivisions to relate these durations to the half-note period, the regularity of a three-second period may well remain only vaguely sensed. Three articulations of that period require 9", stretching the limits of the boundaries of our perceptual present. Given the very long period involved, these half-note periods are in fact comparable to the level of super-pulse. However, as the half-note pulse is periodic, it provides a subtle stability which can enhance the listener's receptiveness to the ephemeral nature of the music. This is in contrast to an unmetered passage where a total lack of predictability could create unease. The regularity becomes more perceptible with the entrance of the second voice as the composite rhythm articulates the quarter-note period (ca.1.5"). Several subsequent sections of the movement also maintain slow articulated periods, although they are more frequently subdivided. The second section beginning at m.20, for example, clearly establishes a half-note period of ca. 2.14" with which the melody is easily parsed. The next theme at mm.35-44 presents a slow period of approximately 2.7" while the background texture articulates a period of the half note (ca. 1.8")

[Ex. 7.2]. As the level of consonance is that of the very long bar period at ca. 5.4", the listener is more likely to track the melody through its subdivisions, and hear the background grouping (if at all) as presenting a 2:3 dissonance.

The technique of sustaining a basic pulse throughout long sections is manifest in a different way in Bartok's fourth movement. Eighth-note sub-pulses are usually present as results of composite rhythms between the first theme and its various accompaniments. However, the more consistent basis is that of the half-note period, which is more likely to be felt as the basic pulse due to the relatively fast tempi. Although tempo fluctuations cause the period to vary, it remains between ca. 0.46" and ca. 0.54" for most of the movement.[4] The half-note is articulated throughout the entire movement with the exception of two adjacent passages, and three additional beats.[5] This usage is a more subtle variant of the technique of a pulse continuum, because the periodicity is removed from the foreground by one level at least. In the first and second movements, the eighth-note sub-pulse was also usually the shortest duration. In the final movement, however, most of the durations are shorter than the half-note, so there is considerable differentiation on the foreground level. Nonetheless, the continuous

sounding of the half-note pulse is crucial in sustaining the momentum.

The passage at mm.204-234 presents the fugal theme from Movement I. Initially, the passage differs from its original presentation by the **absence** of a constantly-sounding eighth-note. The rhythmic consonance of the passage emphasizes the irregular groupings and phrase lengths which characterize the theme. Beginning with the upbeat to m.215, a more complex section begins with typical canonic treatment. From this point to m.231, the eighth-note sub-pulse is articulated by the composite rhythm of the material, producing a period of ca. 0.4".

Concerto for Orchestra

The additive structure of many of the themes in Lutoslawki's work suggests that pulse might figure prominently in his work as well. However, one characteristic of several themes of his work is a contrast between very short and very long durations, and in such contexts an audible pulse could interfere with the effect of the sustained notes. In cases where a pulse is incorporated into a theme, the existence of another layer which is dissonant on several hierarchical levels often obscures the original pulse. Therefore, although pulse may

help delineate the separation of layers, it is not perceived directly as a structural component.

The work does open, however, with an overt pulse. It is present throughout the "A" sections of the ABA form of the first movement. The pulse is articulated in the form of a drone on F♯, and is reiterated for over one minute every 0.75" [**Ex. 5.11a**]. Its cessation signals the end of the first section, and its re-entry confirms the return of the opening material in m.125. This pulse provides a stabilizer for the irregular length of the theme's phrases. It provides a periodicity which is consonant with most of the various modules [**Ex. 6.11**]. The few instances of dissonance between theme and pulse are of the foreground variety in the nature of syncopation and displaced accent. A sparse pattern in the brass which seems unrelated to the main theme is also consonant with the dotted quarter. The pulse therefore presents the only link between those two layers.

When the pulse stops two bars before the "B" section of that movement, it may well sound in the listener's mind through the sixteenth-note motion and even into the first bar of the new theme [**Ex. 5.11b**]. However, irregular groupings of eighth notes in the next bar [**Ex. 4.4a**] interfere with the mental sustaining of the pulse. When

the dotted quarter next appears (mm.52-56), its duple grouping is new and thus does not immediately suggest a recurrence; a subsequent pattern in the brass composed of lengthening durations obliterates any remaining feeling of pulse. The dotted quarter period reappears only subtly in a complex texture at m.64 as the level of consonance of two patterns which are dissonant at lower levels. Section "B" continues in this style throughout: many figures remain aligned with a dotted quarter pulse but groupings resulting from accents, contours, and repeating patterns work against its audibility. Only with the reintroduction of the "drone" in m.125 is the pulse firmly reinstated as a structural unit.

Throughout much of the Capriccio of Movement II and the return of that material at the end of the movement, there is a pulse of a quick quarter note at ca. 0.35". This is complemented in the majority of the section by a super-pulse of a dotted half note (ca. 1.0"). The prominence of the quarter-note pulse recedes in the middle section, due to latent and overt conflicting groupings. A dissonant dotted quarter pulse appears first as a latent grouping in m.200, and then becomes overt with the prominent entry of the third theme in m.208. Later, a five-eighths pattern occurs simultaneously with the quarter-note grouping. In addition, the occasional

introduction of a half-note period, though consonant with the quarter, strongly disturbs the established super-pulse, and therefore threatens the general metric stability. The quarter note is absorbed into the dotted half pulse of the Arioso section, which provides the common denominator of the two dissonant strata. The quarter itself is articulated by horns and trombones. However, increasing use of the dotted quarter in other layers creates a dissonance which emphasizes the dotted half as the level of consonance. A return to the Capriccio section reinstates the quarter pulse.

Although there are components in the various strata of the Passacaglia which can be considered as creating a pulse level, it is often difficult to determine which level would be interpreted as a pulse by the listener, due to the shifting of attention from one level to another. The ground itself incorporates two bars divided by two and six bars divided by three, so the period of the bar itself (ca. 2.6") may be sensed as a slow pulse throughout, if one maintains the ground as reference [**Ex. 6.9a**].

This period is reinforced in later treatments of the passacaglia theme. At m.570 ((62)), the half-note (ca. 0.56") becomes the pulse, and the 4 eighth-note figures which define the half-note period each represent

one bar's worth of the ground [**Ex. 6.9b**]. Later, at m.852, the pulse, this time a dotted quarter (ca. 0.44") again represents one bar's worth of the original [**Ex. 6.9d**]. However, the next variation, at m.876, owes much of its apparent lopsidedness to the fact that the rhythmic patterns no longer correspond to the original presentation [**Ex. 6.9e**]. Every second occurrence of a note which was originally on a downbeat is now clearly in an upbeat position as the third note of a triplet. The period is again that of the half-note, this time at the rate of ca. 0.52". The same period is maintained at m.903 ((97)), but the rhythm is neutralized by the regularity of the subdivision and the compression of two bars' worth of the ground's pitches into one half-note period. This means that although none of the original downbeats are in upbeat positions, alternate ones are on weak beats. The first variation returns at m.953 for one final statement at the breakneck speed of half-note pulse at ca. 0.38".

Chamber Concerto

In the third movement of Ligeti's work, there are several passages where various pulses coexist. In mm.42-58, the rates of periodicities seem particularly favourable to tracking the pulse of one of the slower instruments, and hearing the others in relation to it

[Ex. 4.14]. The length of the passage itself, and the absence of other more prominent material, provides the listener with the opportunity to choose which pulse to track, and then to change from one to another at will. Of course, it is also possible to avoid focussing on any one instrument and follow the composite texture instead.

In the rest of Ligeti's work, pulse does not figure very prominently, though it does arise in some passages as the first level of alignment of foreground dissonance. In most of these passages, the resultant pulse does not continue for more than a few seconds, and does not link with other coexisting layers or adjacent passages. Therefore pulse does not have a significant function except as a component of that particular textural fragment. However, a similar passage in the fourth movement differs from the others by its extensive duration (almost an entire minute), and by its lack of distractors. The passage consists of an increasing number of instruments playing a variety of subdivisions of the beat. The material which does not belong to that layer consists mainly of sustained notes which do not clash significantly. However, the pulse is still not very strong, mainly because the contours of the various component parts form patterns which do not coincide with the beat. As these contours become more jagged (mm.42-

50), and when the patterns become more regular (mm.46,49), the sense of pulse becomes obliterated [**Ex. 8.4**].

In ambiguous cases, interpretation can weight the perceptual effect. In Bartok's work, for instance, the main theme of the fourth movement [**Ex. 6.5**] could have the half-note pulse emphasized by the performer, but this would highlight the irregularities of the theme and might therefore best be reserved for sophisticated audiences for whom the work is familiar and a new angle welcome. Otherwise, the emphasis on the bar period can help unify the structure, since those periods emphasize the alignment of theme and accompaniment. In simple textures, periodicities are usually quite easy to notice and emphasis can make them too blatant. In complex textures, however, stressing the periodic elements especially at the pulse and bar level can help the listener organize the variety of data.

CONCLUSIONS

It seems likely that the continuity of the sub-pulse throughout long passages in Bartok's work is responsible for the fluidity of movement, and at time for the relentless quality of the work. It provides a stability that might otherwise have been lacking, due to the metric

irregularities throughout. Such a lack could easily weaken the entire work. The relatively fast rate of the sub-pulse allows it to work on a level just below consciousness, as the slower level of the pulse is usually more noticeable. The main pulse in Bartok's work often varies between two to three sub-pulses in length, and the groupings of the pulse are likewise often irregular, so that the tedium of a constant period is avoided. The effect of an overt pulse is heard in the first movement of Lutoslawski's work. Tedium is avoided here by the irregularity of the more prominent phrases of the theme, and the insertion of a contrasting section. Some modern works have less use for pulse as a major structural force, especially in passages with high degrees of rhythmic dissonance. Ligeti's work has audible pulses in various places in the third movement, but the presence of several dissonant rates usually precludes any one of them from being the dominant pulse. In other parts of his work, the absence of pulse suggests that the concept is antithetic to the type of textural manipulation employed. Where pulse is present, a contrast in pulse from one section to another is a typical way of establishing sectional boundaries.

C H A P T E R I X

L A R G E - S C A L E S T R U C T U R E

After a careful study of the periodicities of the three works examined, it seems clear that the formal structure emerges most from the degree of contrast both within and between passages. The rôles of periodicity in the large-scale structure of the three works are chiefly manifest at the foreground. This bears out observations by Clarke, who suggests:

> In tonal/metric music, formal boundaries are conveyed by means of relatively abstract musical properties (e.g. cadence, key change, melodic repetition). In contemporary music motivic repetition may function in the same way, but the absence of a generally shared set of compositional procedures indicates that rather more immediate parametric changes (e.g. changes in register, pitch, density, timbre, rate of activity) are probably decisive in establishing large-scale boundaries.[1]

A main factor in delineation of structure was traditionally provided by the appearance or reappearance of a theme. Even in contemporary works, the appearance of a familiar theme or gesture remains a very strong indicator of structure. As discussed in Chapter VI, periodicity often has a fundamental rôle in promoting our recognition of a theme. When a pitch/rhythm configuration is recognized as a distinct identity, it will emerge

quickly from any surrounding material.[2] In most cases, a theme will begin at its beginning, and thus imply initiation of a new section.[3]

Structure can be well-delineated by means of very audible boundaries, or it can emerge from a more fluid metamorphosis from one section to another. Audible boundaries can be immediate or stretch over a short period of time. An immediately perceptible boundary is likely to incorporate a sudden change in periodic structure or other parameters. A different sense can arise from an anticipated boundary, where tension is decreased gradually towards the boundary and gradually increased again into a new section. This is a more traditional approach, and is compatible with the perception of hierarchically-ordered period structure. However, there are many signals for a decrease in tension which are not dependent on hierarchical metric organization. Rhythmic factors include a decrease in temporal density, a resolution of rhythmic dissonance, and a lessening of contrasts.

Music for Strings, Percussion and Celesta

The contrast between the first two movements of Bartok's work extends to the overall structure and degree of change in each one. The first movement has very few

divisions. The climax of m.56 and its pre-climactic point in m.52 have already been mentioned as the culmination of the movement. M.56 exhibits the first rhythmic and pitch unison since the entry of the second voice. After the climax, there is a noticeable ebb of tension created by a reduction in the number of voices, the volume, and the rate of attacks. This leads to a complete, though very brief, pause in the sound (m.64) before a sparse quasi-canonic section. The tension builds up again as the rhythmic dissonance increases. In m.78, a specific point of contrast is created by the entry of the celesta. This point exhibits extreme contrast in foreground density on the textural/ornamental level. The movement ends traditionally by a reduction (approaching the lowest level) in the number of voices, the degree of rhythmic dissonance, the density, the register, and the volume.

The second movement exhibits a completely different scale by presenting many contrasting segments which create many boundaries. Some sections in the second movement are separated by silences, as in the bars preceding the theme at m.69. Even a brief silence, such as that of ca. 0.43" at m.170, seems sufficient to cause a demarcation, due partly to the constancy of the pulse throughout long sections (see Chapter VIII). In three cases, the silences are an integral part of a reference to the first theme,

and thus provide a subtle reinforcement to thematic recognition (see **Ex. 5.6**). In some cases, a change in tempo accompanies the pause; the pause of m.372 is preceded by an allargando; that of m.448 is accompanied by an accelerando.

Rhythmic consonance figures prominently in the delineation of structure in the second movement. A frequent technique involves canonic treatment of a phrase or fragment with an increase in density until a sudden break, or a resolution to rhythmic unison, indicates a boundary (see for instance **Ex. 5.5**). The following section typically begins with rhythmic consonance, often with hierarchical ordering to a greater depth than the preceding passage. The more well-defined a theme, the more its subtleties of hierarchical grouping can be appreciated. The familiarity of the theme contributes redundancy, and certain grouping tendencies will already be established by prior associations.

Several structural boundaries in the movement rely on a change in density on the sub-pulse level. M.110 [**Ex. 5.5**] introduces sixteenth-note movement which contrasts with the preceding eighth-note movement, and the grouping level shifts from three eighths to four, defined by the canonic entries of the sixteenth-note figures.

These figures become texture, and a thematic fragment enters in m.114, accompanied by a tempo reduction. At m.448 there is again contrast on the sub-pulse level by a doubling of note attacks, underlined by the addition of short snare drum rolls. The sections in the latter part of the second movement are quite short, thus contributing to a large-scale rate of activity through contrast. The final eight bars of the movement are preceded by fourteen bars of steady sixteenth-note movement ending with a brief rest (ca. 0.39"). By contrast, the final bars move in longer durations of quarter notes, incorporating two very brief pauses (ca. 0.18"), and a poco allargando. In combination with the pitch/rhythm consonance of both string groups, this gives a brief but still audible reduction of activity suitable to ending a movement.

Bartok's third movement uses aperiodic episodes to help delineate structure. Initially, these are provided by brief dialogues between timpani and xylophone. The middle section, however, disturbs the periodicity by presenting a succession of conflicting grouping patterns [Ex. 5.9]. The entire movement provides large-scale contrast to the second and fourth movements by its very slow pulse, extremes of duration, and presence of "free" rhythms.

The fourth movement of Bartok's work is quite relentless in pace, and makes less use of silence and tempo reductions to delineate different sections. A strong super-pulse often allows for a smooth change from one pitch pattern to another without creating a rhythmic boundary, so that change is achieved without pause (as in **Ex. 5.10**). A regularity of phrase structure leads to expectations of repetition or change at the end of four- or eight-bar phrases which are sometimes fulfilled by a mere change in orchestration [**Ex. 6.5**], sometimes by a change in periodic structure [**Ex. 6.7**], and sometimes by a more dramatic interruption and change [**Ex. 6.8**].

The fourth movement also uses consonance and dissonance to provide contrast. The section beginning at m.136, for example, is strikingly consonant after the preceding canonic passage; all instruments articulate the half-bar period and most articulate the quarter as well [**Ex. 9.1**]. The phrase is clearly grouped into three-bar phrases, which are repeated five times before the entrance of the dissonant piano theme discussed in Chapter VIII. The steady metric organization of that pattern is retained throughout most of the ensuing passage, until it is abandoned in m.180 as though swallowed in the mounting speed. The piano and xylophone continue alone until the strings pick up the same phrase and toss it back and forth

between groups in a presto strepitoso section where the half-note pulse and grouping regularities disappear. The insertion of rests, repeated phrase segments, and sustained notes finally reduce the tension in preparation for the unison presentation of the fugal theme from the first movement.

The contrast between the preceding section and the presentation of the fugal theme at m.20 is quite dramatic. The density of note attacks drops from 14 per second (durations of ca. 0.07") to less than 5 (durations of ca. 0.21"). More noticeably, the melodic movement changes from durations of ca. 0.14" to ca. 0.42". Both of these changes are in a ratio of approximately 3:1. The change is so significant that, in combination with the familiarity of the theme, registral and timbral contrast are unnecessary to create the delineation.

Mm.230-234 can be viewed as a type of "boundary passage", acting as a delineator between two longer sections, much as fugal references demarcate the various sections of the third movement . It therefore seems appropriate that this short episode, which interrupts a statement of the fugal theme, is itself reminiscent of the opening to the third movement. It exhibits a wide internal contrast in durations, from sustained (trilled)

dotted half notes to sixty-fourths, and this range of durations is in marked contrast to the preceding and following sections, which are much more regular. Two other interruptions provide parallel moments of contrast towards the end of the movement. The first is a brief Calmo section, contrasted by temporal density, timbre, and register; it lasts for four bars and includes a molto rallentando. The second is a similar type of interruption, though it lasts for only three half-notes and is contrasted only by a very marked slowing of tempo.

The delineation between movements in Bartok is very marked. The first movement has few divisions, almost no regular metric sense, relatively little contrast in grouping lengths, and generally a slow rate of change in any parameter. It closes with a reduction in activity approaching zero: the work ends on a very soft sustained unison, and implies the need for a short silence before the activity of the second movement begins. The second movement starts with a much faster tempo, a periodic hierarchical organization, and continues throughout with quick alternation of contrasting sections. There are several distinct themes, as opposed to the one theme of the first movement. The movement concludes on a high dynamic level with a relatively dense texture (chromatic movement in sixteenth notes) and only a very slight

reduction in activity. The third movement incorporates sections of almost imperceptible periodicity and freer rhythmic structures. A high degree of contrast in density of texture and in durations encourages a changing parametric focus[4] which compensates for the lack of forward direction. The static quality of its arch form contributes to the anti-teleological character. The fourth movement starts with a very high density of texture and proceeds to hierarchically-organized phrase structure, contrasting with the unmeasured rhythms of the preceding movement. The fourth movement has relatively little contrast of notated durations -- almost all activity is in eighths · quarters -- but there are tempo changes throughout. These changes are minor at first, becoming extreme and more contrasted towards the end. There is little pause in activity, with contrast being provided more by changes in grouping structures. The degrees of rhythmic consonance and dissonance are more extreme in this movement than in any of the others, and those extremes are emphasized by their proximity.[5] The number of independent voices or layers in any given passage fluctuates considerably.

Given the substantial differences in the pacing of each movement in Bartok's work, it seems surprising to discover that the movements are all of similar length. By

Bartok's figures at the end of the work (probably taken from a performance) the durations of the various movements are 6'30", 6'55", 6'35", and 5'40". Howat calculates that Bartok's metronome markings allow for a +/-5% deviation. Certainly the discrepancies between the durations calculated by the metronome markings and between the noted final timings are indicative of this. Therefore, it is not completely artificial to accept a timing of 5% more for the fourth movement and 5% less for the second. That would produce durations of 6'30", 6'34", 6'35" and 5'57". This pushes the first three movements within a 5" range, or less than 1.5%. According to studies with the Weber fraction, however, it is calculated that accuracy in determining long durations may well exceed 10%.[6] Adding ten percent to our "adjusted" timing for the fourth movement produces a timing of 6'33". In other words, it is reasonable to expect that all four movements could be perceived as being of equal length. The fact that they do not encourage such a perception seems conclusive evidence that the sense of experienced duration depends on the nature of the material which fills that duration.

Concerto for Orchestra

Lutoslawski's work does not exhibit such a marked contrast between movements, but it does show a variety of

techniques for creating structural boundaries. Broadly speaking, the first movement is the most clearly and broadly segmented, while the third has more variety of section lengths and ways of demarcating them. The work incorporates many themes and fragments which are readily identifiable, and therefore the appearance or reappearance of any of these can serve to signal the beginning of another section. Lutoslawski also makes extensive use of contrast in the other parameters of texture, timbre, temporal density, register and dynamics. Pitch structure is less contrasted than most other parameters, and could be thought of as a unifying force. This is visible not only in the predominant use of the passacaglia theme throughout the third movement, but also in the transformation of the second theme from Movement I into a new theme in Movement III [**Ex. 9.2**], and in the close relationship between contours in fragments from many of the themes.[7]

The first movement of the Concerto for Orchestra is in a clear ABA form. The A sections are fugal and are therefore undivided, except by the various entries of voices. A figure in the horns is periodic, but dissonant with the other strata; this dissonance is not acute due to the short duration of the figure itself and the length of the intervening rests. The drone pulse provides

continuity throughout. The two-bar boundary between the main sections A and B [**Ex. 5.11b**] is clearly delineated through a logarithmic increase in note density, combined with an increase of dynamics, followed by a brief silence of ca. 0.50". The change is heightened by the absence of the strings timbre and pulse reiteration during those bars.

The B sections are much more complex, and consist of several subsections of three basic types in the general form **abcabca**. The "a" sections consist of a melodic theme accompanied by textures, described in Chapter IV. The first two statements of this texture are roughly the same duration (ca. 27" and 25"), whereas the third statement is twice as long (ca. 54"). The intervening material corresponds exactly to these durations: it lasts for ca. 27" the first time and ca. 56" the second time. However, like the proportions in the Bartok, the listener is more likely to be aware of the differences which fill those durations than of their equivalence. Contrast between the subsections of B involves density of note attacks, change of period lengths, and levels of rhythmic dissonance. In addition, the repetition of entire subsections creates expectations of parallel structuring and therefore allows the listener to anticipate boundaries.

Movement II is in several sections, and has a basic AABA form. Both sections involve multiple layers, but the "A" sections are much more segmented, while the "B" section is unified by the presence of a slow melodic theme. The "A" sections involve repetition of elements on a wide range of levels, from the quarter note to large sections. A high degree of irregularity of grouping structure is balanced by a nearly-constant articulation of a bar period (ca. 1.0") and by nearly exact repetition at immediate or later points in the movement. Each "A" consists of the subsections **abcdeb** which are scarcely altered on their reappearances.

The main periodic aspect which delineates section "**a**" from the preceding movement and following sub-section is the very fast durations which operate in isolation to convey the theme. Sub-sections "**b**","**c**","**d**", and "**e**" are differentiated rhythmically mainly by grouping structure, which becomes increasingly more complex [**Ex. 8.2**]. The "**d**" and "**e**" sub-sections each contain dissonant layers. Those of "**d**" align on the two-bar level, while those of "**e**" are more dissonant but exhibit some alignment at the period of ten eighths. A final statement of the "**b**" sub-section is extended by fragments and rests into an increasingly sparse texture which disturbs the sense of pulse and culminates in silence of about 1" before converging

sixteenth lines return us to the "a subsection once more.

Apart from a quasi-canonic addition to the "a" sub-section, and a five-bar extension to "d", the repetition of the entire section is scarcely changed except for orchestration. The complicated juxtaposition of periodicities and irregular groupings helps maintain the vitality through the repetition, while conversely the repetition helps the listener grasp the more subtle relationships between the various rhythmic structures.

As sub-section "b" exhibits the clearest articulation of the dotted-half super-pulse, it is appropriate that it precedes the middle section (B) of the movement. As discussed in Chapter VIII, the period of the dotted half is the common denominator of the two strata at the opening of that section. Therefore, the contrast between sections **A** and **B** exists not on the level of the super-pulse, but rather on the grouping levels and through the contrast in durations. The melody at **B** incorporates sustained notes and phrase lengths considerably longer than those of **A**, so a sense of tempo reduction is very strong. This provides further contrast when the **A** section reappears with its sixteenth-note movement. The final "b" sub-section of the movement has extra bars inserted between the bar-length fragments. These frame an unusual pianissimo percussion

passage formed out of increasingly short timbral palindromes in quarter notes. The inserted bars effectively slow the motion, as is appropriate to the end of a movement.

The beginning of the passacaglia is not very contrasted with the end of the previous movement, as the register and dynamics are the same. The fact that the last note of the second movement and the first note of the third are both double bass pizzicato indicates that this lack of contrast is quite deliberate. The boundary between the two movements is therefore created by the lack of tension; the passacaglia theme remains very low in density for the first eight bars. The passacaglia, discussed in Chapter VIII, clearly manifests a high degree of activity on both large and small scales. It ends on a very low level of activity, both in temporal density and in dynamics.

The remainder of the third movement is very active, with many different layers and juxtapositions. There are many silences which do not function as structural boundaries but rather as interruptions, thus adding tension to the passage. These interruptions correspond to "gaps" mentioned by Lerdahl & Jackendoff and Benjamin,[8] in which the internal measuring of duration stops, and is

restarted only on hearing the next sound. The opening of the section following the passacaglia is an introduction to this technique. An opening gesture is repeated three times with intervening gaps of silence before the theme begins. This technique accumulates significant amounts of potential energy to be released with the downbeat of m.570. The reasonably fast rate of periodicity in the gestures accentuates the gaps; the rate of note attacks combined with the registral distance traversed imply a certain degree of energy, and thus imply the strength of the opposing force which is capable of stopping the forward motion. A comment by the composer about a different work (Mi-parti) seems equally appropriate here:

> the way it is repeated three times, seems in tune with the psychological flow of the form. One needs to draw a deep breath before tackling a piece which is played without a break over quite a long stretch of time; the beginning is repeated three times for the piece to gather momentum. This device of not quite reaching the climax is often used in compositions which need 'deep breath'. It's easier to remember and absorb something new if this something is repeated from the beginning. It's a classical trick.[9]

Four layers are present in the first section: the first variation of the passacaglia theme, a quarter-note quasi-ostinato, the eighth-note figure from the opening, and irregularly-spaced chords. These are all consonant at the levels of quarter and half notes, but dissonant at higher levels due to irregular groupings. Both the

ostinato and the passacaglia variation tend to be grouped either by two or three halves, delineated by pattern repetition. The other two layers are more irregular. As the figure from the opening has an anacrusis character, it conveys anticipation of a downbeat. The chords are more jarring, as they present equivalent accents, but without warning. After about 45", most of the motion is interrupted by a three-bar palindromic texture [**Ex.4.3**]. It serves to focus the listener's attention for the upcoming change, although one bar of the former passage intervenes before that change takes place. A brief rest is the first since the gaps of the opening, and in this case does serve as an indicator of a boundary. The new section is contrasted initially by a complete change in duration to unaccompanied half-notes. At the downbeat, a well-defined textural passage begins as accompaniment to the theme. The texture [**Ex.4.2a**] moves in eighths and quarters, whereas the theme moves mainly in long durations. However, the inner consonance of the texture and the lack of similarity between periods seems to soften the sense of dissonance, despite a clear stratification, and so this section provides a strong contrast to the preceding one.

The same theme and accompaniment appear again at m.659 (about one minute later). After the first statement, there

is a type of bridge passage which establishes grouping periods anticipating those of the subsequent passage. The melody is repeated four times with an extension on the fourth bar. Apart from a possible sense of indirect dissonance provided by the alternation of meters, there is no dissonance in this passage. The remaining part of the passage is much more developmental, and involves layering. First this is confined to fragments of the preceding theme, but in m.646 a very audible descending line appears in half notes in the brass. The periodic quality and rate of presentation (ca. 0.5") contribute significantly to the audibility of the line.

The second presentation of theme and texture leads to the chorale theme. The texture grows sparser until, in m.675, the patterns cease and the pulse is maintained by the flutes (eighth and quarter) and trumpets (half note). The melodic line has reached its final notes and is heard only in the violins. After two bars, half notes are periodically substituted for the eighth-note movement in the flutes; after two more bars all eighths and quarters disappear, leaving only repeating halves. This procedure effectively slows the pulse from eighth to half, in preparation for the first appearance of the chorale theme.

The chorale is presented in counterpoint with another

faster-moving lyrical theme, which is accompanied by increasingly complex textures [Ex. 4.5]. Due to a highly redundant phrase structure in each of the two themes, and a fixed relationship between the two, the dissonances between them seem quite mild. They consist mainly of textural surface dissonances, canonic imitation of the secondary theme, and an internal irregularity in the phrase structure of the chorale theme itself. The chorale section lasts for over one and a half minutes in its first statement; the entire phrase is repeated three times, with the hemiola of the last phrase extended farther each time, accompanied by texture. It appears again towards the end of the work (at m.922), but is stated only once at that point. In that final statement, the extension is not as substantial as before, but the main theme itself is accompanied by much more intricate textures in place of the secondary theme.

The rest of the movement is characterized by previously-heard material in various developmental treatments, with various degrees of dissonance and various densities of note attacks. A reduction of tension precedes a change of texture in m.903. This texture begins with a slow quasi-canonic passage in a low register and gradually over half a minute and through a variety of textural devices grows to a shrill tremolo in woodwinds

and strings. The tremolo chord coincides with the final reference to the chorale theme. Finally, an abrupt change is caused by the return of an ostinato figure at Presto, with irregular punctuation by the opening gesture figure. This is followed by a sudden and dramatic change of durations, from ca. 0.09" to ca. 1.3", for a few seconds, before a final rush in short durations to the finish.

Chamber Concerto

Ligeti's work exhibits more fluidity of structural form than the other two works studied. In some ways, many passages in his work bear a closer formal relation to the first movement of Bartók's than to any other, due to the absence of strong structural boundaries and the control of form through a gradual increase and decrease of tension in various parameters. However, there are also instances in his work of very stark boundaries. The overall shape of each movement exhibits contrast on several levels. The first movement begins with an extremely restricted registral range: all instruments play in the same mid-range cluster. There is a slightly wider range of contrast in durations, and the durational values are medium. A similar image is produced by a longer temporal focus: the overall degree of contrast for the first minute is medium, with several little increases in activity

mirrored by fewer, greater increases. For example, a burst of activity occurs at A, as the strings enter with a much wider range of durations and articulation; this disappears quickly and a balance is "restored" by a reduction in degree of contrast for the next several seconds. Similarly, the melodic fragment played by the horn presents a very marked contrast in duration, and leads into a section of marked contrast in the opposite direction, with very short durations in the woodwinds. With the initiation of the "canonic" entry pairs, the durational contrast is again sharply reduced, but this is balanced by the high rate of activity.

The range of large-scale contrast gradually increases, and the degree of cohesion between components of each layer seems to increase. The strings layer becomes very loud and immediately very soft, before turning into unison trills. The tension accumulating from the restrictions of the narrow registral band is thus further increased, and the listener's attention is focussed in anticipation. Suddenly in m.38, all instruments play an Eb in a six-octave spread. In retrospect, it seems an obvious solution to the build-up of energy, but it is still rather startling, and certainly dramatic. The sonority clearly announces a change, as it would be difficult to conceive of a return after such a gesture. The tension is built up

again slightly, by sheer refusal of the sonority to disappear over a 45" period, although the texture is enriched by a few added tones. A brief multi-strata passage follows, before the texture reduces again to a single strand. This time the layer is composed of a rumbling in a very low registral band, as restricted as that of the opening but with a different effect, due both to the muddiness of the register itself and to the fast periodic rates and heterophony employed. The movement ends with a texture which is comprised of four lines exhibiting considerable foreground dissonance.

The second movement begins with contrast in activity, in the form of another sustained sonority. This is not as stark as the open octaves of the first movement, and changes more quickly. Soon another, more complex, texture emerges, involving all instruments for over a minute's duration. It is characterized by a greater degree of contrast in durational values; although it is still confined to a medium span of durations, the fluctuations between the extremes are much faster than in the first movement. The texture ends conventionally with a reduction in density, until only a few instruments are playing sustained notes. A change in pitches and dynamics leads to expectations of a new section. The contrast is startling by repeating a gesture from the first movement

in the form of another sustained sonority, though this time it is a tritone. The next texture begins as a leap from this sonority to a high cluster, and a rather strident passage begins which is characterized by rhythmic unison. The activity in this layer increases and decreases again. Accompanying the reduction in constant activity is a loosening of the registral band limits, and a sense of releasing tension is experienced as the pitches become more discernable by their separation. A bridge passage is formed by the sudden change in string durations to a fast but periodic rhythmic unison, leading to the final chord which closes the movement.

The third movement contrasts with the final sustained sonority of the previous movement by its fast reiteration of fixed pitches. As the entire movement is constructed of periodic reiterations at various rates, it could be said that there is little internal contrast of durations within any one strand in a short period of time. However, there is considerable variety in the specific rate of the various periods, the overall length of the various textures, in the overlap of those textures, and in the grouping durations produced by accents of group initiations, dynamics, and pitch changes. The similarity between the various textures in this movement provides contrast at the higher level with the other movements.

The sparse texture and notated silence which end the third movement add an emphasis to the active beginning of the fourth. The constant foreground dissonance of the previous movement is also contrasted, through a rhythmic unison of thirty-second notes in two clarinets. In retrospect, the relative lack of differentiation in some parameters of the third movement is a preparation for the extremes of contrast provided in the final one. The first minute of the movement is characterized by long warbling phrases in various pairs of instruments and at various rates, all relatively fast. A pause in this movement is provided by trills in harpsichord and piano alone, leading to a strange duet with bass clarinet playing very fast periodic durations with (five-) octave doubling on piccolo. This strand develops into a thicker texture, though without contrast of durational values. A horn/piccolo cadenza emerges from this texture at the same time as the pianist begins a frantic hammering. The cadenza is full of durational and pitch contrasts, and is quite easily distinguishable from the piano. However, it is outlasted by the piano, which plays for several seconds alone before stopping suddenly, to be replaced by the double bass's "feroce, impetuoso" line. The linear texture which began the movement is thus re-established, and although the contour becomes increasingly jagged, it

turns into arpeggio figures. In conjunction with the periodicity on the sub-pulse level, these figures contribute a static quality which balance the extremes of movement. As before, the lines become trills which reduce the activity and, being this time in a mid-range, help release the tension as the movement draws to a close. An extremely loud and feroce gesture in the woodwinds is answered by a very audible trombone glissando and a few almost inaudible oscillations on woodwinds and keyboards.

CONCLUSIONS

All three composers share certain techniques for delineating large-scale structure. All employ contrast, not only in different parameters and on different levels, but also in their compositional approaches. In other words, each composer treats similar situations in different ways at different points in his work. Within the three works, a wide variety of methods and techniques are employed. Contrast seems invariably balanced by similarity at another level. Activity in one parameter might be balanced by activity in another, or by a reduction in the level of activity. This type of design is compatible with the approach of composers who work with statistical fields. Ligeti was obviously familiar with this approach, but it is not restricted to composers who

avail themselves of such terminology, and can be understood simply as a formal articulation of a sound compositional approach. Although some composers work entirely on an "intuitive" level, the design of these particular works suggest a degree of cerebral effort combining with the innate talent each composer displays. A balance of contrast is maintained at many levels, and produces complex and intricate designs.

Most of the structural boundaries exhibited in these works involve aspects of rhythm. Many of them involve a periodicity at some level. Periodicity provides contrast with non-periodicity, as well as with periodicities of other rates, so it is a convenient resource. In addition, the existence of hierarchical structuring of periodicities creates a recognizable type of organization that is effectively contrasted with non-hierarchical order. The resolving or removing of rhythmic dissonance is also a frequent contributor to the establishing of boundaries: this is a notable characteristic of Bartok's second movement. Silence can figure as a delineator of structure, although in the last movement of Lutoslawski's work it functions as a tension-provoking interruption as well. In Bartok's work, the establishment of a sub-pulse over long durations clearly contributes to the strong effect of brief pauses in that motion.

All three works seem to be composed of much shorter segments of musical material than is typical of more traditional works. Many passages exhibit a substantial change of melodic material, texture or rhythm after only a few bars. It is striking that such forms can be sustained convincingly for twenty minutes or more. Hierarchical ordering often does not have much chance to be established. However, when it is established, it aids in clear identification of thematic structure. Subsequent presentations of thematic fragments are thus more easily recognized through their complex stress patterns. One result of the incorporation of such structures is a frequent shift in primary grouping levels. Depending on the total length of the phrase, the length of repeated modules, and the placement of accents, the salient grouping level may be on the level of the half-note in one passage, and on the level of the three-bar phrase in the next. The presence of such structures in all three works encourages a fluctuation in temporal and parametric focus. It seems likely that such a fluctuation contributes significantly to the attraction of these works.

Chapter X

CONCLUSIONS

My investigations have confirmed that much useful information about certain compositional structures can be gleaned from a study of the periodicities contained within them. However, such a study requires awareness of the perceptual boundaries which influence our reaction to periodic events. Our perception of durations seems most sensitive within a range which corresponds to the traditional levels of sub-pulse, pulse, and meter. Further analyses should be able to clarify and confirm some of the suggestions and proposals made herein.

My analyses reveal that much of our perception of large-scale form depends on very local aspects of rhythm. The listener seems particularly alert for periodicities on the level of pulse and super-pulse, as their presence can influence grouping and ease memory codification. A focus on foreground periodic structures can thus provide insight into how the listener is likely to interpret the music. Many of the factors involved with perception of patterns and periodic elements indicate that research being conducted in the realms of psychoacoustics and cognitive sciences is relevant to the analysis of complex musical

works. The three works studied suggest that the composers had a good grasp of the perceptual tendencies inherent in our modes of listening. The structures they created maximize those tendencies to produce vibrant compositions which exhibit clarity in passages of texture, multiple strata, and rhythmic consonance. They are also able to delineate sudden or gradual moves from such clarity to more opaque and dissonant structures, thereby pushing the perceptual processes to their limits while maintaining a balance between tension and relaxation on several levels.

The investigation confirmed that periodicities exhibit different characteristics and properties depending on their specific rate of recurrence as well as on their context. Therefore, it seems crucial to determine the correspondence between rate, context, and effect, and to understand those factors which may maximize or attenuate the correspondence. The involvement of memory in almost all understanding of musical structure explains the importance of grouping levels which can be at least partially grasped within the limits of the perceptual present. In fact, the most surprising realization that emerged from my analyses was the extent to which we rely on local configurations for our appreciation of large-scale form. Further investigation suggested that our perceptual tools are tuned to operate precisely within the

sphere of the perceptual present, and thus we are able to differentiate well between durations on the levels of the sub-pulse, pulse, and super-pulse. The level of the super-pulse represents a convenient length of time, as it is contained within the perceptual present and therefore allows "simultaneous" access to the various components. By being able to compare durations directly, simple relationships may be perceived which will encourage more efficient parsing. In addition, short musical patterns or motives (Tenney's "clangs") usually exceed the length of a pulse in duration, so the super-pulse seems an appropriate focus within which an entire clang might be perceived.

The analyses presented above indicate how much our reaction to periodicities changes with the rate of period involved. It seems clear that periodicities on a large scale are virtually indistinguishable from other forms of recurrence or repetition, and that therefore an isolation of their periodic aspect -- i.e. the clock-time intervals between recurrences -- would be misleading. Many who have been contemplating the issue[1] are now convinced that our perception of durations longer than a few seconds is greatly influenced by the nature of the material involved.[2]

It seems undeniable that we have a specific reaction

to lower-range periodicities of specific rates. I originally proposed a tripartite division into three layers: ornamental/textural (below ca. 0.10"), pulse and grouping level (between ca. 0.10" and ca. 10"), and higher levels (greater than ca. 10"). The ornamental/textural boundary proved a very accurate guide to function: many of the textures employed a top value of ca. 0.09". The middle range seems to be the level on which we are most conscious of regularity, and thus a further division into pulse, super-pulse, and higher grouping level can be useful. The suggested link of pulse with the motion of the limbs seems to fit very well, and explains the immediate appreciation and reaction to that range of periodic events. The super-pulse corresponds to the traditional level of metric organization, but is often present in non-metric contexts as well.

By naming this grouping level "the level of the super-pulse", we can discuss these rates of periodicity without involving metric issues. The many instances of three- or four-bar fragments in the works studied confirmed my suspicion that metric analysis would not be satisfactory for such works, and yet the importance of that particular level was increasingly clear. It is usually a grouping level, and as such may well involve a metrical function. However, irregular patterns often group on the level of

the super-pulse as well, and it is useful to discuss their grouping period without implying long-range or deeper hierarchical structuring. In addition, each layer of a multi-strata passage may have its own super-pulse, and frequently the bar-lines in such works are merely performance guides, irrelevant to the structure.

It therefore seems not only important but also feasible to distinguish between those elements which define a rate generally referred to as pulse, and those elements which define a slightly slower rate, usually that of a pulse-grouping level. The advantage of the term "super-pulse" is that it clearly incorporates the hierarchical relationship between pulse, sub-pulse, and super-pulse. It also avoids the necessity of having to stretch the range of pulse rates beyond that which I have already proposed as a reasonable limit: between 40 and 120 pulses per minute. My preliminary estimates of the range of the super-pulse would be 10 to 40 pulses per minute. Remembering the suggested correspondence between limb movement and pulse, it can be imagined that the super-pulse involves one complete cycle of a limb movement, such as the length of a pace measured from left foot through right and back to left again. In addition, Clarke's research indicates that the level of the bar or grouping is the only one at which the performer is likely to

maintain accuracy, strongly suggesting that we should recognize the significance of such a level.

My analyses revealed an astonishingly wide variety of type, degree, and method of contrast between any two successive or coexisting segments. By method, I refer to the way in which the contrast is introduced, including the temporal aspects. There is a marked difference between a gradual emergence of a new texture and a sudden shift. Memory becomes involved when more than a few seconds elapse between the full effect of two contrasting passages. Therefore, the specific configurations on the local level become crucial in interpreting such movement.

Confining the discussion to periodicities, contrast in the three works is either in the area of rate, density, or degree of consonance. Rate refers to the speed with which a level of periodicity moves; it is synonymous with duration when the passage is monophonic and <u>legato</u>. Density is the number of subdivisions of any particular level. Degree of consonance refers to the particular interaction of the various levels of events. The analyses suggest that there are quite different effects of dissonance depending on the levels involved. Contrast through tempo change benefits from a steady pulse which can be recognized for the change in its pace to be

noticeable. The presence of simultaneous multiple tempo shifts in the third movement of Ligeti's work relies on the incorporation of periodicities for its clarity.

Periodicities seem to figure prominently in the establishment of contrasts which help delineate structure and strata in these works. One of the more traditional ways of demarcating structural boundaries involves the projection of period structure and/or the reappearance of familiar themes. As discussed in Chapter VI, hierarchical ordering, or consonance of periodic elements on several levels, contributes to a firm establishment of a theme's identity. The constantly-changing periodic structures in Bartok's and Lutoslawski's work do not seem to inhibit such recognition of consonant structure. Often, a mere two pulses or downbeats are sufficient to expect a third in the appropriate place. On the other hand, in a context of rapidly shifting meters, the mind seems to abandon one interpretation of pulse very quickly when presented with conflicting evidence. One is led to conclude that the durability of a metric pattern is related to the length of time it has previously existed.

In many cases, our initial identification of large-scale musical structure is based on an intuitive grasp of change in tempo or temporal density between juxtaposed

passages. Dense textures can stimulate an even more immediate recognition than a well-defined, hierarchically-organized theme fragment. Interpreting durations under ca. 0.10" as fulfilling the function of texture or ornament is a very useful approach. The only place where there is a discrepancy is in the Capriccio of Lutoslawski's second movement (**Ex. 6.10**). As discussed, this passage seems to be the exception that proves the rule: it is an unusual effect and the reason for its oddity is precisely its rate of presentation.

I was very curious to examine the design of certain passages in the three works studied where I heard some particularly striking dissonances between layers. These include the entry of the piano in m.159 of Movement IV of the Bartok (**Ex. 7.6**), the relation of the two themes at m.311 in Movement II of Lutoslawski's work (**Ex. 7.7a,b**), and the relation of the various themes and fragments to the Passacaglia in the following movement of that same work (**Exs. 7.8, 7.9**). In the first two cases, which seemed to exhibit harsh dissonance, the conflicting phrases have only slightly different periods or, in the case of the Bartok, identical periods at a slightly different initiation period (Type B dissonance).

In the third movement of Lutoslawski's work, on the

other hand, where the dissonances feel milder, though equally striking, it is the incompatibility of the higher period structures (e.g. at the phrase level) which seems to be the crucial factor in causing a perceptual separation. Rhythmically-complex gestures which incorporate ambiguity or are otherwise difficult to interpret seem less likely to produce the same sense of dissonance as a gesture which has a recognizable relationship to a neat hierarchy and "misses" its proper placement by a small duration. This idea indicates that the degree of competition between two streams may increase in direct proportion to the increase of factors which suggest fusion. The mind is increasingly likely to match two similar streams, and therefore segregating factors such as asynchrony (starting at different times) become more critical, and prominent.

The investigation implies that the reaction produced by two layers that seem potentially alignable but which are out of alignment (therefore causing a type of suspense in anticipation of their alignment) is different from the reaction provoked by two layers that are completely independent, of different character, and therefore not provoking any such anticipation. Given the difference in effect, it would be useful to reserve the word dissonance for the former case, and employ another term (such as

"independent") for the latter. However, it is still too early to be able to determine strict rules of application. For now, the terms "mild" and "harsh" can suffice. As we gain a wider sample of dissonances, the increase in available information may allow us to gauge, and express, the degree of dissonance more precisely.

Layers which are perceived as being independent usually incorporate different sub-metrical characteristics through the distribution of durations and motivic rhythms. Therefore the "ornamental" rate of periodicity can be the crucial factor in delineating the structure if a metric structure is not present. To my hearing, all the distinctly multi-level passages in the three works studied differentiated their various component layers either by a contrast of metric schemes (or their starting points, as in the Bartok example), by a contrast of internal construction (ornamental and beat level) or a combination of the two. Passages in Ligeti's work which incorporate instrument pairings and octave doublings suggest that the idea of "internal coherence" which I propose as being crucial for the creation of a strong feeling of independence can be emphasized by instrumentation and register; other passages, however, illustrate that instrumentation and register alone are not enough in themselves to cause a separation.

It seems clear that the degree of rhythmic/metric coherence within a given gesture contributes to the forcefulness of the dissonance (independence). Phrases with well-established metrical and/or sub-metrical identities are more clearly distinguishable from each other and therefore present a more distinct interrelationship. Related to these observations is my conclusion that the point of initiation of phrases is extremely crucial to their perception: phrases that begin together tend to sound related even when they are differentiated (heterophony) whereas phrases that do not begin together, but share many characteristics, tend to be interpreted as representing separate layers, although they may gradually fuse in time. The first movement of Ligeti's work provides several examples of such non-alignment. Research into auditory streaming and fission supports the recognition of the strong segregation tendency of onset asynchrony. These conclusions suggest that there may be identifiable degrees of rhythmic dissonance in a way which parallels harmonic dissonances. Two phrases which are very similar seem to produce a more "grating" dissonance when not aligned than two rather different phrases.

Although three works is not a sufficient sampling to

be conclusive, it seems clear that the effect of dissonance is markedly different depending on the specific levels involved in producing that dissonance. The most common and traditional form of rhythmic dissonance is local, as when two layers producing a dissonance align at the level of the super-pulse. In another situation, the foreground levels are in alignment but the grouping periods are dissonant. A very different effect, more typical of contemporary music, is produced when two or more strata exhibit dissonance at all levels.

My research suggests that in general the ear/mind will tend to search for an ordering structure at the level of the pulse or super-pulse. Therefore, a preliminary rating of the mildness/harshness of dissonance indicates that dissonance at the sub-pulse with consonance at higher levels is the mildest form of dissonance. (Examples of this type can be seen at **Exs. 4.5, 5.13.**) The next mildest would be dissonance at the pulse level, with consonance at higher levels, as when a bar is simultaneously divided by two and by three pulses. This effect will become harsher at very slow tempi, as it effectively requires that the listener be able to track the super-pulse and hear the dissonant pulses as foreground patterning. A medium sense of dissonance may be manifest by two or more strata which are not aligned at any level. In such a case, the

listener can be reconciled to hearing each layer as independent, and therefore not search for an alignment point. Much harsher dissonances can result when two layers are aligned at the level of the pulse or super-pulse, but have dissonant groupings at higher levels. The most harsh of all types seem to be those which exhibit very similar or identical grouping periods, but which are not aligned. The Type B dissonance fits into such a category. Examples include the piano theme in Bartok's fourth movement [**Ex. 7.6**] and two fragments occurring with the Passacaglia in Lutoslawski's third movement [**Exs. 7.8k, 7.9**].

These results can be viewed and understood from the perspective of auditory streaming. Bregman suggests that the mind tries to segregate information into layers which seem to arise from the same source or which in some way belong together. In musical terms, a consonance at the level of the super-pulse strongly suggests that the material is similar and may belong to the same layer. However, any dissonance at a higher level contradicts this reading. Because of the prominence of the super-pulse level in establishing regularity (see Clarke's research) the rivalry between the two tendencies is extremely strong. When two layers are differentiated from pulse or sub-pulse level up, such rivalry does not exist. The two layers can easily be grasped as being separate, unless

other factors are involved, such as registral similarity.

A comparison of the three works provides a fascinating study of the array of devices and designs by which different musical strata can be formed. There are some substantial differences in the structures of the three pieces. In very general terms, it appears that Bartok relies most on the superposition or juxtaposition of motives and phrases with strong pulses and super-pulses, with dissonance frequently on the super-pulse level. He often repeats the same pitch contour but with different rhythms. He also makes use of repeated sub-pulses, and sequential repetition, with truncation to provide rhythmic variety. His work exhibits the most difference in structure between movements, but all three have examples of textural passages, melodic prominence, canonic sections, highly-contrasted sections, slow evolving of textures, dramatic moments, timbral shaping, etc. Lutoslawski often employs a modular approach, constructing passages through the repetition of patterns and introducing variation through low-information means such as the extension of a sustained note or the change in alignment between the patterns and another pulse. He creates unified layers of music, reinforces their identity with timbre, durations, etc., and then arranges the finished patterns and phrases of varying lengths,

densities, and character in a free design. Ligeti plays with a differentiation of pace through varying durations, reinforcing and sometimes contradicting these distinctions through timbre and pitch. His methods often restrict the possibilities for any one passage to a small range, so that all data coming in on a certain level will be drawn from a limited number of pitches and durations. The most striking difference in Ligeti's work is the absence of significant grouping organization and thematic structure. Rochberg has suggested that such lack of grouping may affect memorability. I think this observation may be true, but such an attribute may contribute to the freshness of the work on repeated listenings. It is difficult to remember exactly when certain events are going to happen.

It is theoretically conceivable that if we were to examine the effect of various densities and rates of movement on our perception of duration of short passages, then we might be able to discern the compression or elongation properties of a given passage and thus calculate their effect on our perception of duration. If that were so, periodicity could have more meaning in large-scale structure, because we would not be bound to clock-time measurements of durations. However, the number and variety of factors influencing temporal perception are

likely to preclude anything but vague estimates, as factors such as familiarity with the music change not only from listener to listener, but from repeated hearings by one person. Beyond that, it seems that we are likely to notice the passing of time mainly by contrast. It is the degree and pace of the changes in these areas which seems to affect our perception of time over anything but the shortest durations.

The perception of large-scale form seems to arise from a sensitivity to fluctuations, from expectations, from recognition of familiar themes, and from the awareness of change or contrast. The potential of periodicity for helping evoke these perceptions seems extremely strong. However, it does not seem to depend on long-term regularity. Instead, what we remember of longer durations seems most concerned with the type of activity which was occurring. Thus, we have a clear idea whether a certain pattern or texture or rate of activity has been existing for a long time or not. The precise measurement of that duration does not seem crucial. What really matters to the listener is whether the texture has lasted for too long, or not long enough, or quite a while -- in other words, the subjective value. Therefore, the idea that experienced duration is related to the amount of activity perceived may not need to disturb us. Our impression of

the longer durations is what will remain influential to our perception.

In general, a focus on periodic aspects appears to be a very useful perspective from which to examine musical works, especially those which resist more traditional methods of analysis. Several interesting tangents which appeared through this study suggest that the field is by no means exhausted. For example, a study of textures might incorporate the differentiation between types of textures constructed through the superpositioning of dissonant subdivisions of the pulse, and those which exhibit rhythmic unison on the level of sub-pulse or higher. Similarly, an examination of slight variations in vertical and horizontal periodicities (the concepts of "rhythmic clusters" and "microrhythmic fluctuation" presented in Ligeti's work) might uncover the limits of the range of periodicities which can produce such effects.

Certain properties of periodicities are clearly applicable to a wider range of durations in non-periodic contexts. For example, the perceptual threshold of 0.05"-0.10" will clearly hold for any pattern of durations. In other words, a more complicated series of durations which moves at an average rate of about 0.08" will be at least as difficult to perceive clearly as a periodic series of

the same rate. In fact, periodicity may serve to extend that threshold slightly. Therefore, it might be useful to extract relevant findings from this study and apply them to non-periodic elements. Then, one could begin to gauge to what extent the properties and characteristics are particular to precise periodicities. The application of some of these findings to non-periodic elements would benefit from more research on the accuracy with which we compare durations. Proposed ranges for the JND are vague and/or variable, especially with regard to longer periods such as the super-pulse and higher.

A related area which might benefit from investigation is the correspondence between periodicity and repetition or recurrence. Periodicity can be considered a subset of repetition, insofar as all periodicity requires the repetition of some element, whereas not all repetition involves periodicity. Therefore, a study of repetition could set out to discover those properties which are associated with periodicity but not exclusive to it.

Two more closely-related progressions from this study would be further investigation of the ranking of harshness of dissonance, and a cataloguing of the various means by which contrast can be achieved through periodic elements. The latter would benefit from a classification of

structures as periodic or aperiodic, multi-layered, hierarchically organized, homorhythmic, consonant, etc. In addition, the degree of contrast and the time required to move from one state to the next would both have significant influence.

Many aspects of my investigation have confirmed through analyses the suggestions and theories of various musicians and scholars in the fields of music theory and the cognitive sciences. In particular, reference to Gestalt principles of grouping in conjunction with concepts of auditory streaming and fusion can promote faster understanding of how we recognize themes and differentiate strata in complex works.

I was pleased to have the chance to examine these works in such depth, as the quality of the designs made the study of all levels of construction fascinating, and the fluency of rhythmic expression has been an inspiration. Hopefully, the dissertation will ease the study of other works of similar calibre and complexity. As a composer, I have found that the most stimulating effect of all the research has been that of uncovering a wealth of ideas and strategies for composing new complex musical structures.

Pages 227-287, containing the musical examples, have been omitted from this copy due to restrictions imposed by G. Schirmer and European American Music Corporation. All examples are included in the copy held by the library of the University of Victoria, Victoria, B.C., Canada. The passages under discussion can be found in any score of each of the three works analyzed. The following list supplies the page numbers of the study scores of the following publishers:

Bartok: MUSIC FOR STRINGS, PERCUSSION AND CELESTA
Boosey and Hawkes

Lutoslawski: CONCERTO FOR ORCHESTRA
Eulenberg Edition

Ligeti: CHAMBER CONCERTO
Schott

L I S T O F E X A M P L E S

		SCORE PAGE
Ex. 4.1	Bartok II:199-239	28
Ex. 4.2a	Lutoslawski III: 598-599	90-92
Ex. 4.2b	Lutoslawski III: 600-601	91
Ex. 4.2c	Lutoslawski III: 659-665	104-105
Ex. 4.3	Lutoslawski III: 593-595	89-90
Ex. 4.4a	Lutoslawski I: 41-45	9
Ex. 4.4b	Lutoslawski I: 64-66	13
Ex. 4.4c	Lutoslawski I: 103-108	21-22
Ex. 4.5	Lutoslawski III: 715-717	111
Ex. 4.6	Lutoslawski III: 802-807/822-829	125-127
Ex. 4.7	Bartok I: 78	9
Ex. 4.8	Bartok III: 36	73
Ex. 4.9	Bartok III: 65	85
Ex. 4.10	Ligeti III: all (1-66)	61-86
Ex. 4.11a	Ligeti III: texture "A" - pitch	61-63
Ex. 4.11b	Ligeti III: 4-5	62-63
Ex. 4.11c	Ligeti III: 9-11	66
Ex. 4.12	Ligeti III: 23-27	70
Ex. 4.13a	Ligeti III: 32-39	72-74
Ex. 4.13b	Ligeti III: 36-38	73-74
Ex. 4.14	Ligeti III: 46-48	79
Ex. 4.15	Ligeti I: 17-25	7-11
Ex. 4.16	Ligeti I: 22-23	9-10
Ex. 4.17	Ligeti I: 30-34	15-17
Ex. 5.1	Bartok I: 16-22	2
Ex. 5.2	Bartok I: 29-33	3
Ex. 5.3	Bartok II: 310-338	40-41
Ex. 5.4	Bartok I: 65-69	7
Ex. 5.5	Bartok II: 94-112	18-19
Ex. 5.6	Bartok II: 287-300	38-39
Ex. 5.7	Bartok II: 40-55	15
Ex. 5.8	Bartok III: 6-12	66-67
Ex. 5.9	Bartok III: 50-63	81-84
Ex. 5.10	Bartok IV: 121-129	118
Ex. 5.11a	Lutoslawski I: 1-43	3-9
Ex. 5.11b	Lutoslawski I: 36-40	8
Ex. 5.11c	Lutoslawski I: 160-172	30-32
Ex. 5.12a	Lutoslawski III: 614-617	94-95
Ex. 5.12b	Lutoslawski III: 620-623	96-97
Ex. 5.13	Lutoslawski III: 885-888	138-139
Ex. 5.14	Lutoslawski III: 888-890	139
Ex. 5.15	Lutoslawski III: 698-700	109
Ex. 5.16	Lutoslawski III: 766-770	118-119
Ex. 6.1a	Bartok II: 243-250	33
Ex. 6.1b	Bartok II: 264-285	34-36
Ex. 6.2a	Bartok II: 1-7	11

Ex. 6.2b	Bartok II: 1-19	11-13
Ex. 6.3	Bartok II: 69-76	16-17
Ex. 6.4	Bartok II: 373-377	46-47
Ex. 6.5	Bartok IV: 5-9	95-96
Ex. 6.6	Bartok IV: 15-16	96
Ex. 6.7	Bartok IV: 28-40	97-101
Ex. 6.8	Bartok IV: 74-83	108-109
Ex. 6.9a	Lutoslawski III: 426-433	63
Ex. 6.9b	Lutoslawski III: 570-578	85-86
Ex. 6.9c	Lutoslawski III: 802-809	125-126
Ex. 6.9d	Lutoslawski III: 852-857	134
Ex. 6.9e	Lutoslawski III: 876-877	136
Ex. 6.10	Lutoslawski II: 173-189	33-34
Ex. 6.11	Lutoslawski I: 2-34	3-7
Ex. 7.1	Bartok I: 78-79	8
Ex. 7.2	Bartok III: 38	75
Ex. 7.3a	Bartok II: 113-120	20-21
Ex. 7.3b	Bartok II: 123-127	22
Ex. 7.3c	Bartok II: 149-155	24
Ex. 7.4	Bartok II: 205-211	28-29
Ex. 7.5	Bartok IV: 25-43	96-101
Ex. 7.6	Bartok IV: 136-183	120-125
Ex. 7.7a	Lutoslawski II: 311-324	48-52
Ex. 7.7b	Lutoslawski II: 307-314	47-49
Ex. 7.7c	Lutoslawski II: 323-327	52-53
Ex. 7.8a	Lutoslawski III: 438-441	63
Ex. 7.8b	Lutoslawski III: 447-451	64
Ex. 7.8c	Lutoslawski III: 455-458	65
Ex. 7.8d	Lutoslawski III: 463-467	65
Ex. 7.8e	Lutoslawski III: 471-475	66
Ex. 7.8f	Lutoslawski III: 479-481	67
Ex. 7.8g	Lutoslawski III: 484-485	68
Ex. 7.8h	Lutoslawski III: 498-500	72-73
Ex. 7.8i	Lutoslawski III: 505-508	74-75
Ex. 7.8j	Lutoslawski III: 524-528	79
Ex. 7.8k	Lutoslawski III: 530-532	80
Ex. 7.9a	Lutoslawski III: 434-479	63-67
Ex. 7.9b	Lutoslawski III: 498-543	72-83
Ex. 7.10a	Ligeti I: 8-16	4-6
Ex. 7.10b	Ligeti I: 14-18	6-7
Ex. 7.11	Ligeti I: 19	8
Ex. 8.1	Bartok I:45-53	5
Ex. 8.2a	Lutoslawski II: 189-210	34-36
Ex. 8.2b	Lutoslawski II: 210-221	36-37
Ex. 8.3	Ligeti IV: 48-49	
Ex. 9.1	Bartok IV: 136-138, 148-153	120,122
Ex. 9.2a	Lutoslawski I: 40-43	8-9
Ex. 9.2b	Lutoslawski III: 597-614	90-94

1. For example: Lehrdahl and Jackendoff, A Generative Theory of Tonal Music; Tenney and Polansky, Temporal Gestalt Perception in Music; Lester, The Rhythms of Tonal Music; Smyth, Large-Scale Rhythm and Classical Form.

2. See Benjamin, A Theory of Musical Meter, 358ff. for a discussion of the distinction between grouping and meter for the partitioning of musical time.

3. See Hackman, pp.179-180.

4. Clarke, "Levels of Structure", p.224.

5. See Appendix C for a more detailed summary of factors affecting this choice.

6. Bregman, "Auditory streaming: Competition among alternative organizations", passim.

1. Brower's "Memory and the Perception of Rhythm" presents an excellent summary of the issues. A more general but carefully-articulated approach can be found in Epstein's Beyond Orpheus (ch. 4), where he contrasts various views of time: metrical with experiential, subjective with objective, and chronometric with integral. Fuller ramifications of the philosophical aspects of such distinctions can be found in Clifton's Music as Heard.

2. Ornstein, On the Experience of Time, passim.

3. See for example Boltz, "Time Judgments", p.409. Clifton contributes a phenomenologist's version: "The experience of time is rather a matter of the amount of work required of consciousness to constitute a meaning." "Music as constituted object", p.84.

4. Stockhausen refers to the processes of alteration and the density of alteration; i.e. the degree and rate of change. Structure and Experiential Time, p.64 and passim. Orlov presents a provocative discussion of the whole issue in his "The Temporal Dimensions of Musical Experience" (passim.). See also Boltz, "Time judgments", pp. 409-410 and passim.; Gabrielsson, "Timing in music performance", p.32; Tenney, Meta+ Hodos, p.14; Clarke, "Levels of Structure", pp.229-230, 232.

5. A summary and discussion of the concept of the internal clock can be found in Shaffer, "Rhythm and Timing in Skill", pp.114ff. Povel and Essens also suggest that internal clocks are generated by the music ("Perception of Musical Patterns", passim), but the findings of Monahan et al. suggest that poly-metrical or non-metrical structures can interfere with such generation. ("The Effect of Melodic and Temporal Contour", passim.) Clarke feels that the ability to reproduce tempi to a high level of accuracy confirms the operation of an internal clock in gauging durations, though he proposes that such a clock may operate in conjunction with the model of duration measurement by information content. ("Levels of Structure", pp.222, 231.)

6. Benjamin proposes a musical clock created by the pulse/meter regularity ("A Theory of Musical Meter", p.373). Rochberg takes this concept one step further to point out that as periodic events in music can provide a regulated flow, "the suppression of pulsation

and periodicity radically affects the perception of time in music. One of its more obvious results is to slow down the passage of events, sometimes to the point of near immobility; and even when volleys of rapid projections of sound tend to increase the speed of the passage of events, the perceptual sense of the motion remains essentially non-dynamic." "The Structure of Time", p.145.

7. See for example Monahan and Hirsh, p.229; also Clarke, "Levels of Structure", p. 233 - Table 1.

8. See Appendix B for a sampling of estimates of the length of the perceptual present, and other perceptual boundaries.

9. This conclusion has been reached by numerous people in the last few decades, including Benjamin (pp.403ff.); Berry ("Metric and Rhythmic Articulation, pp.25, 32); Clarke (op. cit., 231-232); Clynes and Walker (p.174); Schachter ("Rhythm and Linear Analysis", pp.3-4); and Tenney (Meta+ Hodos, pp.40, 74-75).

10. Epstein cites Beethoven's metronome as an example of one rumoured to be inaccurate. "Tempo Relations", p.36.

11. The tempo marking indicates ♩=80; the footnote states: "A faster tempo (as virtuoso as possible) is preferred; throughout the movement the metronome markings are the lower limits of the tempo. If a tempo faster than ♩=80 is taken at the beginning, the later tempos (changes of metronome marking) must be correspondingly faster, so that the tempo proportions remain the same. This also applies to the senza tempo passages, whose durations are measured in seconds; these pasages will be shorter in proportion." Chamber Concerto, p.87.

12. These timings are thought to be derived from a performance made after the completion of the work, but that performance must nonetheless have satisfied the composer to a reasonable degree. Howat, "Review-Article", p.71. Helm quotes Sacher's description of Bartok at rehearsals: "Bartok's exactness was amazing. He always had a metronome with him to check the tempos, even when he played. He knew precisely what he wanted and demanded the ultimate in differentiated precision from everyone." Helm, p.62.

13. For this reason, I have rounded off measurement figures of 2" and less to the nearest 100th of a second, and those over 2" to the nearest 10th of a second, as the variations are cumulative. For a discussion of the Weber fraction and the problem of how to determine significance in figures of duration in musical context, see Epstein, "Tempo Relations".

14. Such a situation is most typically found in Ligeti's work, as it contains several instances where perceptual boundaries are explored.

15. Clarke, "Structure and Expression", p.214 and passim, summarized in his "Levels of Structure", pp.224-226. Gabrielsson presents clear graphs of such deviations on pp.165-166 of his "Perception and Performance", and on pp.42-45 of his "Timing in music performance".

16. Clarke, "Levels of Structure", pp.224-228.

17. Clarke, "Levels of Structure", pp.225-226; Monahan and Hirsh, P.228. Epstein suggests that a preference for simple ratios may apply to tempo relations as well. ("Tempo Relations", passim.)

18. We normally associate a ritardando with a decrease of energy, as in the slowing down of footsteps. The fact that a bouncing ball produces an accelerating periodicity when coming to rest seems to emphasize the extent to which our musical associations are linked to human movement.

19. This conclusion is in contradiction to Yeston's claim that it is meter "defined as a relationship betwen levels" which allows us to perceive a slowing of pulse as ritardando (Yeston, p.148). The clear example of increase and decrease in speed provided by the xylophone opening Movement III of Bartok's Music for Strings illustrates that meter is not necessary to the perception of tempo change; the logarithmic increase and decrease of note density is sufficient.

20. Parametric focus means a focus on a particular parameter of music, such as timbre, pitch, or duration. Tenney points out that a parametric focus inappropriate to the passage can be responsible for much of the lack of appreciation of twentieth-century works. On the other hand, he points out that parameters which exhibit the highest intensity will naturally attract our

attention. Meta+ Hodos, pp.18,36.

21. For example, rocks do not change noticeably within a human's lifetime and so most people (except, perhaps, geomorphologists) can afford to treat them as static forms. This concept of time seems compatible with, though not the same as, a phenomenological view of time expressed by Clifton: "time...is a measure of our implication with the events of the world-as-lived-in. The breadth and depth of time have more to do with our relations to events than to any absolute measurement." "Music as constituted object", p.84.

22. Minsky, "Music, Mind, and Meaning", pp.8-9 (and passim.) Similar conclusions are made by Schutz ("Fragments", pp.54-55), though with a more careful appraisal of the conflict of stability with the transitory nature of music.

23. See for example Rochberg, "The Structure of Time", pp.143-146.

24. Epstein, Beyond Orpheus, p.55, and "On Musical Continuity", p.182.

25. Examples include the fairground atmosphere of Stravinsky's Petrushka, and the presentation of three marching bands converging on the village square in Ives' Three Places in New England.

1. "In this region [of 0.1 Hz.-8 Hz., or 0.125"-10"], human perception involuntarily includes temporal relationships" (underline the authors'); Clynes & Walker, p.174.

2. Sachs states with conviction that pulse is related to a walking pace. He argues that the heartbeat, often cited as being the basis for pulse, does not correspond closely enough. Rhythm and Tempo, pp.32-34. His argument itself is weakly stated, but seems true. A heartbeat does not vary as immediately or as extensively as a walking pace, for instance. It is also rarely heard or felt overtly, whereas the sound produced by walking is often audible and certainly felt overtly, being related to much more prominent muscle movements. However, it would be more comprehensive to say that pulse refers to the motion of the limbs. Music frequently suggests dance movements which, though clearly related to walking, tend to incorporate more complicated patterns. In addition, anyone who is familiar with performing on a particular instrument is likely to be sensitive to the motor skills required when hearing music played on that instrument.

3. Berry places this effect first in his list of primary criteria of accent (Structural Functions, pp.339). Tenney states that "it is a common fact of musical experience that a greater subjective intensity is usually associated with a rise in pitch, an increase in dynamic level or in tempo, etc." Meta+ Hodos, p.35.

4. Hackman, pp.179-180.

5. Doob cites Creelman's estimation at 10% (Patterning of Time, p.91); Clarke cites Kristofferson's estimate of 8% but suggests that "we can expect them to become sharper with appropriate context" ("Levels of Structure", p.224). Although he does not clarify "appropriate contexts", the nature of his research might suggest that sharper discrimination would allow us to perceive a logarithmic increase or decrease in successive durations. Epstein quotes a variety of estimates from Getty and Mach, ranging from 5% to 33% depending on the length of the durations involved. The 33% figure was for 15-second durations, but even above 2 seconds there was an increase to at least 10%. Hirsh et al. suggest a threshold between 5% to 10% for durations of 0.2" to 2", but point out that discrimina-

tion ability can be weakened by contextual factors such as an unexpected change in frequency. Laboratory evidence seems scanty, especially with regard to longer durations. The reason for this lack of research is doubtless due to the number of variables involved in estimates of duration exceeding the length of the perceptual present.

6. At ♩=88, ten thirty-seconds has a duration of ca. 0.85; eleven thirty-seconds is ca. 0.94; a difference of approximately 10%. For an example of such a durational series, see Boulez's Structure Ia, analyzed by Ligeti in "Pierre Boulez", p.39.

7. Clarke, "Levels of Structure", p.225.

8. Zuckerkandl, Sound and Symbol, pp. 170ff.

9. Clynes & Walker, p.190. Berry's discussion of initiative and reactive impulses is closely related to these concepts. However, it has broader connotations by relating to the various aspects of the music and not being restricted to the periodic movement of meter. See Berry, "Rhythm and Meter", chapter III, pp. 326-334; Structural Functions of Music, passim. A summary and a diagram can be found on p.10 of his "Metric and Rhythmic Articulation in Music".

10. See Appendix B. Bielawski points out that this region corresponds to that of phonemes in speech. "Zones", p.178.

11. Statistical is used here to mean that one perceives an average durational value as a general property of the ornamental figure or texture. Tenney's terminology as defined in META Meta+ Hodos is relevant here, and is explained in the glossary definitions of temporal density, parameter, statistical feature, etc. (Appendix A). This concept is discussed further in Chapter IV.

12. Rochberg uses the analogy of a "memory bank" provided by "various processes of repetition, recurrency, consistency of motivic and rhythmic elements, variant forms of association, etc.". "The Structure of Time in Music", p.141.

13. For example, the number **123456** is likely to be more readily remembered than the number **425388**, because it

refers to what we consider a logical sequence, and can be remembered as "the first 6 digits, in order". If on seeing the number **123456** one of the digits were blurred with an ink smear, it would be quite easy to guess; likewise if on hearing it recited over the phone a brief noise interrupted, not much would be lost. See Butler (pp.146-153), Rochberg (pp.141-142), and Handel & Oshinsky (p.1) for further discussion.

14. Experiments by Dowling, Lung, & Herrbold are particularly illustrative. See also Monahan, Kendall, & Carterette; Jones, Boltz, & Kidd.

15. Meyer was one of the first to popularize the application of Gestalt principles to perception in music, in his 1956 Emotion and Meaning in Music. An interesting and well-documented discussion of Gestalt theory from a more recent perspective can be found in Chapter 4 of Narmour's book The Analysis and Cognition of Basic Melodic Structures. (The book is dedicated to Meyer.)

16. My discussion of Gestalt principles draws mainly on those of Sloboda (The Musical Mind, pp.154-166); Narmour (pp.59-72); Tenney (Meta+ Hodos, pp.28-54) and Smither ("The Rhythmic Analysis of 20th-Century Music", pp.59-60).

17. See Narmour, p.67, and Ch. 4 passim, for further discussion.

18. Benjamin, "A Theory of Musical Meter", pp. 369-371.

19. Tenney & Polansky, "Temporal Gestalt Perception in Music", passim.

20. See Deutsch, "Memory and Attention in Music", p.118.

21. Monahan, Kendall & Carterette, p.599.

22. Particularly from Bregman's efforts; see his Auditory Scene Analysis and "Auditory Streaming", as well as Wright & Bregman; French-St.George & Bregman; Tougas & Bregman; Steiger & Bregman.

23. Bregman, "Auditory Streaming",p.391.

24. See for example Sloboda's discussion of Fugue XII from the second book of Bach's Well-Tempered Clavier, p.163

of The Musical Mind.

25. Audio examples of this effect and several other related ones are now available on compact disk with Butler's The Musician's Guide to Perception and Cognition, accompanied by explanations of the phenomenon concerned.

26. See McAdams, "Spectral Fusion", for a summary; also Steiger & Bregman; Bregman, Levitan & Liao.

27. Tougas & Bregman, passim. This clearly relates to the Gestalt principle of "good continuation." A similar, perhaps stronger, phenomenon has been demonstrated with both speech and music by Kaminska & Mayer. They found that a noise sounding during a word, or a click sounding during a musical figure, is mentally transplanted to a more appropriate pause in the phrase.

28. See for example Wright & Bregman, pp. 79-80.

29. Pitt & Monahan, pp. 537-538.

30. Pitt & Monahan, passim.

1. The link between this function of musical periodicities and our efforts to interpret our environment in general is summarized by Hackman: "The rhythmic structures of music are clearly derived from internal life processes of human beings and their interaction with their environment... Comprehension of periodicity with its basis in life processes is an essential means of imposing organization on disparate and segmented stimuli, whatever their origin, and music is the most refined manifestation of this achievement." A Clarification and Reconstruction of Meter, 191.

2. "I have always been fascinated by machines that do not work properly ... the ticking of malfunctioning machinery occurs in many of my works..." Ligeti in Conversation, p.16.

3. For example, It's Gonna Rain and Violin Phase. See Reich, Writings about Music, for description of method.

4. Epstein, On Musical Continuity, p.185; reiterated also by Kramer, The Time of Music, pp.90ff.; also Lerdahl & Jackendoff, "On the Theory of Grouping and Meter", pp.486-487. This is an interesting concept, but I am not yet convinced about the usefulness of such a distinction.

5. Clarke, "Levels of Structure", pp.222, 225.

6. For example: Carter, Double Concerto; Cowell, Quartet Euphometric; Crawford, String Quartet; Ives, "Concord" Sonata; Ligeti, Chamber Concerto; Stockhausen, Zeitmasse.

7. See for instance Cowell, New Musical Resources, pp.45ff..

8. See for example Schachter, "Rhythm and Linear Analysis: Aspects of Meter", p.5.

9. Benjamin's reasons for proposing that meter should be able to refer to one level only are quite valid (see "A Theory of Musical Meter", pp. 371-372), but the substitution of the term "super-pulse" in such situations seems less likely to cause confusion.

10. See Appendix B.

11. Narmour (p.208) discusses this tendency with support from Thornassen (1982) and Fraisse (1982). The works studied herein contain several examples which seem to confirm such a reading, though naturally the bias and training of the listener will influence perception.

12. Schachter, "Rhythm and Linear Analysis: Durational Reduction", p.205.

13. Wright & Bregman, p.80.

14. Berry contributes the interesting comment: "One hang-up in the consideration of meter at deeper levels is the assumption that meter is, by definition, periodic, a bias that is, I have argued, of doubtful usefulness in characterizing many surface metric structures, and increasingly questionable at phrase- and, to be sure, at deeper levels." "Metric and Rhythmic Articulation in Music", p.16. For further discussion, see Schachter, "Rhythm and Linear Analysis: A Preliminary Study", pp.301ff. ; Benjamin, pp.403ff..

15. See for example the piano and 'cello parts from the first movement of Messiaen's Quartet for the End of Time, and the third movement of Webern's Variations op. 27. Experiments with isorhythm suggest that it is quite easy to thwart even the rhythmic pattern by imposing a different metric plan: the sense of completion often arises only when the traditional 4-bar phrase completes. See Appendix E for example.

16. Butler, p.239, defines tremolo as the repetitive alteration of the loudness of a sound; low-frequency amplitude modulation. Tenney refers to trills and tremolos as having the "character and function" of basic elements within larger configurations or sound-ideas, and thus can be considered as "materially equivalent" to their "static counterparts". Meta+ Hodos, p.12. McAdams points out that vibrato is also a periodic frequency modulation. "Spectral Fusion", p.283.

17. Ligeti in Conversation, 22-23.

18. I believe that this is what gives the opening of that movement such character: at the first brief pause, the listener begins to realize that the strings sound is not functioning as background texture to something

else, but has its own profile. Therefore, a narrower focus is demanded.

19. For instance, Gabrielssen, "Timing in Musical Performance", pp.41-46; Clarke, "Levels of Structure", p. 225. Because this seems to be a distinct issue in our perception of rhythm, I have considered notationally equal durations as being periodic, in the assumption that such quantization would not fundamentally change the perception of the various rhythms; see Chapter I, pp.18-19.

20. An illustration of our perception relating to our knowledge of performance skills can be found in Nancarrow's Study No. 27 for Player Piano which starts off at a reasonable tempo for a keyboard player but subtly introduces passages at speeds physically impossible for a human performer. The sense of something being awry seems to precede the conscious realization of the specific cause.

21. Deutsch quotes a study by Miller & Heuse (1950) which found that two notes which alternate at a rate of 10 per second would be perceived as a trill if the frequencies were within 15% of each other. "Memory and Attention in Music", p.122.

22. See for example Deutsch, op cit., passim; Bregman, passim; Wright & Bregman, passim; Gregory, passim.

23. See Chapter IV, pp.93, 102-110.

24. Some Javanese music, for instance, is designed to help the listeners achieve a concentration appropriate to the ritual. Healing music of certain tribes in Kenya is likewise designed to put the patient into a trance.

25. See Chapter IV, pp.100-101, and Example 4.6, for an example of an intermittent gesture in Lutoslawski's work.

26. This is discussed in the article "Auditory stream segregation" by Wright & Bregman under the heading "The ecological role of the stream forming process", pp.68ff.. McAdams states "In order to be able to form images of sounds in the environment the auditory system must be able to decide which sound elements belong together, or come from the same source, and which elements come from different sources." "Spectral

Fusion", p.279.

27. Benjamin, pp.372-373.

28. Clarke, "Levels of Structure", p.222.

29. Benjamin, p. 372.

30. This expectation is naturally reinforced by tradition; the expectation would be considerably higher in a classical piece than in one by an experimental composer of this century who might be **expected** to diverge from expectation at the last moment.

31. Berry, Structural Functions, pp. 372ff..

32. Minsky, pp. 9-11.

33. Clynes & Walker, passim.

34. Boulez, Orientations, p.253. He continues the article with a discussion of how Wagner's leitmotifs differ from classical traditions in being presented at a wide variety of tempi. These variations are significant carriers of change in mood or character. The effect of tempo change in reducing instant recognition is counteracted to some extent by the extensive repetition of the leitmotif within the work.

35. In fact, the commonly-expressed opinion that rhythmic patterns are identifiable regardless of tempo variations (such as implied by Stravinsky, Poetics of Music, pp.38-39) seems to be exaggerated. Handel & Oshinsky, commenting on the change in the perception of meter in a study of polyrhythms, state that the results "suggested that meter was an absolute function of the tempo, contradicting the commonsense notion that a rhythmic figure remains invariant through transpositions in time." (Handel & Oshinsky, p.2.) This is borne out by my own casual observations from teaching music to young children; frequently, they cannot recognize a familiar nursery rhyme unless it is played close to its usual tempo.

36. This is assuming that at least one level of periodicity is at the level of a super-pulse or faster, as otherwise the regularity may not be perceptible. The resistance to change is related to, though not identical with, the preconditioning effect discussed by

Berry (Structural Functions, pp.372ff.). Clarke claims support from Longuet-Higgins and Steedman for his statement that "there is considerable resistance to a perceptual reinterpretation of metrical structure".

37. The dramatic effect of tempo change on bird-song was demonstrated to me when I taped the call of the American robin and played it back at quarter-speed; it produced a beautiful, haunting, but absolutely unrecognizable figure.

38. Certainly, however, a composer may find inspiration for unusual musical designs by transposing rhythms of extra-musical phenomena to another range. In fact, such a technique may be recommended, not only for its injection of new rhythmic designs, but for formal reasons; McAdams points out that literal extra-musical references can be so strongly evocative of their origins that they may interfere with the coherence of a work's formal structure. (McAdams, "Music: a science of the mind?", p.55.)

39. See footnote 2, this chapter. The sounds of clocks have a particular relevance to temporal issues. Pink Floyd have a particularly appropriate introduction to their song "Time" utilizing the not-quite-synchronized striking of numerous clocks. My favourite use of the ticking clock metaphor is at the opening of Lutoslawski's Cello Concerto, where the cello is instructed to play short repeated notes at ♩=60 with indifference. This evokes the audible movement of the second hand on a clock.

40. Lendvai, "The Workshop of Bartók and Kodály", p.79. Schachter suggests the bilateral symmetry of the body as a basis for duple meter (Schachter, "Rhythm and Linear Analysis", pp. 16-17); this is another way of emphasizing the link between limb movement and music.

41. Bartok, for instance, meant the passage beginning at m.35 in the third movement of Music for Strings to represent the wind (Lendvai, p.82). He is also quoted as referring to the sound of the sea incorporated into the same work; see Helm, p.35.

42. One is reminded of Sloboda's experiments which sought to discover exactly which musical elements produce the effect of a chill runnning down the spine -- he found surprising agreement on specific points in specific

pieces as causing the effect. Sloboda, "Why do musical events cause emotional responses?", passim.

43. Tenney said, in 1961, "I know of no attempt to define these conditions [relating to musical intensity] explicitly, much less to explain them in non-musical terms. It is a common fact of musical experience that a greater subjective intensity is usually associated with a rise in pitch, and increase in dynamic level or in tmepo, etc. Similarly, a change from a "smooth" or "mellow" timbre to a "harsh" or "piercing" timbre, or form a more consonant to a more dissonant interval, is felt as an increase in subjective intensity." Meta+ Hodos, p.35. Berry incorporates such evaluating of "superior" accentual factors in his discussion of accent in Structural Functions of Music, pp.339ff..

1. This is precisely analagous to the figure/ground relationships of the two-dimensional field. The change in emphasis of the term "texture" is probably an attempt to match the visual aspects of the term more closely. See Deutsch, "Memory and Attention", p.118, and Tenney, Meta+Hodos, p.40, for further discussion of figure and ground in music.

2. Texture "A" of the third movement of Ligeti's Chamber Concerto provides examples of the latter.

3. For a description of the characteristics and origins of statistical fields, see Ligeti, "Metamorphoses of Musical Form", passim; also Stockhausen, "...how time passes...", pp.15, 30ff.; Tenney, Meta+Hodos, pp.67-68.

4. Xenakis combined this stage of the decision-making with probability theory, thus developing his "stochastic" music. See Xenakis, "Towards a Metamusic", pp.3ff.

5. Ligeti, "Metamorphoses of Musical Form", p.10. See Chapter II, p.30 of this dissertation for further support of his arguments.

6. See Appendix B.

7. Ligeti in Conversation, p.39.

8. He continues: "Later I realised that this was nothing new. The string parts at the end of Walküre (Feuerzauber) are such that no violonist [sic] can play them, all of them make mistakes, different mistakes all the time. These mistakes add up and create a floating, fluctuating pattern, i.e. Bewegungsfarbe. Technically, Atmosphères is based on the same principle." ibid., p.40.

9. See for example the third movement of Debussy's String Quartet, and the music of Charles Tomlinson Griffes. The Paris exposition of 1889 was reputed to have influenced several musicians of the time by exposing them to music from the Orient.

10. See pp.100-101 below, and Example 4.6.

11. Textures often move in durations faster than 0.10"; compare for example with the celesta passages' durations of the same work with a periodicity of ca.0.09"; see Examples 4.7-4.9.

12. The theme is familiar because it is a variation of the second theme from the first movement, presented at mm.40, 64, and 100. The previous statements are also accompanied by textures, described later in this chapter (**Ex.4.4**).

13. Krebs has made the very useful distinction between dissonances which arise from groupings of pulses whose cardinalities differ (Type A) and those whose cardinalities are identical but out of alignment (Type B). See Krebs, "Some Extensions of the Concepts of Metrical Consonance and Dissonance", pp.103ff.

14. Ligeti in Conversation, 135.

15. The audibility of the subdivisions' periods can be obscured by the irregularity of the entries, due to the sforzando accent on the first note of each group. This is more emphasized in certain performances, such as the Boulez recording used for the accompanying examples. Although this produces an interesting effect and ties in with the end of the movement, the effect is weakened by the harpsichord, bringing into question the benefits of such an interpretation. Because the harpsichord is unable to differentiate notes by volume, its periodicity is quite audible.

16. In other words, it would not sound quite the same produced electronically, because we can both hear and imagine the difficulty of producing such an effect.

17. Ligeti relates this process to the analogy of machinery breaking down: "what attracts me is the idea of superimposing several levels, several different time-grids moving at different speeds, and so very subtly achieving rhythmical deviations. That is what I meant when I said the machine breaks down." Ligeti in Conversation, p.108.

18. Score to Chamber Concerto, p.80.

19. The piano articulates a period of 3 x septuplet sixteenths at a tempo of ♩=60, while the harpsichord arrives at a period of 2 x septuplet sixteenths at the tempo of ♩=40; each produces a periodicity of 0.43".

20. The importance of "onset synchrony" in promoting perceptual fusion is discussed in McAdams, "Spectral Fusion", pp.287-289.

1. The concept of "resolving into consonance" is borrowed from Berry, and refers simply to the realignment of a dissonant structure with a previously-established or currently-sounding structure. See Berry, Structural Functions, pp.324, 326 n.22.

2. Ligeti in Conversation, pp.135-137.

3. The timbral difference between the pairs of strings (violins play sul pont. while lower strings play con sord. and sul tasto) does not seem to work against the similarity. In fact, the more marked difference between the upper and lower strings lessens the effect of the timbral difference between the keyboard pair and the violins.

1. See footnotes 15 and 16, Chapter II.

2. The pervasiveness of 2:1 ratios in Western music would cause many listeners to deduce the quarter-note period even before the recurrence of C on the second beats of mm.3 and 4. The triple repetition of the opening figure A-C emphasizes both the eighth-note period and that of the 2/4 bar. Such a 1:4 ratio causes expectations of its filling-in by an intermediating period of twice the shorter period.

3. This expectation is strengthened by years of tradition.

4. The three-bar grouping suggests, in retrospect, that the opening passage might be heard as 2-bar groupings with occasional 1-bar tags. It seems more reasonable, however, to hear the single bars as a compression of two.

5. The note of seven eighths' duration in mm.17-18 is simply a delaying of the final "tag" bar by the addition of an inverted upbeat/downbeat eighth-note motive, thereby neatly turning the tag into its (proper) 2-bar unit. The figure of the single bar is an ambiguous signal, and functions both as a phrase beginning and a phrase ending. The extra hold on the note gives added impact to the final occurence of the motive, and the downbeat of m.19 sounds unequivocally like a downbeat and the end of a section.

6. In fact, it has a rhythmic precedent in mm.40ff., though imitation there obscures the upper voice's statement of the gesture.

7. These places begin at m.44, m.248, and m.280.

8. In fact, the opening rhythm of the piano theme is identical with the strings' figure which begins on the upbeat to m.30.

9. This seemingly odd ending is explained by studying the folk song from which the ground is derived; it moves in a duple meter and includes the sixteenths in the penultimate bar.

10. It also shares some characteristics with the opening of Mendelssohn's Midsummer Night's Dream.

1. Much of the validity of Schenker's theories seems related to this perceptual tendency to group pitches which are registrally close together. The tendency can also be viewed from the perspective of the Gestalt principle of "good continuation"; see Chapter II, pp.34-35 for further discussion.

2. Bregman, "Auditory Streaming", p.392.

3. The fact that the timpani articulates every eighth note, however, means that the pattern might be heard to adapt to a duple division as the passage continues. Its tendency to do so may depend upon the performer. The notation does not indicate that the 3+3+2 grouping must be retained, and therefore the 4+4 grouping is likely to dominate. This has ramifications for the indirect dissonance of mm.36-39.

4. Indirect dissonance is one in which conflicting series of periodicities are juxtaposed, so that the second one conflicts with the imagined continuation of the first. See Krebs, "Some Extensions of the Concepts of Metrical Consonance and Dissonance", p.105. This concept is related to Berry's idea of "preconditioning".

5. The tension is further heightened by several means. Initially, these include a stringendo and a crescendo. Subsequently, a truncation of the theme in each voice discards the repeated-pitch segments, and that lack of redundancy contributes to the momentum and mounting tension. Other factors include the addition of harp glissandi and the doubling of the attacks on each note in both piano and strings. These thicken the texture, add to the volume, and contribute to the growing sense of frenzy. The xylophone also enters to double the piano line, emphasizing the prominence of that layer. At m.180, the strings suddenly cease, and three bars later the piano and harp drop out under a new (but related) section in the strings. (N.B. The Boosey and Hawkes pocket score has mistakenly notated the piano part at m.181 as harp.)

6. In fact several aspects of Stucky's description of these "variations" (Stucky, pp.54-55) seem suspect. He states that the first five variations are each eight bars long. However, the first piano segment spreads over fourteen bars. The second "variation", which I agree begins eight bars after the first, does not stop but evolves in the woodwinds. As it does so, other

layers of material emerge, which seem unrelated to it. Similarly, what he calls variations six and seven I interpret as being one unit. I agree that a new segment begins in the same bar as ground statement 11, but as their downbeats do not coincide exactly, I maintain that they are extremely dissonant; to call that point an intersection of the "two" strata therefore seems a bit arbitrary. Similarly, I do not agree with his description of m.530 as being another point of "coinciding" of ground and "variation." Etc.

1. Everett Helm refers to the climax as being at "measure 52ff." as well as being "on the note E-flat, fortissimo", doubtless indicating his reluctance to separate the point in m.52 from the significance of the Eb a few bars later ("The Music of Béla Bartók" pp. 46, 44). Oddly enough, one reason why Howat distrusts a Golden Section analysis of this movement is because it places the climax after the second eighth of m.54. This would give more credence to Bartok's having thought of the climax as being a short section, from m.52 to m.56, rather than one point. See Howat, p.78.

2. Other factors also contribute to the stress on the downbeat of this bar. Probably the most immediately noticeable is the culmination of a cymbal trill (at mf) which began in the previous bar from a pianissimo level. The tempo also slows marginally after having increased in m.38, though it remains slightly above the initial tempo of the movement. The first occurrence in the work of double stops in all instruments adds more sound to a fortissimo marking. Double stops produce a D-A chord against which the G of violin I is particularly strident. The D and A are likely to be played on open strings in violin and viola contributing a particularly sonorous timbre.

3. Lutoslawski comments: "The famous xylophone rhythm in the introduction of the slow movement is an everyday phenomenon in Chinese music. Bartok must have been aware of this, and consciously drew on it." (Lutoslawski/Varga, p.18.) On the other hand, Doflein confidently ascribes it to the wooden drum of Japanese Noh dramas. (Lendvai, p.85.)

4. The exceptions are one passage at ca. 0.3" (mm.150ff.) and one passage at ca. 0.83" (mm.244-247).

5. The two passages are at mm.184-203 and mm.204-234. One is irregularly-metered and the subsequent one contains the fugal reference. Although the 3/4 bar at m.270 is dissonant with the half-note period, it is balanced by another 3/4 bar two bars later, so the dissonance can be thought of as local.

1. Clarke, "Levels of Structure", p.232.

2. Tenney quotes Koffka as saying that a figure is distinguished by "a greater `energy density', and by a higher degree of `internal articulation' than the ground." Tenney, Meta+Hodos, p.40.

3. Some gestures sound like opening gestures, and even in the absence of a theme will provide the same sense of initiation.

4. See footnote 19, Chapter I.

5. For example, the three-strata passage containing the piano theme in its Type B dissonance is preceded by a four-voice consonant phrase with periodic structure to the 4 x 3-bar level.

6. See Epstein, "Tempo Relations", p.41, who quotes Getty as putting the upper limit at 17.5% for 3.5".

7. Compare for example the first notes of the chorale theme with the first theme from Mvt.II; and the last five notes of phrase v of theme I with the last 9 notes of the passacaglia theme.

8. Lerdahl and Jackendoff, "Generative music theory and its relation to psychology", pp.62-67, and Benjamin, "Levels of Musical Structure", p.380. Tenney and Polansky refer to this same tendency in Gestalt terms of segregation in their development of a computer programme designed to establish basic rhythmic groupings; see their "Temporal Gestalt Perception in Music", p.209 and passim.

9. Lutoslawski/Kaczy, p.83.

1. For example: Orlov ("Temporal Dimensions", passim.); Boltz ("Time Judgments", passim.); Clarke ("Levels of Structure", pp.231-232); Reynolds (p.285); Schachter ("Rhythm and Linear Analysis: Aspects of Meter", pp. 3-4, and "Rhythm and Linear Analysis: A Preliminary Study", pp.308-309); Schenker (Der Freie Satz, p.199 [referred to by Schachter, "Rhythm and Linear Analysis: A Preliminary Study", p.298]); Tenney (Meta+Hodos, p.74).

2. This issue is often raised in reference to the Golden Section and Fibonacci series found in Movements I and II of Bartok's work particularly. Although such designs may have contributed to an elegant sense of proportions, it seems unlikely that they are audible in the same immediate and direct way that we hear ratios of 2:3, for example, on the level of the super-pulse. Ligeti, in talking about his own use of the Golden Section in designing Apparitions, states simply: "Looking back on it, I must say that I could have applied any other principle of proportions just as well." (Ligeti in Conversation, p.43.)

B I B L I O G R A P H Y

N.B. PRIMARY SOURCES are highlighted

ANTOKOLETZ, Elliott. The Music of Béla Bartók. Berkeley: University of California Press, 1984.

BAILEY, Kathryn. "Bartók's Tonal Ellipsis in the Music for Strings, Percussion and Celeste", Studies in Music (1983):37-46.

BARTOK, Béla. Bela Bartok Essays, ed. Benjamin Suchoff. London: Faber and Faber, 1976.

BATSTONE, Philip. "Musical Analysis as Phenomenology", Perspectives of New Music, 7/2 (1969): 94-110.

BENJAMIN, Walter. "A Theory of Musical Meter", Music Perception 1 (1984): 355-413.

BERRY, Wallace. "Metric and Rhythmic Articulation in Music", Music Theory Spectrum 7 (1985): 7-33.

_____. Musical Structure and Performance. New Haven: Yale University Press, 1989.

_____. **Structural Functions in Music. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1976.**

BERSANO, James Richard. Formalized Aspect Analysis of Sound Texture. Ph.D. diss., Indiana University, 1980.

BIELAWSKI, Ludwik. "The Zones of Time in Music and Human Activity", The Study of Time 4 (1981): 173-179.

BOLTZ, Marilyn. Time judgments of musical endings: Effects of expectancies on the 'filled interval effect'", Perception & Psychophysics 46/5 (1989): 409-418.

BORETZ, Benjamin. ""In Quest of the Rhythmic Genius", special issue of Perspectives of New Music, 9/10 (1971): 149-155.

BORETZ, Benjamin, Harold Oliver, Barney Childs, and Charles Whittenberg. "The Nature of Continuity in Music", Proceedings of the American Society of University Composers, v.6 (1971): 49-82.

BOULEZ, Pierre. "Form", text of a course given at Darmstadt in 1960; reprinted in Orientations: collected writings of Pierre Boulez: 90-96.

_____. "Timbre and composition - timbre and language", Contemporary Music Review 2/1 (1987): 161-171.

_____. "Time, Notation and Coding" from a lecture given at Darmstadt in 1960; reprinted in Orientations: collected writings of Pierre Boulez: 84-89.

BREGMAN, Albert S. "Analyzing Spectra That Won't Stand Still", Canadian University Music Review (1982): 31-48.

_____. **Auditory Scene Analysis: The Perceptual Organization of Sound**. Cambridge, Ma.: The MIT Press, 1990.

_____. **"Auditory streaming: Competition among alternative organizations", Perception & Psychophysics, 23 (1978): 391-398.**

_____. "Fusion of auditory components: Effects of the frequency of amplitude modulation", Perception & Psychophysics, 47 (1990): 68-73.

BROWER, Candace. "Memory and the Perception of Rhythm", Music Theory Spectrum, 15/1 (spring 1993): 19-35.

BUTLER, David. The Musician's Guide to Perception and Cognition. New York: Schirmer Books, 1992.

CARTER, Elliott. "Music and the Time Screen", pp. 63-88 of Current Thought in Musicology (Austin: University of Texas Press, 1976).

CHILDS, Barney. "Time and Music: A Composer's View", Perspectives of New Music, 15/2 (1977): 194-219.

CLARKE, David. "Structural, cognitive and semiotic aspects of the musical present", Contemporary Music Review 3/1 (1989): 111-131.

CLARKE, Eric C. "Levels of Structure in the Organization of Musical Time", Contemporary Music Review 2/1 (1987): 211-238.

_____. "Mind the gap: formal structures and psychological processes in music", Contemporary Music Review 3/1 (1989): 1-13.

_____. "Some aspects of rhythm and expression in performances of Erik Satie's 'Gnossienne No. 5', Music Perception 2/3, (1985): 299-328.

_____. "Structure and Expression in Rhythmic Performance", Musical Structure and Cognition, (1985): 209-236.

CLIFTON, Thomas. "Music as Constituted Object", Music and Man 2 (1976): 73-98.

_____. Music as Heard: a study in applied phenomenology. New Haven: Yale University Press, 1983.

_____. "Some Comparisons between Intuitive and Scientific Descriptions of Music", Journal of Music Theory 19 (1975): 66-110.

CLYNES, Manfred, and Janice Walker. "Neurobiologic Functions of Rhythm, Time and Pulse in Music", in M. Clynes (ed.): Music, Mind, and Brain, 171-216. (New York: Plenum Press, 1982)

COGAN, Robert, and Pozzi Escot. Sonic Design. Englewood Cliffs, N. J.: Prentice-Hall, 1976.

COOPER, Grosvenor, and Leonard B. Meyer. The Rhythmic Structure of Music. Chicago: The University of Chicago Press, 1960.

COWELL, Henry. New Musical Resources. New York: Something Else Press, 1969 (originally published by Knopf, 1930).

DAVIDSON, Barbara, Roderick P. POWER, and Patricia T. MICHIE. "The effects of familiarity and previous training on perception of an ambiguous musical figure", Perception & Psychophysics 41/6 (1987): 601-608.

DEUTSCH, Diana. "Memory and Attention in Music", Music and the Brain (eds. Critchley & Henson; London: Heinemann, 1977): 95-129.

_____. "Organizational Processes in Music" in M. Clynes (Ed.): Music, Mind, and Brain (New York: Plenum Press, 1982): 119-136.

_____. "The Psychology of Music", chapter 9 (pp. 191-224) of Handbook of Perception 10 (Perceptual Ecology), ed. Edward C. Carterette and Morton P. Friedman, 1978.

DOOB, Leonard W. Patterning of Time. New Haven: Yale University Press, 1971.

DOWLING, W. Jay. "Aiming attention in pitch and time in the perceptin of interleaved melodies", Perception & Psychophysics 41/6 (1987), 642-656.

_____. "Dichotic recognition of musical canons: Effects of leading ear and time lag between ears", Perception & Psychophysics, 23 (1978), 321-325.

DOWLING, W. Jay, and Edward C. Carterette, eds. The Understanding of Melody and Rhythm, special edition of Perception & Psychophysics 41/6, June 1987.

EDLUND, Bengt. Performance and Perception of Notational Variants: A Study of Rhythmic Patterning in Music. Uppsala: Acta Univ. Ups. Studia musicologica Upsaliensia Nova, series 9, 1985.

EPSTEIN, David. Beyond Orpheus: Studies in Musical Structure. Cambridge, Mass.: The MIT Press, 1979.

_____. "On Musical Continuity", The Study of Time 4 (1981): 180-197.

_____. "Tempo Relations: A Cross-Cultural Study", Music Theory Spectrum 7 (1985): 34-71.

ERICKSON, Robert. "New Music and Psychology", The Psychology of Music, pp. 517-536. See D. Deutsch.

_____. Sound Structure in Music. Berkeley: Univ. of California Press, 1975.

_____. "Time-Relations", The Journal of Music Theory, 7:2 (1963): 174-92.

ESSENS, P. J. and D.-J. POVEL. "Metrical and nonmetrical representations of temporal patterns", Perception & Psychophysics 37 (1985): 1-7.

FRAISSE, Paul. The Psychology of Time. New York: Harper, 1963.

_____. "Rhythm and Tempo", The Psychology of Music, ed. D. Deutsch, 149-180.

FRANCES, Robert. The Perception of Music. Translation by W. Jay Dowling (Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1988) of La Perception de la Musique, 1958.

FRASER, J.T. "The Art of the Audible 'Now'", Music Theory

Spectrum 7 (1985): 181-184.

FRENCH-ST. GEORGE, Marilyn, and Albert S. BREGMAN. "Role of predictability of sequence in auditory stream segregation", Perception & Psychophysics 46 (1989): 384-386.

GABRIELSSON, Alf. "Perception and Performance of Musical Rhythm" in M. Clynes (Ed.): Music, Mind, and Brain (New York: Plenum Press, 1982): 159-170.

_____. "Timing in music performance and its relations to music experience" in Generative Processes in Music, ed. John A. Sloboda (Oxford:Clarendon, 1988): 27-51.

GIBBON, John, and Lorraine Allan, eds. Timing and Time Perception, 423 (May 1984) of Annals of the New York Academy of Sciences.

GIBSON, J. J. "Events are Perceivable But Time Is Not", The Study of Time 2 (1975): 295-301.

GREGORY, Andrew H. "Listening to Polyphonic Music", Psychology of Music 18 (1990): 163-170.

GRIFFITHS, Paul. György Ligeti. London: Robson Books, 1983.

HACKMAN, Willis Haverstock. A Clarification & Reconstruction of the Concept of Meter.... Ann Arbor, Mich.: Xerox Univ. Microfilm, 1975.

HANDEL, Stephen and James S. Oshinsky. "The meter of syncopated auditory polyrhythms", Perception & Psychophysics, 30 (1981): 1-9.

HARVEY, Jonathan. "Stockhausen: Theory and Music", The Music Review 29 (1968): 130-141.

HASTY, Christopher F. "On the Problem of Succession and Continuity in Twentieth-Century Music." Music Theory Spectrum 8 (1986): 58-74.

_____. "Rhythm in Post-Tonal Music: Preliminary Questions of Duration and Motion", Journal of Music Theory, 25 (1981): 183-216.

HATZIS, Christos. "Chronochroma." Interface (1979): 73-90.

HELM, Everett. Bartok. London: Faber and Faber, 1971.

_____. "The Music of Béla Bartók", European Music in the Twentieth Century, ed. Howard Hartog. Harmondsworth, England: Pelican Books, Rev.ed., 1961.

HINTON,Geoffrey, and James ANDERSON. Parallel Models of Associative Memory. Hillsdale, N.J.: Lawrence Erlbaum Assoc., 1981.

HIRSH, Ira J., Caroline B. MONAHAN, Ken W. GRANT, and Punita G. SINGH. "Studies in auditory timing: 1. Simple patterns", Perception & Psychophysics 47 (1990): 215-226.

HOLBROOK, Morris B. and Punam Anand. "Effects of Tempo and Situational Arousal on the Listener's Perceptual and Affective Responses to Music", Psychology of Music, 18 (1990): 150-162.

HOWE, Michael A.J. Introduction to Human Memory: A Psychological Approach. New York: Harper & Row, 1970.

HYDE, Martha M. "A Theory of Twelve-Tone Meter", Music Theory Spectrum 6 (1984): 14-51.

IVES, Charles E. Memos, ed. John Kirkpatrick. New York: W.W. Norton, 1972.

JACKENDOFF, Ray, and Fred Lerdahl. "Generative Music Theory and its Relation to Psychology", Journal of Music Theory 25/1 (1981), 45-90.

JONES, Daniel. "Some Metrical Experiments", The Score (June 1950): 32-48.

JONES, Mari Riess. "A tutorial on some issues and methods in serial pattern research", Perception & Psychophysics 30 (1981): 492-504.

JONES, Mari Riess, Marilyn Boltz, and Gary Kidd. "Controlled attending as a function of melodic and temporal context", Perception & Psychophysics 32 (1982), 211-218.

KAMINSKA, Zofia, and Pete MAYER. "Metamorphosis, migration and materialization: shades of illusion in the perception of music", presented at the 2nd International Conference on Music and the Cognitive Sciences, Cambridge, England, Sept. 1990.

KENDALL, Roger A. and Edward C. CARTERETTE. "The effect of melodic and temporal contour on recognition memeory for pitch change", Perception & Psychophysics 41/6

(1987): 576-600.

KIELIAN-GILBERT, Marianne. "The Rhythms of Form: Correspondence and Analogy in Stravinsky's Designs", Music Theory Spectrum, 9 (1987): 42-66.

KRAMER, Jonathan D. "Moment Form in Twentieth-Century Music", The Musical Quarterly 64/2 (1978): 177-194.

_____. "New Temporalities in Music", Critical Inquiry 7 (1981): 539-56.

_____. "Studies of Time and Music: a bibliography", Music Theory Spectrum 7 (1985): 72 -106.

_____. "Temporal Linearity and Nonlinearity in Music", The Study of Time 5 (1985): 126-137.

_____. The Time of Music. New York: Schirmer Books, 1988.

KREBS, Harald. "Some Extensions of the Concepts of Metrical Consonance and Dissonance", Journal of Music Theory, 31 (1987): 99-120.

KROO, György. A Guide to Bartók, transl. Ruth Pataki and Mária Steiner. Boston: Branden Press, 1971.

KUPFERMAN, Meyer. "The Acrobat of Apollo", special issue of Perspectives of New Music 9 & 10 (1971): 141-149.

LEE, C. S. "The Rhythmic Interpretation of Simple Musical Sequences: Towards a Perceptual Model", Musical Structure and Cognition, pp. 53-69.

LENDVAI, Ernö. The Workshop of Bartók and Kodály. Budapest: Editio Musica, 1983.

LERDAHL, Fred, and Ray Jackendoff. "Generative music theory and its relation to psychology", Journal of Music Theory 25 (1981): 45-90.

_____. A Generative Theory of Tonal Music. Cambridge, Mass.: MIT Press, 1983.

_____. "Toward a Formal Theory of Tonal Music", Journal of Music Theory 21/1 (1977): 14-71.

_____. "On the Theory of Grouping and Meter", The Musical Quarterly, 67 (Oct. 1981): 486-489.

_____. "An Overview of Hierarchical Structure in Music",

Music Perception 1 (1984): 229-252.

LESTER, Joel. The Rhythms of Tonal Music. Carbondale, Ill.: Southern Illinois University Press, 1986.

LEWIN, David. "Some Investigations into Foreground Rhythmic and Metric Patterning", Music Theory: Special Topics, 101-137.

LIGETI, Gyorgy. "Pierre Boulez", Die Reihe 4 (1960):36-62.

_____. Ligeti in Conversation. With Péter Várnai, Josef Häusler, and Claude Samuel. London: Eulenburg Books, 1983.

LOCHHEAD, Judy. "Temporal structure in recent music", The Journal of Musicological Research 6 (1986): 49-93.

LOFTUS, Geoffrey, and Elizabeth F. Loftus. Human Memory: The Processing of Information. Hillsdale, N.J.: Halsted Press, 1976.

LUTOSLAWSKI, Witold. Lutoslawski, ed. Ove Nordwall, trans. C. Gibbs. Stockholm: Edition Wilhelm Hansen, 1968.

_____, in conversation with Bálint András Varga. Lutoslawski Profile. London: Chester Music, 1974.

_____, in conversation with Tadeusz Kaczynski. Conversations with Witold Lutoslawski, trans. Yolanta May. London: Chester Music, 1972, trans. & rev. 1984.

MacKAY, John. "Some Psychophysical and Psychological Aspects of the Experience of Duration as Related to the Perception of Music." Unpublished paper.

_____. "Some Comments on the Visual/Spatial Analogy in Studies of the Perception of Musical Texture", ex tempore 1/2 (1981): 39-58.

McADAMS, Stephen. "Music: A science of the mind?", Contemporary Music Review 2 (1987): 1-61.

_____. "Spectral Fusion and the Creation of Auditory Images" in M. Clynes (Ed.): Music, Mind, and Brain (New York: Plenum Press, 1982): 279-298.

McPHEE, Colin. "Eight to the Bar", Modern Music XX (1943):

MAYR, Albert. "Creative Time-Organization versus Subsonic Noises." Diogenes 121 (1983): 45-63.

_____. "Sketches for a Low-Frequency Solfege." Music Theory Spectrum 7 (1985): 107-113.

MEYER, Leonard B. Emotion and Meaning in Music. Chicago: The University of Chicago Press, 1956.

_____. Music, The Arts, and Ideas. Chicago & London: The University of Chicago Press, 1967.

MINSKY, Marvin. "Music, Mind, and Meaning", Music, Mind, and Brain (M. Clynes, ed.; New York: Plenum Press, 1982): 1-19.

MOLES, Abraham. Information Theory and Esthetic Perception. Urbana: University of Illinois Press, 1966, trans. Joel E. Cohen, of Théorie de l'information et perception esthètique.

MONAHAN, Caroline B. and Ira J. HIRSH. "Studies in auditory timing: 2. Rhythm patterns", Perception & Psychophysics 47 (1990):

MURSELL, James L. The Psychology of Music. New York: W.W. Norton, 1937.

NARMOUR, Eugene. The Analysis and Cognition of Basic Melodic Structures: The Implication - Realization Model. Chicago: The University of Chicago Press, 1990.

ORLOV, Henry F. "The Temporal Dimensions of Musical Experience", Musical Quarterly, 65 (1979): 368-378.

PERRY-CAMP, Jane. "Time and Temporal Proportion: the Golden Section Metaphor in Mozart, music, and history", The Journal of Musicological Research 3, n.1-2 (1979): 133-176.

PIKE, Alfred. A Phenomenological Analysis of Musical Experience and other related essays. New York: St. John's University Press, 1970.

PITT, Mark A., and Caroline B. MONAHAN. "The perceived similarity of auditory polyrhythms", Perception & Psychophysics 41/6 (1987): 534-546.

POVEL, D.-J., and P. ESSENS. "Perception of temporal patterns." Music Perception 2 (1985): 411-440.

REICH, Steve. Writings About Music. Halifax: NSCAD Press, 1974.

REPP, Bruno. "Expressive Microstructure in Music: A Preliminary Perceptual Assessment of Four Composers' 'Pulses'", Music Perception 6/3 (spring 1989): 243-274.

REYNOLDS, Roger. Mind Models. New York: Praeger, 1975.

_____. "A perspective on form and experience", Contemporary Music Review 2/1 (1987): 277-308.

ROCHBERG, George. "The Structure of Time in Music: Traditional and Contemporary Ramifications and Consequences", The Study of Time 2 (1975): 136-149.

ROTHSTEIN, William. Phrase Rhythm in Tonal Music. New York: Schirmer Books, 1989.

ROWELL, Lewis. "The Creation of Audible Time", The Study of Time 4 (1981): 198-210.

_____. "The Subconscious Language of Musical Time", Music Theory Spectrum 1 (1979): 96-106.

SACHS, Curt. Rhythm and Tempo: A Study in Music History. New York: W.W.Norton, 1953.

SALLIS, John. "Time, Subjectivity, and the Phenomenology of Perception", The Modern Schoolman 48 (May 1971): 343-357.

SCHACTER, Carl. "Rhythm and Linear Analysis: A Preliminary Study", The Music Forum 4 (1976): 281-334.

_____. "Rhythm and Linear Analysis: Durational Reduction", The Music Forum 5 (1980): 297-232.

_____. "Rhythm and Linear Analysis: Aspects of Meter", The Music Forum, 6 (1987): 1-59.

SCHULDT, Agnes Crawford. "The Voices of Time in Music", The American Scholar, 45(1976): 549-559.

SHAFFER, L. H. "Rhythm and Timing in Skill", Psychological Review 89/2 (March 1982): 109-122.

SKARDA, Christine A. "Alfred Schutz's phenomenology of music", The Journal of Musicological Research 3 (1979): 75-132.

SLOBODA, John A. "Immediate Recall of Melodies", Musical Structure and Cognition, pp. 143-167.

_____. The Musical Mind: the cognitive psychology of music. Oxford: Clarendon Press, 1985.

_____. "Why do musical events cause emotional responses?" presented at the 2nd International Conference on Music and the Cognitive Sciences, Cambridge, England, Sept. 1990.

SMITH, Jacqui, Steven HAUSFELD, Roderick P. POWER, and Angela GORTA. "Ambiguous musical figures and auditory streaming", Perception & Psychophysics, 32 (1982):454-464.

SMITHER, Howard Albert. "The Rhythmic Analysis of 20th-Century Music", Journal of Music Theory 8 (1964): 54-88.

SMYTH, David H. "Large-Scale Rhythm and Classical Form", Music Theory Spectrum 12/2 (1990): 236-246.

STEIGER, Howard, and Albert S. Bregman. "Competition among auditory streaming, dichotic fusion, and diotic fusion", Perception & Psychophysics 32 (1982), 153-162.

STEVENS, Halsey. The Life and Music of Béla Bartók. London: Oxford University Press (1953), rev. ed. 1964.

STOCKHAUSEN, Karlheinz. "Actualia", Die Reihe 1 (1958): 45-51.

_____. "The Concept of Unity in Electronic Music", trans. Elaine Barkin, Perspectives of New Music 1 (fall 1962): 39-48.

_____. "...how time passes...", trans. Cornelius Cardew. Die Riehe 3 (1959): 10-40.

_____. "Structure and Experiential Time", trans. Leo Black, Die Reihe 2 (1959): 64-74.

_____. Stockhausen on Music. Lectures and interviews compiled by Robin Maconie. London: Marion Boyars, 1989.

STUCKY, Steven. Lutoslawski and his music. Cambridge, Eng.: Cambridge University Press, 1981.

TENNEY, James. Meta+ Hodos & META Meta+ Hodos: A Phenomenology of 20th Century Musical Materials & an Approach to the Study of Form. Frog Peak Music, 1988, 2nd rev. edition.

_____ and Larry POLANSKY. "Temporal Gestalt Perception

in Music", Journal of Music Theory 24 (1980): 205-41.

THOMPSON, William Forde. "Composer-Specific Aspects of Musical Performance: An Evaluation of Clynes's Theory of Pulse for Performances of Mozart and Beethoven" in Music Perception 7.1 (1990): 15-42.

TODA, M. "Time and the Structure of Human Cognition", The Study of Time 2 (1975): 314-324.

TOOP, Richard. "New Music and Neurobiologic Research: Can They Meet?" in M. Clynes (Ed.): Music, Mind, and Brain (New York: Plenum Press, 1982): 387-398.

TOUGAS, Yves, and Albert S. BREGMAN. "Auditory streaming and the continuity illusion", Perception and Psychophysics 47 (1990):121-126.

WOODROW, H. "The Perception of Time" in Handbook of Experimental Psychology (ed. S.S. Stevens) Wiley, New York.

WRIGHT, James K., and Albert S. BREGMAN. "Auditory stream segregation and the control of dissonance in polyphonic music", Contemporary Music Review 2/1 (1987): 63-92.

XENAKIS, Iannis. "Concerning Time", Perspectives of New Music (winter 1989): 84-92.

_____. Formalized Music: Thought and Mathematics in Composition. Bloomington: Indiana Univ. Press, 1971.

YESTON, Maury. The Stratification of Musical Rhythm. New Haven: Yale University Press, 1976.

ZUCKERKANDL, Victor. Sound and Symbol: Music and the External World. New York: Pantheon Books, 1956.

APPENDIX A

G L O S S A R Y O F T E R M S

A.P.I. - ATTACK POINT INTERVAL -- term used by Yeston (1975:39-41) and others for INTER-ONSET INTERVAL (q.v.).

AUDITORY STREAMING -- the tendency in certain contexts for the listener to perceive a succession of notes as falling into two separate lines or "streams"; this is most commonly achieved through registral separation, and depends on our tendency to group by similarity. It is usually associated with a very fast rate of presentation (Monahan et al. [1987] put that rate at 8-10 notes per second). See Chapters II and VIII. Also called FISSION, STREAM SEGREGATION, PERCEPTUAL STREAMING.

BACKGROUND -- the level of the slowest-moving rhythms of the music. Background rhythms are created by the more pronounced accents and groupings of lower levels. See LEVEL, FOREGROUND.

BEAT -- the basic unit of metric organization, being the subdivision of the bar. It is often equated with pulse, though Epstein has stressed that pulse is the felt periodicity whereas beat is the expected point of reiteration. See Chapter III.

BIT - in INFORMATION THEORY, a unit measure of information; short for binary digit and strictly speaking therefore an aspect about which a simple yes/no judgement can be made.

CHRONOMETRIC TIME - see CLOCK TIME.

CHUNK - "1.Loosely, an aggregate of smaller units of information that have been grouped mentally to form a larger single percept. 2. A synonym for perceptual group." (Butler, p.223.)

CLOCK TIME - time as measured by clocks. Clock time is the time referred to by metronome markings, psychology experiments where "sounds of 20 ms. were played..." etc. Named to distinguish it from less easily definable time measurement such as SUBJECTIVE TIME, which is the individual's experienced sense of a specific duration. See Chapter I for further discussion. Also called REAL TIME, OBJECTIVE TIME, CHRONOMETRIC TIME. see also

SUBJECTIVE TIME.

COMPOSITE RHYTHM - The rhythm formed by the combining of all attacks of the foreground level. Yeston calls this a resultant rhythm. (Yeston, p.77) When there is a simple relationship between these attacks, the composite rhythm is quite prominent. In complex situations, however, a horizontal listening mode may take precedence.

CONSONANCE / DISSONANCE (rhythmic) -- the alignment or lack of alignment between two (or more) series of pulses or other periodicities. Consonance usually exists when one level of periodicity is a simple multiple of another (most commonly in a 2:1, 3:1 or 4:1 ratio). The term may have been first used in conjunction with rhythm by Charles Seeger (1930). The concept was developed extensively by Yeston (1976), and crucially refined by Krebs (1987), who pointed out that two series of pulses with identical periods sound dissonant if they do not share initiation points (producing a TYPE B DISSONANCE). My analyses suggest that Type B dissonances may be in fact a particularly harsh variety. See also LEVEL OF CONSONANCE.

CONTRA-RHYTHMIC -- Berry's term (1976, 193) for lines or layers whose rhythms are in marked contrast, as opposed to HOMO-RHYTHMIC and HETERO-RHYTHMIC (q.v..)

DENSE -- Having many notes within a short period of time and/or registral space. Opposite of SPARSE; both are relative terms used to describe TEXTURE.

DENSITY -- The number of notes, STRINGS, LAYERS, etc. per unit time: a major property of TEXTURE.

DISSONANCE -- See CONSONANCE/DISSONANCE.

DYNAMICS -- the volume of sound: louds and softs. Subtle dynamic stress is often combined with a slight slowing of tempo to mark the downbeat of a bar in metric passages, and can thus be very influential in the perception of periodic organization above that of the pulse level, even when subtle. Dynamic differentiation can also figure in perception of strata delineation.

EXPERIENTIAL TIME --see SUBJECTIVE TIME.

FIGURE/GROUND -- A term borrowed from the visual arts and Gestalt grouping, whereby an image is seen as prominent and distinct from other visual information which functions as a less significant background. The musical

equivalent is that of a melody and accompaniment. As figure and ground also have musical meanings which are different to these, I place the words in quotation marks when referring to their analogic function.

FISSION -- see AUDITORY STREAMING.

FOREGROUND -- the surface activity of the music, as represented by all the notes in the score. See LEVEL.

FUSION -- The opposite of AUDITORY STREAMING. I take this in its broadest sense, suggested by Bregman (1990, p.68), to mean the grouping together of component frequencies or features of sounds into appropriate descriptions. It usually implies a situation where the components are not easily perceived as separate.

GESTALT, pl. GESTALTEN -- collection of data which the mind grasps as a single shape or structure, being able to retain that shape or structure separate from other data surrounding it. See Chapter II.

GESTALT PSYCHOLOGY -- school of thought that suggests we "organize formal properties of the objects that we perceive visually according to several principles such as similarity, proximity, and good continuation" (Butler, 104). Used extensively in recent musical research. See Chapter II.

GROUND -- Two meanings: one relates to the bass theme of a passacaglia (see Chapter III) and the other to the FIGURE/GROUND phenomenon. In the text, I place the word in quotation marks to indicate the latter meaning.

GROUPING -- "partitioning of music's time span by associations perceived within and among punctuated or articulated unit-orderings of events." Berry Structural Functions of Music, p.306. Grouping is a process, and although the process itself may be very complex in specific cases, the concept is very simple: certain data will be chunked because it seems to belong together. Lerdahl and Jackendoff point out that this may be a spontaneous process. ("On the Theory of Grouping and Meter", p.480.) Benjamin points out that the level of a group is "a function of its length in relation to that of the entire context in which it is found." He also notes that groups on various levels can be open-ended. A Theory of Musical Meter, p.377.

HETERORHYTHMIC -- "mild and very local diversification" (Berry 1976, p.193) in two or more lines or layers of

music. Compare CONTRA-RHYTHMIC, HOMO-RHYTHMIC.

HOMO-RHYTHMIC -- Berry's term (1976, p.193) for lines whose rhythms are identical. I use the term RHYTHMIC UNISON. Compare HETERORHYTHMIC, CONTRARHYTHMIC.

HYPERMEASURE. -- a unit corresponding to a measure or bar but on the next highest level, such as a four-bar phrase. See HYPERMETER.

HYPERMETER -- term used to describe a relationship between bars and groups of bars that parallels the relation between beats and bars; in other words, the discussion of the metric-style relationship between a bar level or higher, with the next hierarchical level. The concept has limited validity as it is not rate-restricted.

INFORMATION THEORY - a theory of perception which uses the model of a computer for the human mind; it concerns the encoding of information gathered by the senses in BITS, storage of that information in LONG-TERM MEMORY, and retrieval as necessary.

INTEGRAL TIME -- see SUBJECTIVE TIME.

INTER-ONSET INTERVAL (IOI) -- the distance between the onset attacks of two adjacent attacks in a STRING of attacks, measured in note values or seconds. The convenience of such a measurement is that it does not require identical durations to illustrate the audible regularity of their starting points. The term is used widely in the field of psychoacoustics, which is why I choose it over the equivalent term ATTACK POINT INTERVAL.

JND -- see JUST-NOTICEABLE DIFFERENCE.

JUST-NOTICEABLE DIFFERENCE -- "the smallest amount of change in a stimulus that can be detected at an accuracy level significantly above chance." (Butler, 1992).

LEVEL (hierarchical) -- originally from Schenker's work; applied in rhythmic investigations by Yeston and others. Refers to a hierarchy as revealed by analysis with the "background" representing the essential form or skeletal structure, and "foreground" being represented by all the notes of the score. Middleground levels are all the intermediate levels. In this paper, a level is defined by the rate of similar events: sixteenth notes grouped by fours in 4/4 meter in a four-bar phrase exhibit a sub-pulse level (sixteenth notes), pulse level (four-

note groups), bar level (series of downbeats), phrase level (four-bar group) and probably some intermediate levels between the bar and phrase. In this case, the sixteenth-note levels would be the foreground level; all the others are middle-ground. See also LEVEL OF CONSONANCE.

LEVEL OF CONSONANCE - the level on which the dissonances of lower hierarchical levels are in alignment. For example, the level of consonance of a string moving in dotted quarters and one moving in quarters (in the same tempo) would be the level of the dotted half.

LOCAL -- events which happen locally are temporally close to each other, being contained within a short period of time, most likely that of the PERCEPTUAL PRESENT.

LONG-TERM MEMORY -- see MEMORY, MEMORY CODIFICATION.

METER -- Meter refers to the grouping of the basic pulse by another, usually regular, pulse or beat, and therefore is expressible only through the relationship of one level to a hierarchically-adjacent one. Meter seems extremely RATE-dependent; there seems to be a fairly narrow range in which regularity is interpreted as meter. When I use the term METER, it is in the most conventional form referring to the stress pattern as traditionally indicated by the time signature and barlines. Thus: "a 2/4 meter is implied". I also use the term of METRIC LEVEL as a simple way of referring to that level which groups pulses, usually by 2, 3, or 4.

MEMORY -- Psychologists divide memory into SHORT-TERM and LONG-TERM; short-term coincides with the PERCEPTUAL PRESENT and is the part of memory to which we have direct access. This is a buffer zone, and has limited space, thought to be able to contain no more than 5-9 items (McAdams, 1987:21). It is a temporary storage for interpreted data from the environment as well as any data which might be retreived from long-term memory. Anything beyond this time limit is considered to be in long-term memory, which has virtually limitless storage space. Long-term memory stores data from the short-term buffer zone and requires subsequent retrieval to be accessed by the conscious mind. Which data is chosen for storage, and how that data is stored for efficient or practical retrieval is extremely variable and dependent on the individual. Such variables make investigation in this field extremely difficult. See also MEMORY CODIFICATION, PERCEPTUAL PRESENT.

MEMORY CODIFICATION - the way in which the brain packages information for more efficient storage and retrieval. This is not fully understood yet, but research shows there are certain tendencies to organize simple material in certain ways. GESTALT theory suggests some of these.

ORNAMENTAL/TEXTURAL LEVEL -- my term for the level of events which recur at a rate faster than ca. 0.10". See Ch. III, pp.61-63, Ch. IV, passim., and Appendix B.

OSTINATO - a musical figure that repeats exactly and numerous times -- See Chapter III for more detail.

OUTSIDE-TIME - term coined by Xenakis to refer to those compositional processes which do not depend on time for their determination: thus the determination of which key and instrumentation to be used in a work are outside-time activities, as opposed to the composing of the rhythm of a melody, which relies on a particular set of time values.

PATTERN RECURRENCE -- the immediate repetition of any recognizable musical figure. It is a strong indicator of periodicity when the pattern recurs in a regular cycle. Described by Yeston (1975), 50-53.

PERCEPTUAL PRESENT - The "now" as perceived by means of short-term memory; all data back into the immediate past and perhaps into the "predictable" immediate future to a probable limit of 7"-10", i.e. the range of SHORT-TERM MEMORY. See Appendix B for estimates of length.

PERCEPTUAL STREAMING - see AUDITORY STREAMING.

PERIOD - the length of time elapsing between two events in a stream of regular events. Measured in seconds or in note values.

PERIODIC -- occuring at regular intervals in time.

PERIODICITY -- the repetition of any event at regular intervals in time.

POLYRHYTHM -- basically, any presentation of more than one rhythmic idea at a time. Berry's refinement of HETERORHYTHMIC and CONTRARHYTHMIC are somewhat more useful, as polyrhythm is reminiscent of polyphony. Polyphony suggests a more carefully-balanced design of similar intertwined threads, and as such is less typical of a 20th-century polyrhythmic composition.

PULSE -- the most basic periodic unit, usually between 40-120 beats per minute. See Chapter III.

RATE -- the speed at which a periodic interval recurs, usually measured by clock time.

REDUNDANCY (information theory) -- those aspects of a message which do not contribute new information but instead increase probabilities of outcomes indicated by previous information. Redundancy serves to control the rate of information transmitted and enhance the receiver's encoding processes. An ostinato is a musical example of high redundancy.

RHYTHMIC CONSONANCE/DISSONANCE -- see CONSONANCE/DISSONANCE (rhythmic)

RHYTHMIC FISSION -- see AUDITORY STREAMING.

RITARDANDO - slowing down (of a pulse, set of notes, etc.)

SHORT-TERM MEMORY -- see MEMORY, PERCEPTUAL PRESENT.

SPARSE -- Having few notes within a short period of time and/or registral space. Opposite of DENSE; both are relative terms. Used to describe TEXTURE.

STATISTICAL FIELD -- a perspective reflecting a technique of composition (or analysis) articulated by Stockhausen and Ligeti (among others) whereby a passage is viewed in terms of its overall character, and constructed (or analyzed) by parameters such as the TEMPORAL DENSITY of notes and the level and fluctuation rate of dynamics.

STOCHASTIC -- Xenakis's production of STATISTICAL FIELDS incorporating laws of probability.

STRAND -- A sub-layer of musical material. It may be composed of a few instruments playing complementary material which nevertheless is perceived as very closely related -- usually homo- or heterorhythmic. I distinguish it from LAYER as being less substantial. A strand is part of a layer or texture; one voice of a canon would be a strand. See Chapter IV.

STRATUM (pl. STRATA) a layer of musical material. Introduced into discussions of rhythmic analysis by Yeston (1976). However, I use the term more narrowly than Yeston, as I reserve it for referring to one of two or more audibly-distinct layers which retain a certain independence at several levels. A stratum usually

involves a certain degree of inner complexity as well.

STREAM SEGREGATION -- see AUDITORY STREAMING.

STRING -- a term from computer languages denoting "a succession of literal elements" and used by Yeston (1975:35) to refer to musical lines.

SUBJECTIVE TIME -- Time as experienced, and therefore not fully compatible with clock durations. Epstein calls this INTEGRAL TIME, and defines it as "time enriched and qualified by the particular experience within which it is framed." (1981, 183) Stockhausen (among others) refers to it as EXPERIENTIAL TIME. Compare with CLOCK TIME.

SUB-PULSE -- A subdivision of a pulse. The reiteration of a sub-pulse produces a periodic layer. The sub-pulse level refers to the level below (faster than) that of pulse at which (periodic) events occur.

TEMPO (pl. TEMPI) - the speed of a piece. This is somewhat subjective, as it depends on the unit chosen for measurement. However, it seems that tempo has a fairly narrow band which I put at approximately 40-120 beats per minute. Beats which move much faster or slower than that are halved or doubled to produce a realistic tempo. A piece of music can present several tempi simultaneously; this is a result of (and therefore indicator of) polyrhythm.

TEMPORAL DENSITY -- the number of notes or other events in a given period of time; a parameter of a STATISTICAL FIELD or TEXTURE.

TEXTURE - Traditionally, musical texture refers to the arrangement of notes in a passage. Sparse texture consists of few notes per time unit, and/or spread over a wide registral range, where each component can be heard individually. Dense texture is composed of many notes sounding together or close together in time, and/or compressed into a portion of the registral range. A more modern definition, which I use throughout this paper, adds to this definition the prerequisite that there is little melodic activity as well, so that the properties of the texture are in fact the focus of the listener's attention. See Chapter IV for further discussion and examples.

TIMBRE -- the particular quality of a sound, such as an oboe timbre, a mellow timbre, a plucked string timbre.

Timbre appears very important in the perceptual segregation of STRANDS and STRATA. Traditionally, a change of orchestration usually implied a change of line. In the twentieth century, composers began to explore the potential of timbral shifts within one line: this is frequent in the first movement of Ligeti's Chamber Concerto.

TYPE B DISSONANCE -- see CONSONANCE / DISSONANCE.

WEBER FRACTION -- derived from the research of a 19th-century physicist. It provides a way of calculating the amount of temporal deviation from exact integral ratios tolerated in the comparison of durations. Epstein summarizes the research, and places a Weber fraction of about 5% when the durations concerned fall in the range of 0.4-2.0 seconds. In other words, a duration in that range would have to change by more than 5% for the change to be perceived as such. Outside that range the fraction rises steeply, and has been put at 18% for 2.5 seconds, and 33% for 15 seconds. (Epstein, "Tempo Relations", p.41.)

APPENDIX B

ESTIMATES of PERCEPTUAL BOUNDARIES

"estimates range from a timeless instant up to several seconds in duration" ---------- Butler, p.144

LOWER LIMITS below which rhythmic patterns (temporal ordering) become difficult to distinguish

1. 0.125"
4. 0.5"
5. 0.1"
6. 0.05"
7. 0.06"
8. 0.05"

UPPER LIMITS of PERCEPTUAL PRESENT

1. 10"
2. seldom more than 5"
3. in rare cases, 7"
7. 8.0"
9. generally 2-5", sometimes up to 10"
10. 8"-10", "up to 20 seconds under extreme conditions"

1. Clynes & Walker, p.174. Stated as "0.1 Hz to 8 Hz", to be the region of musical rhythm -- "The rhythms more rapid than 8-10 per second which we can experience are exerienced not as composed of individual events but as continous sensation, that is, as a particular kind of integral of their dynamic characteristics." ibid., p.175.

2. Fraisse, quoted in Butler, p.144

3. Reynolds, "A Perspective on Form and Experience"

4. "two sound events that are similar in character and arrive within about 25-50 milliseconds of each other will tend to be integrated over time and perceptually fused into a single event; whereas those separated by more than 50 milliseconds are easily heard as separate events." McAdams, "Music: a science of the mind?", p.37.

5. "The ability to resolve patterns into separate pitches starts to disappear at rates above 10 notes per second", Monahan, Kendall, and Carterette, p.581.

6. Ligeti states the threshold variously as "less than fifty milliseconds" (Griffiths, p.26); "over 20 per second" (Ligeti in conversation, p.39) and "18 separate sounds per second to reach the threshold" (ibid., p.22).

7. Stockhausen puts lower limit at 1/16" ("...how time passes...") and puts the region of meter/rhythm between ca. 1/8 and 8 secs. ("The Concept of Unity", p.43.)

8. Hackman -- p.118 "sounds must be separated by at least one-twentieth of a second if they are to be perceived as distinct." I assume he actually means that the **attacks** of sounds (inter-onset interval) must be separated by that much.

9. Hasty puts the limit of the perceptual present at 2"-5", but says that due to "integrations" it can extend to 10", with a maximum of 8 to 24 pulses. (pg.186) He also suggests that a skilled musician such as a tabla master, for example, "could be capable of sensing unities of much greater duration".

10. Kramer, The Time of Music, p.371.

APPENDIX C

REASONS for the CHOICE of WORKS

My initial motivation for this study was an interest in polyrhythmic structures. Although there has been a welcome increase in the amount of research into rhythmic structure during the past few decades, the majority of it has tended to avoid the type of complex structures that typifies this century's explorations. There seemed insufficient evidence to believe that exhaustive study of monorhythmic structure would lead us any closer to an understanding of polyrhythmic structure. In other words, there is a danger in assuming that polyrhythmic structure is simply a piling up of monorhythmic layers. It appears more likely that the interaction of layers has a significant effect on our perception of them. I chose to analyze some polyrhythmic works and see what could be deduced. At a later stage, it became apparent that a study of the nature and functions of periodicities in general would be an essential preliminary step. Therefore, I searched for works that incorporated both polyrhythmic structures and a variety of periodic events.

The choice of the historical period of the twentieth century was immediate: as a composer I have been most influenced by concepts, forms, and rhythms of this century and I have been disappointed in the quantity of recent research which bases its conclusions on compositional models of previous eras. Much music from other centuries is very pleasing to me, but it remains unmistakeably more distant from my own perspective. The variety of the 20th century is to me irresistable, and reflects an environment which I can usually imagine with much greater accuracy than I can for that of Haydn or Schumann.

In order to keep the discussion within reach of theorists who are less familiar with the avant-garde, I chose to limit myself to works from the general "mainstream tradition" in which the composer has been steeped in Western classical styles. It seemed that works from other styles and cultures would introduce too many complications into an already complex task. In particular, I was interested in choosing works for which the scores are quite specific, easily decipherable to

traditionally-trained eyes and easily imaginable to traditionally-trained ears - thus ruling out, for example, all electronic works and works which include extended aleatoric techniques. I also wished to choose works which are reasonably well-known, readily accessible in reasonably good qualities of recordings, and apparently well-respected by a wide audience.

Given all these constraints, I then chose works in which the periodic and polyrhythmic components seemed to contribute to their elegance. This led to my final choices: Bartok's Music for Strings, Percussion & Celesta, Lutoslawski's Concerto for Orchestra, and Ligeti's Chamber Concerto. Initially, I hesitated about subjecting works of this stature to my unadjusted calipers. On reflection, however, it seemed likely to be easier, more rewarding, and more valuable to study the work of composers who have obvious skill in presenting their ideas with clarity. The fact that the three works might be understood as representing an historical progression was not deliberate, but rather a result of searching for a variety of compositional approaches.

The fact that the three composers are all of Eastern European origin did not occur to me at first, but I suspect that the particular modes and rhythms which are characteristic of that region's heritage influenced my choice. (I have a bias towards music that incorporates "strong" and "irregular" rhythms, and non-major modes.) In addition, the choice shows my predilection for a certain degree of intellectual organization of the sort manifest in fugal and canonic structures.

These three works are by no means intended to illustrate the widest range of possible approaches to rhythmic organization, but I believe they represent a sufficient variety to provide good material for discussion. Certain shared features, such as the mixed timbral pallette and relatively large size of the ensembles, seemed a favourable ingredient to the discussion.

APPENDIX D

CONVERTING METRONOME MARKS to CLOCK TIME

Metronome marks indicate the number of units per minute.

FORMULA:

If metronome mark is notated as ♩=x, then
60 ÷ x = duration of the quarter note, in seconds.

(If metronome mark is stated in terms of eighth note rather than quarter note, all column headings must be halved; metronome marks stated in terms of half note are indicated in brackets.)

Figures were calculated to 6 decimal places for each column, and rounded off to 3 decimal places. It is recommended to round them off further for musical use to reflect perceptual discrimination and performance variation; see Chapter I, pp.16-19.

When my calculations resulted in a figure whose fourth decimal place is a 5, the third decimal place numeral has been rounded up; i.e., for ♩=92, 60 ÷ 92 = 0.6521739, and 0.6521739 x 3 = 1.9565217. Therefore, the quarter note is indicated as 0.652", and a dotted half is indicated as 1.957".

METRONOME MARK to CLOCK TIME CONVERSION CHART

all figures in these columns indicate duration in seconds

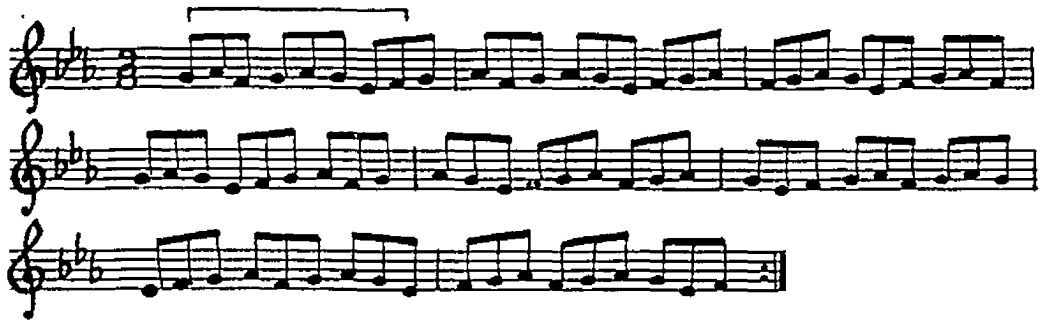
♩ = x (𝅗𝅥 = x)	𝅘𝅥𝅯	𝅘𝅥𝅮	♩	𝅗𝅥	𝅗𝅥.	𝅝
	(𝅘𝅥𝅯)	(𝅘𝅥𝅮)	(♩)	(𝅗𝅥)	(𝅗𝅥.)	(𝅝)
144	.104	.208	.416	.833	1.250	1.666
140	.107	.214	.429	.857	1.286	1.714
136	.110	.221	.441	.882	1.324	1.765
132	.114	.227	.454	.909	1.363	1.818
128	.117	.234	.469	.938	1.406	1.875
124	.121	.242	.484	.968	1.452	1.935
120	.125	.250	.500	1.000	1.500	2.000
116	.129	.259	.517	1.034	1.552	2.069
112	.134	.268	.536	1.071	1.607	2.143
108	.139	.278	.556	1.111	1.667	2.222
104	.144	.288	.577	1.154	1.731	2.308
100	.150	.300	.600	1.200	1.800	2.400
96	.156	.312	.625	1.250	1.875	2.500
92	.163	.326	.652	1.304	1.957	2.609
90	.167	.333	.667	1.333	2.000	2.667
88	.170	.341	.682	1.367	2.045	2.727
86	.174	.349	.698	1.395	2.093	2.791
84	.178	.357	.714	1.429	2.143	2.857
82	.183	.366	.732	1.463	2.195	2.927
80	.187	.375	.750	1.500	2.250	3.000
78	.192	.385	.769	1.538	2.308	3.077
76	.197	.395	.789	1.579	2.368	3.158
74	.203	.405	.801	1.622	2.432	3.243
72	.208	.417	.833	1.667	2.500	3.333
70	.214	.429	.857	1.714	2.571	3.429
68	.221	.441	.882	1.765	2.647	3.529
66	.228	.455	.909	1.818	2.727	3.636
64	.234	.469	.938	1.875	2.813	3.750
62	.242	.484	.968	1.935	2.903	3.871
60	.250	.500	1.000	2.000	3.000	4.000
58	.259	.517	1.034	2.069	3.103	4.138
56	.268	.536	1.071	2.143	3.214	4.286
54	.278	.555	1.111	2.222	3.333	4.444
52	.288	.577	1.154	2.308	3.462	4.615
50	.300	.600	1.200	2.400	3.600	4.800
48	.312	.625	1.250	2.500	3.750	5.000
44	.341	.682	1.364	2.727	4.091	5.455
40	.375	.750	1.500	3.000	4.500	6.000
36	.417	.833	1.667	3.333	5.000	6.667
32	.469	.938	1.875	3.750	5.625	7.500

APPENDIX E

EXAMPLES of METER OVERRIDES

The following examples illustrate the strength of metric organization over other periodicities. The first gives a simple pitch pattern whose period is dissonant with the period of the notated bar. The second gives a partial cycle of isorhythm. To my ears, the four-, eight-, twelve-, and sixteen-bar phrases are more prominent than the periodicity of either the pitch or rhythm patterns.

a)



b)