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THE OHIO STATE UNIVERSITY, PH.D., 1978

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1978
A PSYCHOPHYSICAL INVESTIGATION OF COMPLEXITY IN MUSIC

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Joyce Kathryn Conley, B.A., M.A.

* * * * *

The Ohio State University
1978

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# TABLE OF CONTENTS

ACKNOWLEDGMENTS .................................. ii  
VITA ............................................. iii  
LIST OF TABLES ..................................... vi  
LIST OF FIGURES ..................................... viii  
LIST OF MUSICAL EXAMPLES .......................... ix  
INTRODUCTION ...................................... 1  

Chapter  
I. REVIEW OF THE LITERATURE .......................... 6  
   Experimental Research in Musical Perception  .......... 6  
   Experimental Research in Complexity ................. 18  
   Summary ........................................ 32  
II. THE MUSICAL STIMULI: BEETHOVEN'S "EROICA" VARIATIONS, OP. 35 .......................... 37  
   Choice of music .................................. 38  
   Stimulus Variables ............................... 40  
   Application of Stimulus Variables to the "Eroica" Variations ........................................ 48  
III. METHOD ......................................... 74  
   Subjects ......................................... 74  
   Apparatus ....................................... 76  
   Procedure ....................................... 80  
IV. RESULTS ........................................ 83  
   Comparison of the Judgments of Complexity by Subjects, Within Groups and Among Groups .......... 83
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relation between Physically Specified Variables in the Music and Subjects' Judgments of Complexity</td>
<td>104</td>
</tr>
<tr>
<td>V. DISCUSSION</td>
<td>117</td>
</tr>
<tr>
<td>Similarity of Judgments of Complexity</td>
<td>117</td>
</tr>
<tr>
<td>Intercorrelations Among Musical Variables</td>
<td>121</td>
</tr>
<tr>
<td>Musical Variables in Future Research</td>
<td>125</td>
</tr>
<tr>
<td>Similarities and Differences Among the Groups in the Relation Between Musical Variables and Judgments of Complexity</td>
<td>128</td>
</tr>
<tr>
<td>Support for a Psychophysical Theory</td>
<td>133</td>
</tr>
<tr>
<td>Conclusions</td>
<td>138</td>
</tr>
<tr>
<td>LIST OF REFERENCES</td>
<td>147</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Quantitative Specification of Musical Variables in Beethoven's &quot;Eroica&quot;</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>Variations, Op. 35</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Spearman Rank Coefficients of Correlation of the Judgments of Complexity of</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Graduate Subjects</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Spearman Rank Coefficients of Correlation of the Judgments of Complexity of</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>Sophomore Subjects</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Spearman Rank Coefficients of Correlation of the Judgments of Complexity of</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>Non-major Subjects</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Coefficients of Concordance of the Rank-orders of Order Subgroups Within Each</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>Group</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Average Rank-orders of the Judgments of Complexity by Order Subgroups and by</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>Groups for Each Variation</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Coefficients of Intercorrelation of the Complexity Scores Derived from Graduate Subjects' Judgments of Complexity</td>
<td>94</td>
</tr>
<tr>
<td>9.</td>
<td>Comparison of Graduate Subjects' Raw Scores, Standardized Scores, and Rank</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>Scores Derived from Judgments of Complexity</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Comparison of Sophomore Subjects' Raw Scores, Standardized Scores, and Rank</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Scores Derived from Judgments of Complexity</td>
<td></td>
</tr>
</tbody>
</table>


**LIST OF TABLES (Continued)**

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Comparison of Non-major Subjects' Raw Scores, Standardized Scores, and Rank Scores Derived from Judgments of Complexity</td>
<td>98</td>
</tr>
<tr>
<td>12. Coefficients of Correlation of the Standardized Complexity Scores Between Groups</td>
<td>99</td>
</tr>
<tr>
<td>13. Standard Deviations of the Standardized Complexity Scores of Each Group for Each Variation</td>
<td>100</td>
</tr>
<tr>
<td>15. Coefficients of Intercorrelation of Musical Variables</td>
<td>105</td>
</tr>
<tr>
<td>16. Coefficients of Correlation of the Musical Variables with the Standardized Complexity Scores of Each Group</td>
<td>107</td>
</tr>
<tr>
<td>17. Analysis of Variance of the Standardized Complexity Scores of Each Group of Subjects and the Groups Pooled, with 9 Musical Variables and 16 Pieces of Music</td>
<td>108</td>
</tr>
<tr>
<td>18. Stepwise Regression Analysis of Graduates' Standardized Complexity Scores</td>
<td>110</td>
</tr>
<tr>
<td>19. Stepwise Regression Analysis of Sophomores' Standardized Complexity Scores</td>
<td>111</td>
</tr>
<tr>
<td>20. Stepwise Regression Analysis of Non-majors' Standardized Complexity Scores</td>
<td>112</td>
</tr>
<tr>
<td>21. Stepwise Regression Analysis of the Pooled Standardized Complexity Scores of All Groups</td>
<td>115</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Percentage of variability in subjects' responses accounted for by the step-wise regression models for each group.</td>
<td>113</td>
</tr>
</tbody>
</table>
LIST OF MUSICAL EXAMPLES

Beethoven, "Eroica" Variations, Op. 35

<table>
<thead>
<tr>
<th>Example</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation 1 (Introduzione col Basso del Tema)</td>
<td>49</td>
</tr>
<tr>
<td>Variation 2 (A due)</td>
<td>51</td>
</tr>
<tr>
<td>Variation 3 (A tre)</td>
<td>52</td>
</tr>
<tr>
<td>Variation 4 (A quattro)</td>
<td>53</td>
</tr>
<tr>
<td>Variation 5 (Thema)</td>
<td>55</td>
</tr>
<tr>
<td>Variation 6 (Var. I)</td>
<td>56</td>
</tr>
<tr>
<td>Variation 7 (Var. II)</td>
<td>57</td>
</tr>
<tr>
<td>Variation 8 (Var. III)</td>
<td>58</td>
</tr>
<tr>
<td>Variation 9 (Var. IV)</td>
<td>60</td>
</tr>
<tr>
<td>Variation 10 (Var. V)</td>
<td>61</td>
</tr>
<tr>
<td>Variation 11 (Var. VIII)</td>
<td>63</td>
</tr>
<tr>
<td>Variation 12 (Var. IX)</td>
<td>65</td>
</tr>
<tr>
<td>Variation 13 (Var. X)</td>
<td>66</td>
</tr>
<tr>
<td>Variation 14 (Var. XI)</td>
<td>68</td>
</tr>
<tr>
<td>Variation 15 (Var. XII)</td>
<td>70</td>
</tr>
<tr>
<td>Variation 16 (Var. XIII)</td>
<td>71</td>
</tr>
</tbody>
</table>
INTRODUCTION

Purpose

Complexity is a term used in talking about music. Leonard Meyer in discussions of value and greatness in music stated,

length, size, or complexity [are not] as such criteria of value, though . . . . complexity does have something to do with excellence. (1967, p. 24)

What is crucial [in the evaluation of music] is relational richness, and such richness (or complexity) is in no way incompatible with simplicity of musical vocabulary and grammar. (1976, pp. 693-694)

Meyer did not define complexity; he assumed that his readers would know what complexity is. Likewise, it is assumed by most other musicians that musical scholars and practitioners know what it is that makes some music more or less complex than other music. However, the term, complexity, has not been adequately defined nor has a good measure of it been established.

The following are some common musical situations in which music teachers, theorists, historians, listeners, performers, and composers make judgments of complexity:
A teacher, in picking out music for students to study, to perform, or to analyze asks, "is this music too simple or too complex according to the students' capabilities?"; "how does this music compare with the music already studied or with the music which I plan to have students study in following months?"

In teaching students about levels of analysis, levels of listening, and different ways of performing, a teacher makes categorical judgments, such as, "some music (jingles, top-40 tunes, certain chorale harmonizations) is so simple that it could be used to demonstrate only one level of analysis--surface analysis; whereas other music, which is more complex, is composed of numerous layers and may be analyzed (and listened to and performed) in a variety of ways." Analyses according to the principles of Schenker (Katz, 1935) and Cone (1968) are examples of analytical procedures through which music of the latter category may be explored.

Music historians compare the music of different eras, of different composers, of different periods of a single composer's life and make such statements as, "the music of Wagner is more complex than the music of Bruckner."

The educated listener upon first hearing a piece of music asks, "does this music seem complex enough that with further listening and study I will discover new
relationships?"; "is there any reason for me to listen to this again?"

Being able to predict how complex a given composition would sound to an audience would aid the performer in programming (variety could be assured by not having music of the same complexity throughout) and would aid the composer (he could be more certain of appealing to his audience by composing music which would neither overtax nor undertax his listeners). Comparing the complexity of different pieces of music in ordering a program is something that performers do, and it is something that they learn to do, though the rules are never explicitly stated.

The purpose of this study is five-fold:

1. to define complexity in music by investigating the relationships between judgments of complexity and physically specified variables in the music.
2. to compare the listening patterns of groups differing in musical training.
3. to show that variables in "real" music, that is, music that has stood the test of time, music that has not been composed for experimental purposes, can be quantitatively specified.
4. to show that such music can be used as a source of stimulation in a psychophysical experimental situation.
5. to provide a basis which has not previously existed for objectively describing and comparing music.
Chapter Outlines

In Chapter 1 literature dealing with experimental research in musical perception and experimental research in visual and auditory form/pattern complexity will be reviewed. A rationale for a psychophysical theoretical framework will be presented, as will a rationale for experimentation with actual music instead of experimentation with specially constructed sound sequences. Experimental questions will be posed.

Chapter 2 will be a discussion of the music used in this experiment, Beethoven's 15 Variations with Fugue in E-flat on a Theme from "Prometheus" ("Eroica" Variations), Op. 35. Specific topics will include: criteria formulated for choosing the music, definition of and justification for the particular musical variables which were specified, and presentation of the music and quantitative specification of variables in the music.

Chapter 3 will be a presentation of the experimental method, including descriptions of the subjects who participated in the experiment, the tapes of the musical stimuli and other apparatus, and the experimental procedure.

Chapter 4 will contain a presentation of the experimental results divided into two main sections: a comparison of subjects' judgments of complexity and the relation between the physically specified variables in the music and subjects' judgments of complexity.
In Chapter 5 the experimental results and their implications will be discussed. Topics considered will be: similarity of judgments of complexity, intercorrelations among musical variables, musical variables in future research, similarities and differences among the groups in the relation between musical variables and judgments of complexity, support for a psychophysical theory, and conclusions.
CHAPTER 1

REVIEW OF THE LITERATURE

My approach to the problem of investigating complexity in music is experimental. This chapter will furnish a review of experimental literature, dealing first with studies in musical perception and secondly with experimentation in visual and auditory form/pattern complexity. The rational foundation for experimentation within a psychophysical theoretical framework will be included in both of these sections.

Experimental Research in Musical Perception

Poland (1961) noted that

we need both historical and experimental research to aid in the solution of musical problems. In general, historical research attacks problems related to musical documents and experimental research attacks problems of measuring, controlling, and shaping musical behavior. (p. 8)

The experimental approach to musical problems has been utilized for decades. Important reviews of experimental literature are contained in psychology of music texts by Diserens and Fine (1937), Seashore (1938) and Farnsworth (1969).
Berlyne (1974) outlined two directions that a study in experimental aesthetics could take:

1. The **synthetic** approach

   consists in singling out particular variables or factors that might play a part in aesthetic appreciation and designing stimulus patterns that will enable these variables or factors to be isolated and manipulated for study. The objects to which subjects are required to respond are thus artificial and relatively simple. Nobody would call them works of art, but they are such as might well be found among the elements of works of art. The synthetic approach has the advantage of permitting control over independent variables, so that an experimenter can be reasonably sure which ones are responsible for observed variations in subjects' reactions. But it might be objected that it misses some of the essential and decisive attributes of art. The impact of a work of art surely depends in large measure on how its elements are combined and arranged, and on how its attributes interact with one another. (pp. 17-18)

2. The **analytic** approach

   brings one closer to what happens when people encounter art in real life, but any specimen of existing art will inevitably incorporate many elements, variables, attributes, and factors that could have some influence over the reactions that are recorded. It is difficult, to say the least, for the experimenter to control the operative independent variables or even to measure them. (p. 18)

Unfortunately, most of the literature in the area of the psychology of music, or experimental aesthetics, that has dealt with actual music—that has utilized the analytic approach--has been speculative in nature. In my master's
thesis (Conley, 1975) I reviewed the literature dealing with differentiation and categorization of ways of listening to music and discovered a wealth of speculation, but no concrete experimental results. In addition, I found the most comprehensive work to have been done by P. E. Vernon (1934) over forty years ago. Because I consider Vernon to be a major figure in the field of musical perception, his speculations will be presented in detail.

Over a period of six years Vernon examined two hundred subjects, "ranging from the very musical to the very unmusical" (1934, p. 128). Some were examined by detailed questionnaires which were given in person; some attended an experimental concert and wrote down the thoughts and feelings they experienced while listening to music. His conclusions, which follow, are based upon the data gathered in these sessions and upon his critical analysis of the literature.

Though it must be admitted that every individual listens to, and appreciates, music differently from every other, and that the same individual listens in many different ways at different times, yet it would seem justifiable to classify all musical perception, in the words of Edmund Gurney, as either 'indefinite' or 'definite.' Indefinite listening is more or less passive reception: Vernon Lee calls it merely 'hearing' music; whereas definite listening is characterized by active attention to the notes, themes, harmonies, rhythms and counterpoints, as objects external to the listener.
The main varieties of response which may be distinguished in indefinite listening are:

(a) Reflex, physical, soothing or stimulating effects on the muscular activities and metabolism of the organism.
(b) General euphoria, and other pleasant or unpleasant organic sensations.
(c) Stimulation of the thought processes, and wandering of attention to topics quite unrelated to music.
(d) Emotional moods or interpretations of the so-called 'meaning' of the music.
(e) Dramatic visual images or day-dreams, based on these emotions; these differ from (c) in that they follow the general structure of the music.
(f) Mere awareness that sounds are going on in the external world, but no further response.
(g) Lapsing of this awareness into the 'margin of consciousness.' (pp. 128-129)

The first two varieties of response, (a) and (b), Vernon continued, are typical in animals, primitives, and infants. On the other hand, (c), (f), and (g) do occur among trained musicians, for example,

When . . . they hear music in a restaurant which does not interest them, or when they find themselves incapable of perceiving 'definitely' music in an unfamiliar idiom by modern composers. (1934, p. 129)

Sometime early in an individual's musical history definite listening grows out of indefinite listening. The types of definite responses are as follows:
(a) Kinaesthetic reactions, or delicate muscular adjustments in a variety of parts of the body--larynx, lips, head, eye-muscles, arms, diaphragm, feet, toes, etc.

(b) Synaesthetic processes, or translations of keys, timbres, chords, pitch level, intensity and rapidity of the music into terms of colours, moving or static patterns, tastes, smells and temperatures.

(c) Visualization of the notes on the pianoforte keyboard, or other instruments, or on a printed musical stave.

(d) Verbalization of the names of the notes or keys, etc.; both (c) and (d) usually depend on a sense of absolute pitch.

(e) Emotional and organic responses to particular features of the music which may be projected on to, or considered to be properties of, the music itself. These responses are more subtle and specialized than the general indefinite response to music.

(f) Auditory imagery.

(g) Intellectual processes, such as technical analysis of formal and theoretical aspects of the music. (1934, p. 130)

Noting that attention can fluctuate and listeners may shift from definite to indefinite listening, Vernon stated,

It is obviously untrue to say that all the musical listeners attend and that all the unmusical indulge in free trains of irrelevant thought. Probably the stimulatory effects are present in all types of listeners, but are not so much a source of enjoyment in themselves among the more musical. Any musician would admit that his attention lapses if the music is very bad or boring; that personal associations with previous performances and more or less distracting thoughts of historical and technical interest tend to enter continually and may be very pleasurable. Many subjects noted that their attentiveness varied with mood, fatigue, the type of music, etc. . . . Some attend far better when they are
already acquainted with the composition, others analyze new pieces and later allow them to 'sink in.' It seems that one must allow that musical people develop a capacity whereby they voluntarily repress other impressions. (1930, pp. 54-55)

From this analysis Vernon concluded that

musical perception depends on an extraordinary diversity of physiological and psychological reactions, and that different listeners employ a variety of different modes of response in their perception of the same features of the music; that the abstract perception of the notes as auditory objects is an exceptional state of affairs, a level which is reached only by the most highly trained musicians. (1934, p. 130)

More recent work in the differentiation and categorization of ways of listening to music has been done by Sessions (1950), Schoen (1955), Meyer (1956), Mueller (1956), Yingling (1962), Pike (1967), Colwell (1966), Crickmore (1966, 1968), Prince (1971), Hedden (1973), Smith (1973), and Bartlett (1974). These studies are disappointing, because not only have they provided merely speculative data, but they have also failed to add anything not contained in the speculations of Vernon (1934) decades earlier. In fact, Crickmore (1968) was the only investigator who cited Vernon (1934); it may be assumed that he was the only one who was aware of the groundwork laid by Vernon.
In order to move from experimentation with actual music which provides merely speculative data to experimentation with actual music which provides interpretable concrete results, a sensible theoretical framework is needed. In the words of Neisser (1976), this must be a theory [that] has something to say about what people do in real, culturally significant situations. What it says must not be trivial, and it must make some kind of sense to the participants in these situations themselves. If a theory lacks these qualities--if it does not have what is nowadays called "ecological validity"--it will be abandoned sooner or later. (p. 2)

The theoretical framework which seems to have the most potential for studies in musical perception is J. J. Gibson's (1959) psychophysical theory of perception. Within this framework, perception is the correspondence of variation and constancy in experiences and/or behaviors with changes and invariants in the environment. According to Gibson there is, then, some set of physical properties in the environment which determines every perceptual response; that is, every perceptual response is based upon some combination of objectively measurable variables.

Two important aspects of this theoretical framework are:

1. There is no concern for mediating mechanisms or stages of information processing. It is the relationship
between a subject's behavior or experiences and the environmental stimulation which is important. As stated by Owen (1977),

The strategy of research and theory in perception should not . . . be a search for mechanisms. Rather, the study of perception must be conceived as an attempt to answer the question: What in the environment has to be varied over time to allow the perceiver to report seeing, or otherwise respond to, an object or an event in a certain way? . . . It follows that the functions served by perceiving need no longer be labeled as activities inferred to take place inside the perceiver. The constructing, judging, and coding processes can be discarded and replaced by the empirically assessed reciprocities of the perceiver and the perceived. (pp. 60-61)

2. It is postulated that a subject perceives patterns, not elements--in Gibson's terms, higher order variables and invariants. He stated, "transformation . . . is one kind of stimulus information . . . the invariants under transformation are another kind of stimulus information" (1966a, p. 145).

Examples of higher order invariants (detectable constant patterns in stimulation) and variables (detectable changes of pattern in stimulation) that have been experimentally specified in music are: melody and melodic contour (Dowling and Fugitani, 1971); inversion (Dowling, 1971); melodic range (Dowling, 1973); and melodic motives
and register (Attneave and Olson, 1971). These studies, which are discussed briefly below, are synthetic; they did not deal with actual music but with particular musical variables in isolation. Although it can not be assumed that the findings will generalize to actual musical situations, the studies do point out the sort of higher order variables and invariants that merit investigation.

Melodic contour was investigated by Dowling and Fugitani (1971) who stated that "the pattern of relationships among tones in a melody is what is important, and not their absolutely defined pitches" (p. 524). They suggested that

preservation of contour through changes in interval size is an important organizational principle in . . . tunes. This organizational principle is based on the psychological similarity of phrases having the same contour. Memory for the contour is an important aspect of memory for melody, so that tunes like "Three Blind Mice" derive cohesion from the fact that the listener recognizes the contour of the first phrase as he hears the second phrase. (p. 524)

Experimental results indicated that subjects were able to detect contour invariants but had difficulty differentiating between a melody which was an exact transposition of a pattern and a melody which merely had the same contour as a previous pattern.
Dowling (1971) investigated the recognition of inversion of melodies and melodic contours, specifically addressing the questions, which are applicable to both visual and auditory pattern recognition: "What distortions of detail leave the pattern recognizable?" "What are the effects of various changes of orientation of shape on recognition?" (p. 348). An important perceptual problem was addressed: this experiment constituted "a test of whether melodic inversion can function as a formal device understood by the listener or must be viewed as an empty formalism" (p. 348). Dowling found that inversion was indeed a perceivable compositional device but that distinguishing between exact inversions and inverted contours was extremely difficult.

Dowling (1973) studied the perception of interleaved familiar melodies. Experimentation showed that individual melodies could not be identified until they were separated so that the ranges of the melodies were not quite overlapping. Dowling concluded that

The perceptual basis for the fact that melodies throughout the world are restricted to fairly narrow pitch ranges in the sense of having narrow intervals between successive tones . . . may be that rapid wide-range melodies split apart into separate pitch-defined groups of tones. (p. 33)
Transposition of short melodic patterns or motives was investigated by Attneave and Olson (1971), who found that musical intervals and/or short motivic patterns are freely transposable over a wide range of specific pitch levels. That is, over a large range of pitch, an intervallic pattern is perceived to be invariant. Among Attneave and Olson's conclusions was the following:

Perhaps the most provocative finding of these studies is the abrupt deterioration of musical transposition that occurred at about 5,000 Hz. [which is about four half steps above the upper range of the piano]. . . . Something changes rather dramatically at this level; phenomenally it is identifiable as a loss of musical quality, whatever that may be. . . (p. 163)

Register, then, may be a variant through which invariants, such as, intervallic patterns, may be perceived within certain boundaries.

The two important aspects of a psychophysical theoretical framework—no concern with mediating mechanisms or processing stages, and focus on perception of higher order variables and invariants (not elements)—are in contrast with much of the recent literature in musical perception. A preoccupation with mediating mechanisms and processing stages is evident in the work of Deutsch (1969, 1975) and Chamberlain (1974) in the area of recognition and memory, of Cuddy (1971) in experimentation on the training of

Although no experiment with actual music has been done within a psychophysical framework, the two most certainly seem to be compatible. Music is characterized by patterns and repetitions of and changes in patterns, by higher order variables and invariants. It seems logical that what an individual perceives when listening to music is based upon the patterns in the music. It is this relationship or correspondence between variation and constancy in musical behaviors and/or experiences and changes and invariants in the musical environment (stimulation) that is investigated in a psychophysical experiment. The major problem in such experimentation is the specification of musical variables. It would be much simpler to utilize the synthetic approach, to isolate particular musical variables and to construct sound sequences for use in experimentation. But since my purpose is to investigate musical complexity and to specify quantitatively those aspects of
music upon which judged complexity is based, not to investigate complexity in "music-like" structures, the analytic approach is essential. Since it is not known what the primary factors are which determine judged complexity, they cannot be abstracted and studied in isolation. In addition, it seems that the mainstream trend within the field of the psychology of music has been to utilize the synthetic approach and to generate reams of data whose applicability to music has not been demonstrated (Roederer, 1973; Ward, 1970; Doehring, 1969, 1971; and Madsen, Edmonson, and Madsen, 1969). It has been assumed that music contains too many unspecifiable variables. My solutions to the problems of specification of musical variables will be presented in detail in Chapter 2.

Experimental Research in Complexity

Complexity has been specified as a higher order variable or invariant in a number of studies. This review of experimental research in complexity will deal first with studies in the visual modality, those that are synthetic and those that are analytic. A discussion of experimentation in auditory pattern complexity will follow; all of these are synthetic studies.

Over the past twenty years a number of psychologists have conducted investigations dealing with visual form complexity. The experiments that have been psychophysical
have also been synthetic—subjects have judged the complexity of nonrepresentational shapes, and these judgments have been related to the measurable physical characteristics of the forms by use of a multiple correlational technique. In these synthetic studies subjects were given no definition, either explicit or implicit, of "complexity;" and in most of the experiments (all but Berlyne, Ogilvie, and Parnham, 1968) the subjects viewed all of the stimuli before making their complexity ratings, so that they became acquainted with the range of variability. All of the experimenters had subjects rate the complexity of the forms on a given interval scale, which contained from five to twenty points, depending upon the experimenter. Elliott (1958), in addition to using such a complexity scale, obtained complexity ratings from paired-comparison judgments.

Stimulus variables found to account for significant variance in subjects' judgments of complexity were:

1. Number of turns (Attneave, 1957)

2. Symmetry (Attneave, 1957; Arnoult, 1960; Elliott, 1958; Stenson, 1966)

3. Angular variability (Attneave, 1957; Arnoult, 1960; Elliott, 1958; Stenson, 1966)

5. Perimeter\(^2\)/area (Arnoult, 1960; Elliott, 1958; Stenson, 1966)

6. Perimeter (Stenson, 1966)

7. Number of elements (Berlyne, Ogilvie, and Parnham, 1968)

8. Unitariness (Berlyne, Ogilvie, and Parnham, 1968)

In contrast to the above experiments, which were both synthetic and psychophysical, are a number of analytic studies which dealt, at least indirectly, with visual form complexity. In these experiments, which will be discussed below, the relationship of one or the other of two behavioral variables to judged complexity was investigated. These behavioral variables are: exploration time, the amount of time that a subject looks at each of a succession of patterns; and exploratory choice, the one pattern of two patterns previously seen which a subject chooses to view again. Some experimenters studied exploration time; others investigated exploratory choice.

The graphic shape of the relationship between exploratory time or choice and judged complexity is often compared

\(^1\)Owen and Brown (1970) discovered that perception of complexity is independent of input modality; complexity ratings for both visual and tactual modalities were found to be closely related to the number of independent sides of the forms.
to the functions that Berlyne and others (Berlyne, 1971, 1974) have found when investigating two kinds of verbal evaluative judgments in connection with judged complexity: that which is "pleasing" (good, beautiful, liked) and that which is "interesting." The general findings are:

1. There is a rising monotonic relation between judged complexity and "interestingness;" "interestingness" varies directly with judged complexity.

2. "Pleasingness" reaches a peak and sometimes several peaks in relation to judged complexity; stimuli of medium complexity are preferred over those of high or low complexity (Munsinger and Kessen, 1964; Vitz, 1966a, 1966b; Terwilliger, 1963; Day, 1967; Berlyne, Ogilvie, and Parnham, 1968; Aitken, 1974; Berlyne, 1971, 1974).

These analytic visual form studies may be summarized as follows:

1. In a study by Leckart and Bakan (1965), slides of landscapes and objects, which had previously been rated on a seven-point scale of complexity and then divided into groups of high, middle, and low complexity, were viewed by subjects for as long as they wished. A direct, positive relationship was found "between complexity and looking time." A later experiment (Leckart, 1966) confirmed this direct relationship.
2. Gaschk, Kintz, and Thompson (1968) defined three levels of complexity, high, middle, and low, based upon earlier ratings of objects on a seven-point complexity scale. Subjects were divided into two groups and either viewed slides of these objects or manipulated these objects for as long as they wished. "Analysis of the time scores from these two groups revealed that both inspective manipulation time and free looking time increased as a function of stimulus complexity" (p. 319).

3. In a study by Wohlwill (1968) teams of judges rated the complexity of two sets of slides, those of the geographic environment and those of non-representational modern art, on the basis of "amount of variation along five attributes: color, shape, direction of dominant lines, texture and natural vs. artificial" (p. 308). These measures were then converted to complexity ratings. Subjects were asked to rate their preference of each picture and were allowed to look at each picture as often as they liked. Exploratory behavior "emerged as a linearly increasing function of complexity, while the relationship between complexity and preference was curvilinear, reaching a maximum at an intermediate level of complexity" (p. 307).

4. Saklofske (1975a) had a group of subjects rate the level of complexity of 15 paintings on a seven-point scale. The paintings were then divided into three groups of
complexity, simple, medium, and complex. The task for another group of subjects was to view each painting for as long as they wished. Looking time was found to vary directly with rated complexity. In a later study Saklofske (1975b) found "a significant U-shaped relationship between attractiveness and complexity of 15 paintings of human figures while rated interest tended to increase with complexity" (p. 813). When subjects were asked which of all the paintings they would most like to view again and which they would least like to view again, those paintings rated highly attractive and moderately complex were most often selected for the former and least often for the latter.

There is a major problem with this group of analytic studies: there was absolutely no concern with psycho-physical relationships. It was assumed by the experimenters that physical complexity and judged complexity are equivalent. In the studies by Leckart and Bakan (1965); Gaschk, Kintz, and Thompson (1968); and Saklofske (1975), no attempt was made to specify the physical characteristics upon which complexity judgments were based. In Wohwill's study (1968), the experimenter defined complexity, as the "amount of variation along five attributes: color, shape, direction of dominant lines, texture and natural vs. artificial" (p. 308), and asked judges to rate accordingly. Subjects had no knowledge of the experimenter's definition
of complexity, and there is no evidence that they would have agreed with this definition. The view expressed by Leckart and Bakan (1965), below, seems to be shared by all of these experimenters:

Of special interest . . . is the demonstration that phenomenological reports in the form of judgments can be utilized for the quantification of stimuli where more objective methods such as those based on information theory are not applicable. (p. 17)

This was supposedly demonstrated by the finding of a relation between looking time and judged complexity similar to the relation found (in earlier experimentation, cited by Leckart and Bakan, 1965) between looking time and stimuli which had been quantitatively specified as complex. Therefore, the experimental results were taken to confirm the validity of the use of the judgments upon which the experimental results were based. This is a circular argument.

The closest any analytic study has come to specifying the physical variables upon which judgments were based is evidenced by the work of Kunnapas and Norman (1971), dealing with similarity, not complexity. In a study involving multidimensional scaling of similarity estimates of paintings by Cezanne, three relevant dimensions were found: "complex vertically arranged motive," "vertical central
"figure," and "central figure without background."

Subjects were of three types: professional painters, pupils of an art school, and non-artist students. Some intersubject differences were found—differences in judgments of similarity between the professional painters and the non-artist students were greater than either the differences between the pupils of art school and the non-artist students or the differences between the professional painters and the pupils of art school. Expectations that art pupils were more like the professionals than were the non-artists were, therefore, confirmed. Unfortunately, this study was poorly constructed and poorly reported. The conclusions do not seem to be firmly grounded in the experimental results.

The applicability to music of any of these findings from studies of visual form complexity is dubious. Parallels can be discovered only through experimentation with music and the finding of results comparable to results found in visual form studies. Some of the studies, especially the synthetic psychophysical studies, are of value, however, for their methodology—the quantitative specification of physical variables and the multiple correlation technique by which the relation of those variables to judgments of complexity was established.
Although in the present experiment (to be described in Chapter 3) there are no tasks involving exploration time or exploratory choice, it seems that these will be fruitful areas for research after some groundwork has been completed concerning complexity in music. In the future the findings from the analytic studies dealing with the relation of judged complexity to these particular behavioral variables may be important. Overriding this potential positive aspect, however, is the disappointing fact that in none of these analytic studies was the relation between judged complexity and physical variables considered.

There have been fewer experiments conducted in the auditory modality dealing with pattern complexity, and all of these have been synthetic experiments.

In a psychophysical experiment comparable to those of Attneave (1957) and Arnoult (1960) (and the others cited on pp. 19-20), Haltmeyer (1962) found judgments of complexity to increase as the number of notes (pitch classes) in a chord increased.

Of passing interest are two studies in which the experimenter gave a definition of complexity, although testing that definition was not a part of the experiment. Yeager (1969), in an investigation of time estimates, defined three levels of complexity: "a monotone (simplest),
a regular alternation of two pitches (more complex), and an irregular alternation of two pitches (most complex)" (p. 177). Steck and Machotka (1975), in an investigation of subjects' preferences for tone sequences, equated complexity with density, which they defined as number of attacked tones per second.

There are two experiments which have been particularly influential (both positively and negatively) in the formulation of the present study. Both have a psychophysical basis—a primary consideration is the relation of judged complexity to variables in the music. In neither experiment were subjects given a definition of complexity. In one experiment (Heyduk, 1975) subjects heard all of the stimuli to get an idea of the range of complexity before rating them; in the other experiment (Crozier, 1974) the subjects heard the stimuli only once.

Heyduk (1975) created original piano compositions that "were intended to engage listeners in a . . . natural music appreciation task without sacrificing a clear operational definition of complexity" (p. 85). Complexity in music was specified as being related to rhythm and chord properties. Subjects listened to and rated both the complexity and their degree of liking of the four original musical compositions on 13-point scales. The compositions were quite similar (in form, length, and chord changes) except for
variations in chord structure and in the "amount and kind of syncopation." Subjects' ratings confirmed Heyduk's predictions that (1) the greater the variation in chord and rhythmic structures, the more complex a composition is judged; (2) the relation between ratings of liking and variation in chord and rhythmic structures was an inverted-U function.

There are a number of problems with this study:

1. Heyduk claimed to give a clear operational definition of complexity. Number of different chords is a clear-cut measure, but amount and kind of syncopation is not. Evident in Heyduk's compositions are progressively irregular groups of accent patterns—not syncopation, which may be defined as irregularity within a regular context.

2. Heyduk's assumption that this approximates a natural music appreciation task is unfounded. His music is clearly triadic but is not idiomatic for any style with which I am familiar.

3. Heyduk investigated only the ordinal relationship between judgments of complexity and variation in chord and rhythmic properties. There was no further analysis of the data. That is, Heyduk constructed the compositions so that the order of complexity, based upon the variables that he (inadequately) specified, would be A<B<C<D. Using a counterbalanced design, he found that the average of subjects'
ratings gave this same order. This is the evidence upon which Heyduk's conclusions were based.

4. Because Heyduk confounded the varying of chord and rhythmic properties, it is impossible to tell if one of these variables was more important as a determinant of complexity than the other, or if they were equally important.

Another experimenter, Crozier (1974), investigated the relation between the information-theoretic measure of uncertainty (determined by number of pitches, durations, and loudness levels) and subjects' judgments of the melodic complexity, interestingness, and pleasingness of 20-second sound sequences. Subjects, who were both music majors and non-music majors, judged the sound sequences on a seven-point scale. Results showed that (1) "mean complexity [was] a monotonically increasing linear function of uncertainty level . . . . Trend analysis indicated that the linear component accounted for 99.14% of the uncertainty sum of squares" (p. 38); (2) in judging complexity music majors used a scale of greater range than did the non-music majors; (3) interestingness increased as a function of stimulus uncertainty with music majors differing from non-music majors in using a scale of greater range; and (4) pleasingness ratings were an inverted U-shaped function of uncertainty.
Giving the basis for additional experimentation, Crozier stated,

while man may talk endlessly about music, its most important impact on human behavior is shown by the amount of time spent in listening to the auditory stimuli we call music. Our laboratory analogues of natural, unrestrained listening and choice behavior were Listening Time and paired-comparison choice (or Exploratory Choice). (p. 34)

In one experiment Crozier found "Listening Time" and in another "Exploratory Choice" to increase with uncertainty level, though not rising steadily with increased uncertainty. There were no significant differences between music and non-music students.

The positive and negative features of Crozier's study are:

1. Crozier clearly defined objective complexity, or as he termed it, uncertainty level, as being based upon the number of pitches, durations, and loudness levels—the larger the number of each of these, the greater the uncertainty level.

2. Twenty second sound sequences generated to represent particular uncertainty levels are not an adequate laboratory analogue of actual music. There is no reason to assume that the experimental results would generalize to musical situations.
3. Crozier's analysis of data was sophisticated (I have given only a sampling of the results that he presented).

4. Because Crozier confounded the variation in pitch, duration, and loudness, he was unable to see if one particular variable was the most important determinant of judged complexity. He admitted this shortcoming, though, and stated,

In our sequences ..., degrees of uncertainty with respect to the three parameters, pitch, duration and loudness, were correlated. So, it is impossible to tell how much variation of each of these parameters contributed to the effects we observed. Musical tradition would lead one to suppose that variations in pitch loom largest in melodic perception, with duration coming second. (p. 86)

Suppositions based upon musical tradition (whatever that is) are a poor substitute for experimental research concerning the role of pitch and duration in melodic perception.

Since all of these auditory studies were synthetic—all dealt with elements of music, not actual music—there are the same problems with generalizing findings to musical events as there are with visual form studies.

Comments made following the presentation of visual studies concerning the potential for experimentation with exploration time and exploratory choice (supra, p. 26) are
relevant, again, to Crozier's study. It is hoped that the present study will lay a basis for such experimentation with music.

Summary

Literature dealing with experimental research in musical perception and experimental research in form/pattern complexity was reviewed.

In the review of experimental research in musical perception, Berlyne's (1974) distinction between the synthetic approach and the analytic approach to problems in experimental aesthetics was introduced. It was noted that analytic studies in music have, in the past, yielded merely speculative data. Specific examples were given of research in differentiation and categorization of ways of listening to music, the most important work in the area having been done by Vernon (1934) over forty years ago.

A psychophysical theoretical framework was proposed as being fruitful for research in musical perception. Within this framework what is studied is the correspondence of variation and constancy in musical experiences and/or behaviors with changes and invariants in musical events. It was proposed that perception is direct, is a function of what is attended to; and there is, therefore, no need to search for mediating mechanisms or information processing stages. It was proposed that one does not perceive
elements but higher order variables and invariants. Examples of higher order variables and invariants that have been specified in the literature were given. All were synthetic studies.

There has been no previous experimentation with actual music (an analytic study) within a psychophysical framework. A rationale for such experimentation was given.

The review of experimental research in form/pattern complexity yielded a number of psychophysical studies in visual form complexity which utilized the synthetic approach. In these studies subjects' judgments of complexity were related to physically specified characteristics of the forms. The stimulus variables which were found to account for significant variance in subjects' judgments of complexity were: number of turns, symmetry, angular variability, independent sides, perimeter^2/area, perimeter, number of elements, and unitariness.

Analytic experiments relating to visual form complexity have evidenced no concern with psychophysical relationships. The relation between behavioral variables, such as, exploration time and exploratory choice, and judged complexity has been investigated. There has been no consideration, however, of the determination of the physical characteristics of the paintings or the other objects
upon which judgments of complexity are based. Wohlwill (1968) asserted, but did not subject his assertion to test, that complexity (in slides of the environment and of art) was based upon variation in color, shape, direction of dominant lines, texture, and natural vs. artificial landscape. No other experimenter even suggested what the physical bases for judgments of complexity might be.

In synthetic studies in auditory pattern complexity, experimenters have found judgments of complexity to be related to the number of notes in a chord (Haltmeyer, 1962), the number of different chords and rhythmic regularity (Heyduk, 1975), and the number of pitches, durations, and loudness levels (Crozier, 1974). Untested definitions of complexity were advanced by Steck and Machotka (1975) as number of attacked tones per second, and by Yeager (1969) as the number of and the regularity of pitches in a sequence.

There is evidence, then, from synthetic visual and auditory studies to substantiate the theory of Gibson (1959) that perceptual responses, in this case, judgments of complexity, can be accounted for by the physical variables of the stimulus object or event. This theory has not previously been tested in an analytic music experiment.

Two studies reviewed in this chapter investigated differences in perception between/among groups of subjects
differing in background and experiences. Kunnapas and Norman (1971), in experimentation with professional artists, student artists, and non-artists, found that the groups differing most in their judgments of similarity of paintings were the professional artists and the non-artists. Crozier (1974), in his investigation of complexity judgments for sound sequences by music majors and non-music majors, found that the music majors differed from the non-music majors in using a scale of greater range.

The primary aims from the five-fold purpose of this study outlined in the introduction (supra, p. 3) can now be presented as two pairs of specific experimental questions:

1. What are the relationships between physically specified variables in the music and judged complexity? Do groups differing in musical background and training differ in this regard?

2. Within like groups of subjects are judgments of complexity similar? Do groups differing in musical background and training differ in this regard?

In addition to these specific questions are three more general questions:

1. Can variables in "real" music, music that has stood the test of time, music that has not been composed for experimental purposes, be quantitatively specified?
2. Can such music be used as a source of stimulation in a psychophysical experimental situation?

3. Can new tools and new ideas for musical analysis be discovered from experimentation with music, from the specification of musical variables and determination of relationships between/among them?
CHAPTER 2

THE MUSICAL STIMULI: BEETHOVEN'S "EROICA" VARIATIONS, OP. 35

Crozier (1974), in describing music, spoke of "the elusive and only qualitative nature of the independent variable" (p. 27). Although quantitative specification of musical variables has never before been attempted in an analytic study, there is no evidence that it can not be done; and while the nature of music may, at times, be elusive, there is no evidence that it is "elusive and only qualitative." Specification of musical variables is not an easy task, but as Neisser (1976) noted, we must make "a commitment to the study of variables that are ecologically important rather than those that are easily manageable" (p. 7).

This discussion of the music used as the source of stimulation in this experiment includes: criteria formulated for choosing the music, definition of and justification for the particular musical variables which were specified, and presentation of the music and quantitative specification of variables in the music.

2The complete title is 15 Variations with Fugue in E-flat on a Theme from "Prometheus"("Eroica" Variations), Op. 35.
**Choice of Music**

In choosing music for this experimental investigation, the following criteria were considered to be important:

1. The music should be a set of variations. A group of variations has basic structural similarities (a common basis) and is by the same composer.

2. The variations should be short. Such pieces are comprehensible as a unit; they can be attended to as a whole and can be remembered and compared. Many different members of the variation set can be presented during an experimental session, and as large a number of different variations as possible is desirable for statistical purposes (in calculation of degrees of freedom).

3. The variations should have the same instrumentation. No effective means of dealing with the quantitative specification of instrumentation was known at this point. There are enough other variables to study that are ecologically important that can not be easily controlled, and instrumentation can be.

4. The variations should have the same form. There are problems in this area, as well, with quantitative specification. It seemed important to control for the basic scheme of repetition and contrast, and to utilize music having sections of the same relative length.

5. The variations should be relatively unknown. This reduces the likelihood of responses based upon past
associational experiences.

These criteria were met by Beethoven's "Eroica" Variations, Op. 35, for piano. These variations are short, they have the same instrumentation, most are of the same form, and they are relatively unknown. They contain numerous differences, though, in texture, harmony, and rhythm. The entire set of variations was not used in the experimental situation; 16 members of the variation set were selected as stimuli. Because the theme was not identified to the subjects, the various members of the variation set are labelled for convenience as Variation 1, 2, 3, . . . , 16 (the Arabic number to the left of the title of each variation in the list which follows is the number used to identify that variation in this study).

The variations are:

1. Introduzione col Basso del Tema
2. A due
3. A tre
4. A quattro
5. Thema
6. Var. I
7. Var. II
8. Var. III
9. Var. IV
10. Var. V
11. Var. VIII
12. Var. IX
13. Var. X
14. Var. XI
15. Var. XII
16. Var. XIII

These variations were chosen because they are in the same key (E-flat Major), they are of the same form (rounded binary), and they are of comparable length. Variation VII met these criteria but was eliminated because it is highly contrapuntal (a canon at the octave), whereas the other
chosen 16 variations are either contrapuntal for just a few measures or are not contrapuntal at all. Although fewer than 16 variations could have been chosen, 16 was a good number for the experimental design (this will be amplified in Chapter 3).

Stimulus Variables

The major problem in the quantitative specification of stimulus variables, which in subsequent discussion will be referred to as musical variables, is to determine what objectively measurable variables out of the multitude of variables which may be present in music are to be specified. Attneave and Arnoult (1956), who worked in visual form perception, addressed this problem of specification of variables:

Of all the conceivable physical measures of shape, analytic as well as gestalt, there are undoubtedly many that have little or no value from a psychophysical point of view. On the other hand, it appears unlikely that any single system of physical measurement can be optimal for all psychophysical situations . . . . Unfortunately, there is no quick and easy way to determine which physical measures have greatest psychological relevance; only experimentation can answer this question. (p. 470)

Because there had been no previous research with complexity in music, I had no experimental basis for
hypothesizing and specifying the musical variables upon which judgments of complexity would depend. I could, however, bring my musical knowledge to bear, logically or experientially making choices based upon what seemed musically important, relatively easy to measure, and likely to be related to judgments of complexity.

All of the musical variables that I have specified are aspects which music theorists talk about and measure in analyses of music. The importance of many of these variables was suggested by experimenters in synthetic studies working with "music-like" structures (supra, p. 34). These variables may be categorized as follows:

1. Textural
   Regularity/Irregularity of number of tones in vertical structures
   Number of independent parts

2. Harmonic
   Number of different harmonies
   Number of changes of harmony
   Number of measures of tonic harmony
   Number of measures of dominant harmony
   Number of measures of other harmony

3. Rhythmic/Time
   Number of changes in activity
   Rate of activity
   Length

Each of these variables is discussed below. The musical scores to which references are made and relevant discussions are presented on pp. 49-72.
Regularity/Irregularity of Number of Tones in Vertical Structures (X1)

The rationale for two aspects of this variable needs to be established:

1. The use of the term "vertical structure" instead of "chord" (as used by Haltmeyer, 1962).
   A chord is generally considered to be composed of three or more different tones. Since in these variations there are, at times, only one or two tones, or the same tone tripled, it seems that the term "vertical structure" is a more general, yet precise and unambiguous term.

2. The specification of regularity or irregularity, a dichotomous variable, instead of a discrete variable.
   Since the number of tones in vertical structures varies in many variations from one vertical structure to the next, "the number of tones in vertical structures" is not a possible measure. The measures, "predominant number" or "average number of tones in vertical structures" were considered, but for variations, such as, Variation 6 (see p. 56 for the score), the rationale for specifying such variables could only be shakily established.

   Since there is irregularity in all variations that are otherwise regular in measures (mm.) 9-12, the variable is further defined as excluding those measures.
The variable, then, which is specified is the regularity (0) or irregularity (1) of the number of tones in vertical structures, excluding mm. 9-12. There are slight irregularities within these variations that are labelled regular—usually in m. 8 and/or m. 16. Such irregularities are discussed when they occur for each variation.

Number of Independent Parts (X2)

A part is defined as a cohesive, structured, horizontal occurrence which can be composed of any number of tones (vertically and horizontally). These are independent—separate and distinct from each other—in rhythm and/or range (often both).

The number of independent parts is usually expanded or reduced in mm. 9-12. Thus, this variable is predominant number of independent parts.

Number of Different Harmonies (X3)

Harmonies, which may be composed of a single pitch, an interval, or a chord, are labelled with upper case Roman numerals. Harmonies containing diatonic sevenths are labelled just with the Roman numeral and are considered to be the same harmony as a pitch, interval, or triad with the same Roman numeral label.
The symbol, $V$, is used for all diatonic dominant harmonies--$V$, $V7$, $VII$, $VII7$ (half-diminished). These harmonies are often used interchangeably; and it is often impossible, especially when dealing with implied harmony, to determine whether the root of a chord is the dominant or the leading tone.

The cadential $i_4^6$ is labelled, $V$, as well; its function is dominant, not tonic. Piston (1969) referred to this as "a dominant chord in which the sixth and fourth form appoggiature to the fifth and third respectively" (p. 96).

The symbol, $V/$, is used in the representation of all secondary dominant triads and seventh chords. For example, $V/V$ is the label for $V/V$, $V7/V$, $VII/V$, $VII7/V$ (both diminished and half-diminished).

Harmonies which are dominant in function but which contain chromatically altered tones are counted as separate and distinct harmonies from the diatonic dominant harmonies ($V$)---for example, a (fully) diminished seventh chord ($VII7$--$d7$), an altered dominant with a raised fifth ($V^+$).

The variable, number of different chords, was used by Heyduk (1975), but this variable did not cover all possibly significant harmonic aspects. Therefore, four
additional harmonic variables are specified in this investigation dealing with the frequency of harmony changes and the proportions of harmonic functions.

Number of Changes of Harmony (X4)

An eight measure alternation of I V I V I V I V is different from eight measures of I - - - V - - -. This difference is not reflected in a count of different harmonies--there are two different harmonies in each. This difference is indicated, though, by a count of seven changes of harmony in the first pattern and only one change of harmony in the second pattern.

Number of Measures of Tonic Harmony (X5)

All of the different harmonies can be categorized as having tonic, dominant, or other function. The tonic category includes all chords labelled I.

Number of Measures of Dominant Harmony (X6)

Included within the dominant category are all diatonic and chromatic harmonies based on the dominant or on the leading tone.

Number of Measures of Other Harmony (X7)

All other harmonies, that are neither tonic nor dominant, are categorized as other.
Changes in the Established, Collective Pattern of Rhythmic Activity (X8)

Established patterns of activity are defined as being at least one measure long. Changes can be (1) brief deviations from established patterns and back without the establishment of a new pattern, as in mm. 9-11 of Variation 4 (see p. 53), and many other variations; or (2) changes from an established pattern to a new pattern which is established, for example, mm. 1-8 of Variation 4.

There is one change of activity which characterizes all the variations: the fermata, m. 12. Since this is a constant for all variations, it is not counted as a change in activity.

It is common in all music that there be a cessation or slowing of activity at cadence points. Since the cadence structure for all variations used in the study is the same, such a cessation or slowing of activity is not counted as a change in activity.

Although no previous experimenter had specified this variable, changes of rhythmic activity, variables dealing with rhythmic regularity, which are somewhat comparable, were previously specified by Crozier (1974, number of durations), Heyduk (1975, rhythmic regularity), and Yeager (1969, regularity in alternation).
Rate of Rhythmic Activity (X9)

Rate of rhythmic activity, the number of tones per unit time, is a variable dependent upon the particular performance. The variations were not specially recorded according to the experimenter's instructions; a recording by Sviatoslav Richter, a pianist of repute, was used in experimentation. The rate of activity was, therefore, determined in the following manner:

A metronome was set to coincide with the basic beat, the frame of reference given at the beginning of a variation and confirmed through usage. If the collective rhythmic pattern contained more than one note value, as in Variations 4 and 8 (see pp. 53, 58), the basic beat was considered to be the shorter note value. An exception was made to this if the quicker note values were clearly ornaments, as in Variation 14 (see p. 68), where the eighth note is the consistent movement and the triplet figures ornament the melody. As is usually the case with all music, the performance of these variations was not metronomic; there are slight fluctuations in the rate of activity. The metronome reading, then, gave in beats per minute the predominant rate of rhythmic activity.

Comparable to this rate of rhythmic activity variable is the density variable, number of attacked tones per second, previously defined as being related to complexity by
Steck and Machotka (1975).

Length (X10)

Length in seconds was calculated for each variation. As with rate of activity, length is a variable dependent upon the particular performance of the set of variations used in experimentation.

Length is a variable that is usually controlled in experimentation with "music-like" structures. Such control was not possible with this experimentation using music by Beethoven; this set of variations was picked to have the maximum amount of control and yet still be music. It was, therefore, necessary to specify this variable, although the variations are quite similar with regard to length.

Application of Stimulus Variables to the "Eroica" Variations

The 16 "Eroica" Variations which were used in this study are presented on the following pages. Underneath each score the musical variables and the corresponding measurements for each variation are listed. When explanations or elaborations are necessary, an asterisk follows the measurement, and the explanation or elaboration is presented on the following page. For clarification, independent parts are labelled with circled numbers on the score, harmonies are labelled with Roman numerals, and each change of activity is marked with an X.
Example 1. Variation 1 (Introduzione col Basso del Tema)

Note. The first chord of "Introduzione" was deleted from the tape as presented. It functions as an introduction to the entire set of variations. By deleting it, the form of this theme was made identical to that of the other pieces of music.
Example 1, continued.

X1: There are three tones in all vertical structures but for the two tones in the one beat structure in m. 16. This is considered to be an extremely minor irregularity, thus, the number of tones in vertical structures is labeled "regular."

X4: This variation contains the only instances of rests in all parts in any of the chosen variations. The problem arises in the quantitative specification of harmonic properties: how does silence function harmonically? It seems obvious that in the one beat rests in m. 8 and m. 16 and in the half beat rest in m. 10, the respective dominant and tonic harmonies are implicit.

M. 9 and 11 are considered to be "dominant silence." M. 9, the first time through, is preceded by the dominant. M. 11, in both instances, is preceded and followed by the dominant. The silence functions as a dominant extension.

The repeat of m. 9 is considered to be dominant harmony as well, although this decision is not clearcut. The rationale is as follows: although the preceding harmony is tonic, the following harmony is dominant, and m. 9 is heard in the context of just having previously been heard when the silence was clearly dominant.
Example 2. Variation 2 (A due)

X1: 0
X2: 2
X3: 5 (I V V/II V/V II)
X4: 26
X5: 10
X6: 18
X7: 4
X8: 4
X9: 196
X10: 48.8
Example 3. Variation 3 (A tre)

\[
\begin{align*}
&\text{Eb: I V I V I V II V V V} \\
&\text{V II V I I V I}
\end{align*}
\]

\[
\begin{align*}
X_1: & 0 \\
X_2: & 3 \\
X_3: & 5 (I V V/II V/V II) \\
X_4: & 30 \\
X_5: & 10.5 \\
X_6: & 15.5 \\
X_7: & 6 \\
X_8: & 0 \\
X_9: & 206 \\
X_{10}: & 50.6
\end{align*}
\]
Example 4. Variation 4 (A quattro)

X1: 1
X2: 3*
X3: 6 (I V V/II II V/V IV)
X4: 34
X5: 11
X6: 15
X7: 6
X8: 7
X9: 436
X10: 39
Example 4, continued.

X2: The number of independent parts is predominantly 3. The change to 2 parts in mm. 9-12 is continued through m. 13.
Example 5. Variation 5 (Thema)

X1: 1
X2: 3
X3: 5 (I V V/II II V/V)
X4: 30
X5: 11
X6: 17.5
X7: 3.5
X8: 10
X9: 184
X10: 48
Example 6. Variation 6 (Var. I)

X1: 1
X2: 3
X3: 5 (I V V/II V/V II)
X4: 40
X5: 11
X6: 16.5
X7: 4.5
X8: 3
X9: 476
X10: 35.3
Example 7. Variation 7 (Var. II)

Note. This is the only variation to have a cadenza-like extension (m. 12).
Example 8. Variation 8 (Var. III)

X1:  1
X2:  3*
X3:  8 (I V bVI VII V/II V/V IV II)
X4:  32
X5:  9.5
X6:  16
X7:  6.5
X8:  7*
X9:  444
X10: 41
Example 8, continued.

X2: Tracing the independent parts in this variation is difficult. It is clear that there are basically 3 parts; however, the separation is not always clear.

X8: The question might be raised: why is not the straight eighth note movement in m. 2 (and again in m. 4) considered a change of activity? My position is that the initial pattern of activity is:

\[
\begin{align*}
\text{\textbf{r}} & \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \\
\text{\textbf{r}} & \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \\
\end{align*}
\]

which is further established by its repetition in truncated form:

\[
\begin{align*}
\text{\textbf{r}} & \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \\
\text{\textbf{r}} & \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \text{ \textbf{m}} \\
\end{align*}
\]
Example 9. Variation 9 (Var. IV)

\[ \begin{align*}
X1 &: 1 \\
X2 &: 2 \\
X3 &: 5 (I \ V \ V/II \ II \ V/V) \\
X4 &: 32 \\
X5 &: 11 \\
X6 &: 17.5 \\
X7 &: 3.5 \\
X8 &: 0 \\
X9 &: 460 \\
X10 &: 39.5
\end{align*} \]
Example 10. Variation 10 (Var. V)

X1: 1
X2: 2*
X3: 6 (I V V/III III IV II)*
X4: 26
X5: 11.5
X6: 16.5
X7: 4
X8: 7
X9: 200
X10: 49.8
Example 10, continued.

X2: In mm. 1-4 and 13-16 there are clearly two independent parts. The bass part of mm. 4-8 might be considered a third, different, part—if so, it is the only time a third part occurs. Therefore, this texture is labelled predominantly two-part. It might be argued that there are three parts in mm. 9-12. The bass line is a distinct part, but the upper lines sound like one arpeggiated part.

X3: At first glance it seems that the "a" and "f-sharp" in m. 12 might be nonharmonic tones. The vertical importance of these tones is obvious, though, when one notices that they introduce the pattern of harmonic rhythm for the next two measures (mm. 13 and 14):

\[ \text{Example Diagram} \]
Example 11. Variation 11 (Var. VIII)

X1: 1
X2: 3*
X3: 5 (I VII7 V V/V II)
X4: 24
X5: 10
X6: 15
X7: 7
X8: 0
X9: 372
X10: 48
Example 11, continued.

X2: There are three parts in mm. 1-12 but only two parts in mm. 13-16.
Example 12. Variation 12 (Var. IX)

X1: 0
X2: 2
X3: 3 (I V II)
X4: 26
X5: 13
X6: 17
X7: 2
X8: 8
X9: 339
X10: 40.2
Example 13. Variation 13 (Var. X)

Example:

\[ X_1: 0 \]
\[ X_2: 2 \]
\[ X_3: 8 \] (I V V+ dim1 dim2 dim3 \( \triangledown VI VII \))
\[ X_4: 33 \]
\[ X_5: 7.25 \]
\[ X_6: 4.75 \]
\[ X_7: 20 \]
\[ X_8: 4 \]
\[ X_9: 504 \]
\[ X_{10}: 38.6 \]
Example 13, continued.

X3: The diminished-seventh chords in mm. 2, 6, 7, 13-15 are labelled dim 1, 2, or 3:
Dim 1 is: c-sharp, e, g, b-flat (or an enharmonic equivalent).
Dim 2 is: c, e-flat, g-flat, a.
Dim 3 is: c-flat, d, f, a-flat.

Harmonic labels for mm. 9-12 pose an interesting problem. When the "c-flat" - "b-flat" alternation begins in m. 8, it seems that the "c-flat" is the ornament to the dominant. By m. 10, however, it is obvious that the "b-flat" is the ornament to the "c-flat." The movement from "c-flat" to "d" (m. 12) comes as a surprise. It sounds like a change in harmony, although in retrospect mm. 9-12 could be considered to be an expanded VII7 (fully diminished). I do not think that this higher level of analysis adequately describes what is heard. For counting purposes I have labelled the measures of "c-flat" as one harmony and the "d" in m. 12 as another harmony. The labels ♭VI and VII are somewhat arbitrary, but they do represent the respective scale degrees. These may be diminished chords, as those specified dim 1, 2, 3, above, but the context of mm. 9-12 is different from that of the rest of the variation. They are, therefore, counted as different harmonies.
Example 14. Variation 14 (Var. XI)

X1:  0
X2:  3*
X3:  6 (I V V/II VI 0VI II)
X4:  36
X5:  10.75
X6:  15.75
X7:  5.5
X8:  7
X9:  210
X10: 44
Example 14, continued.

X2: Independent parts consist of:
1. a treble figure that predominates mm. 1-6.
2. a constant accompaniment figure.
3. an imitative bass figure that appears in mm. 6.5-8 and 13-16.
Example 15. Variation 15 (Var. XII)

X1: 1
X2: 2
X3: 5 (I V V/II V/V II)
X4: 32
X5: 12
X6: 16
X7: 4
X8: 4
X9: 476
X10: 42
Example 16. Variation 16 (Var. XIII)

X1: 0*
X2: 3
X3: 4 (I V V/V II)
X4: 24
X5: 10.67
X6: 18.33
X7: 3
X8: 0
X9: 342
X10: 37.3
Example 16, continued.

XI: There are a few irregularities, but this vertical structure is basically regular. If the irregularities in m. 8 (beat 2) and m. 16 (beat 1) are dismissed as leading into the contrasting B section, and the irregularity in m. 8 (beat 1) is dismissed as a brief thinning out at the cadence, the only remaining irregularities are m. 7 (beat 1) and m. 15. M. 7 may be considered the result of voice leading -- "e-flat" and "g" both lead to "f." In m. 15 (beat 1), as well, the "a-flat" and "c" lead to "b-flat." The second beat of m. 15 contains an extra note.

The quantitative specification of musical variables for all 16 variations is summarized in Table 1.
### TABLE 1

**QUANTITATIVE SPECIFICATION OF MUSICAL VARIABLES IN BEETHOVEN'S "EROICA" VARIATIONS, OP. 35**

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<th>X3</th>
<th>X4</th>
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*The names of the variables corresponding to the labels are:

- **X1**: Regularity/irregularity of number of tones in vertical structures
- **X2**: Number of independent parts
- **X3**: Number of different harmonies
- **X4**: Number of changes of harmony
- **X5**: Number of measures of tonic harmony
- **X6**: Number of measures of dominant harmony
- **X7**: Number of measures of other harmony
- **X8**: Number of changes in activity
- **X9**: Rate of activity
- **X10**: Length (seconds)*
CHAPTER 3

METHOD

Details of the experimental situation are provided in this chapter. Descriptions are given of the subjects who participated in the experiment, the tapes of the musical stimuli and other apparatus, and the experimental procedure, including instructions to the subjects.

Subjects

All subjects participating in this experiment were enrolled at The Ohio State University. There were three groups of subjects differing in musical training; group size of 19-20 was decided upon as being large enough, for statistical purposes, to show patterns in responding if such patterns did indeed exist.

Group 1 was composed of 20 graduate music students, representing all divisions of musical activity: theory, history, education, composition, and performance. This distribution of subjects from different areas of specialization was necessary if the experimental results were to be generalized to graduate music students as a group. Although the individual subjects of this group were committed to different specializations, all subjects had a
comparable musical background—an undergraduate degree in music. This is a relatively standard program over undergraduate schools because of National Association of Schools of Music (NASM) requirements.

Subjects were told that an experiment in musical perception was being conducted, and they volunteered to participate. Subjects were assigned to one of four experimental groups (five subjects in each) based upon the times that they were available to participate.

Group 2 was composed of 20 sophomore music majors. These students were completing their last quarter of a two-year music theory/ear-training sequence and their last quarter of a one-year music history sequence. Sophomore music majors, unlike graduate music students, have not yet specialized in a particular area of musical activity. It is expected that they are a more homogeneous group than are either graduate music students or non-music majors.

Subjects received extra credit in their sophomore ear-training class for participation in the experiment. Because of problems in scheduling rooms for the experiment, and because of the inflexibility of the schedules of these sophomore music majors, subjects participated individually. They were randomly assigned to one of four experimental conditions (five subjects in each condition).
Group 3 was composed of 19 students in introductory psychology. These subjects professed a casual interest in music and were not music majors, music teachers, or professional musicians.

Participation in this experiment partially fulfilled the requirements of the introductory psychology course. Five subjects signed up for each of four posted experiment times. However, one subject became ill immediately prior to the experiment, and one subject reported for a session other than the one for which he was scheduled. Therefore, the number of participants in each of the four experimental groups was: 3, 6, 5, 5.

**Apparatus**

**Tapes of Musical Stimuli**

Monaural cassette tapes of the 16 Beethoven "Eroica" Variations, Op. 35, for piano (presented in Chapter 2) were made from the recording of Sviatoslav Richter (Angel, S-40183). There were four different tapes made, composed of four different orderings of the 16 variations as a control for sequence or order effects. These orderings were determined in the following manner:

Ten musical variables, hypothesized to possibly be related to complexity, were quantitatively specified for each of the 16 variations. These were defined and
discussed in Chapter 2 and are presented in Table 1 (p. 73). It was expected that the variables, "number of measures of tonic harmony" and "number of measures of dominant harmony," if applicable at all, would be inversely related to complexity, and that all other variables, if applicable at all, would be positively related to complexity. Standard scores were calculated for each of the stimulus variables, and these scores were summed (with the variables, "number of measures of tonic harmony" and "number of measures of dominant harmony," weighted negatively) for each variation (see Table 2). This provided an objective ordering of complexity with all specified variables weighted equally. This objective ordering was divided into quarters from least complex to most complex, giving: (variation no. 12 16 1 2/9 15 3 10/14 5 6 11/4 7 8 13).

Two order and sequence effects needed to be controlled for: (1) the overall distribution of "simple" and "complex" variations, and (2) the specific order so that no variation followed the same variation more than once.

Harmony was categorized as either "tonic," "dominant," or "other." It was expected that the more "other harmony" there was, the more complex the music would be judged to be. Since the number of measures was a constant, the greater the amount of "other harmony" there was, the less the amount of "tonic" and "dominant harmony."
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*a The names of the variables corresponding to the labels are:

- X1: Regularity/irregularity of number of tones in vertical structures
- X2: Number of independent parts
- X3: Number of different harmonies
- X4: Number of changes of harmony
- X5: Number of measures of tonic harmony
- X6: Number of measures of dominant harmony
- X7: Number of measures of other harmony
- X8: Number of changes in activity
- X9: Rate of activity
- X10: Length (seconds)

*b The sum reflects the negative weighting of X5 and X6. The scores of X5 and X6 were multiplied by 2 and their signs (positive or negative) were reversed.
To solve this problem each variation was assigned to a quartile which consisted of one variation from each level of objective complexity (as given above). In the order design each quartile appeared in each position, first, second, third, and fourth, once. In no case were the variations within the quartile in the same order.

Tapes were constructed so that no variation followed the same variation more than once; each variation appeared in each quarter of the tape exactly once. The four different orderings of the musical stimuli were:

- Tape 1--15 13 12 6/3 4 16 11/10 7 1 14/9 8 2 5
- Tape 2--5 2 8 9/14 1 7 10/11 16 4 3/6 12 13 15
- Tape 3--16 3 11 4/2 9 5 8/12 15 6 13/1 10 14 7
- Tape 4--7 14 10 1/13 6 15 12/8 5 9 2/4 11 3 16

Playback Equipment

Tapes were played on a Sony TC-121A cassette player-recorder, through Advent speakers for graduate music students and non-music majors, and through Koss K-6 headphones for the sophomore music majors. This difference in apparatus between the groups was unavoidable due to the listening facilities that were available when the sophomore subjects were free to participate in the experiment. Both the tapes and the equipment were of excellent quality.
Experimental Setting

Subjects participated in a quiet, well-lighted and well-ventilated room and were seated at tables such that they would not be distracted by the experimenter or by the other subjects.

Procedure

The experimental sessions consisted of three parts:

1. The subjects heard all of the variations, without rating them, to get an idea of the range of complexity with which they would be dealing.

2. The subjects heard the variations again and judged their complexity.

3. The subjects heard the variations one more time and had a chance to revise their ratings of complexity. The rationale for this third phase of the experiment was as follows: It was assumed that judging the complexity of these 16 variations would be a difficult task and that a third hearing of the music, with an opportunity to revise ratings, would increase the precision of the subjects' judgments. Even with this third phase, the experimental session took only one hour.

Subjects were instructed to use the method of magnitude estimation (Stevens, 1962) in judging the complexity of each variation. First, they were provided with a notebook containing a page of instructions and 16 response
pages and were asked to read the instructions while hearing them read on tape. Subjects were assured that any questions they had would be answered by the experimenter before the experiment began.

The instructions were:

Complexity is a term used to talk about music. We don't know much about it; we have no good measure of it. The purpose of this experiment is to get peoples' judgments of the relative complexity of short pieces of music. There can be no wrong answers because each individual is the sole judge of what is complex from his point of view. What we want to know is the extent to which people agree.

The musical selections that you will hear are 16 of Beethoven's "Eroica" Variations, Op. 35, for piano. If you have heard this set of piano variations before, please circle "yes;" if this is music which you have not previously heard, please circle "no." (yes no)

Your task will be to rate the complexity of each of these 16 variations. There are three parts to the experiment.

PART 1

Before rating any of the variations, you will hear all 16 of them so that you can become acquainted with the range of complexity with which you will be dealing. There will be 6 seconds of silence between variations. The order in which you hear the variations will be the same in all parts of the experiment, although it will be different from the order used by Beethoven.

As you are listening to these variations, determine what you consider to be a medium level of complexity and assign a value of 100 to it.

PART 2

When you hear the series of variations a second time, you are to rate each variation in comparison to the medium level of complexity (100) which you have decided upon. For example, if a variation seems 2 times as complex as music which you consider to be of medium complexity, your
response would be 200. If it seems 1/5 as complex as your standard of medium complexity, you would rate it 20.

You will have 20 seconds of silence after each variation in which to decide upon your rating of complexity and to write your response on the notebook page in front of you. After you have responded, turn to the next page in the notebook. I will announce each variation (by saying, "no. 1," "no. 2," etc.) 6 seconds before it begins.

PART 3

You will hear the variations a third time so that you can check over your ratings of complexity. If you decide to change a rating, mark your new rating underneath your previous rating. There will be six seconds of silence after each variation. Each variation will be announced as in Part 2.

Any questions raised were answered. Typical questions were: "Do we just listen the first time?" (Answer: Yes, just listen and decide what you consider to be a medium level of complexity). "What do you mean by complexity?" (Answer: You are to use your own definition of complexity).

Subjects then heard one of the four tapes, the tapes differing only in the order in which the variations were heard. Each tape consisted of three parts as detailed in the instructions above.
CHAPTER 4

RESULTS

The presentation of results is divided into two main sections: (1) a comparison of subjects' judgments of complexity and (2) the relation between the physically specified variables in the music and subjects' judgments of complexity.

Comparison of the Judgments of Complexity by Subjects, Within Groups and Among Groups

Because of the lack of precedents in this area of experimental investigation, subjects' judgments of complexity (from Part 3 of the experiment, their revised judgments of complexity) were treated in a variety of ways: as rank-orders, as standardized scores, and as logarithmic scores.

Comparison of Subjects' Judgments of Complexity According to Rank-Orders

For initial analysis the judgments of complexity made by each subject were rank-ordered. As the following will demonstrate, rank-orders were useful in spotting deviant subjects, in checking for order and/or sequence effects, in investigating differences among groups in homogeneity, and
in investigating the effect of prior familiarity with this set of variations upon judgments of complexity.

Within each group Spearman rank correlation coefficients of each subject's rank scores with the rank scores of every other subject were calculated. These rank-order correlations are presented in Tables 3 (Graduate), 4 (Sophomore), and 5 (Non-major). The critical value for significant agreement between subjects is .43 (n = 16, p = .05); nonsignificant correlations are underlined to aid in the detection of deviant subjects.

Most subjects evidenced significant agreement with other subjects in their group. However, Subject A3 of the graduate sample evidenced significant agreement with none of the other graduate subjects, and Subject D2 of the sophomore sample evidenced significant agreement with none of the other sophomore subjects. These subjects were considered to be deviant and were eliminated in further analysis of the data.

Non-major Subjects A1 and B3 evidenced little significant agreement with other non-major subjects and did not correlate significantly with each other. Non-major

\[ ^4 \text{Graduate Subject A3 evidenced significant disagreement (} r \geq -0.43 \text{) with a number of the other graduate subjects. Although these relationships may be meaningful, they were disregarded in this study.} \]
**TABLE 3**

SPEARMAN RANK COEFFICIENTS OF CORRELATION OF THE JUDGMENTS OF COMPLEXITY

OF GRADUATE SUBJECTS

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| B1 |  .42 | .43 | .53 | .45 | .55 | .39 | .47 | .36 | .28 | .31 | .49 | .31 | .55 | .40 |
| B2 |  .86 | .56 | .79 | .60 | .76 | .84 | .75 | .69 | .66 | .73 | .76 | .82 | .85 |
| B3 |  .66 | .62 | .39 | .77 | .87 | .66 | .74 | .76 | .65 | .83 | .84 | .89 |
| B4 |  .48 | .33 | .46 | .76 | .29 | .77 | .29 | .56 | .40 | .74 | .55 |
| B5 |  .70 | .52 | .68 | .65 | .41 | .41 | .73 | .49 | .69 | .61 |

| C1 |  .58 | .43 | .55 | .12 | .41 | .53 | .37 | .54 | .47 |
| C2 |  .66 | .56 | .50 | .89 | .40 | .70 | .75 | .89 |
| C3 |  .73 | .77 | .62 | .56 | .72 | .77 | .84 |
| C4 |  .40 | .54 | .50 | .74 | .52 | .66 |
| C5 |  .33 | .60 | .54 | .67 | .62 |

| D1 |  .25 | .79 | .68 | .92 |
| D2 |  .35 | .57 | .44 |
| D3 |  .80 | .87 |
| D4 |  .86 |

| D5 |

**Note.** n = 16.

The letters, A, B, C, and D denote the order subgroups.

Nonsignificant (r < .43) correlations are underlined.

An asterisk (*) marks those subjects who indicated that they had heard the "Eroica" Variations for piano before.
### TABLE 4

**SPEARMAN RANK COEFFICIENTS OF CORRELATION OF THE JUDGMENTS OF COMPLEXITY**

**OF SOPHOMORE SUBJECTS**

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**Note.** n = 16.

The letters, A, B, C, and D denote the order subgroups.

Nonsignificant (r < .43) correlations are underlined.

An asterisk (*) marks those subjects who indicated that they had heard the "Eroica" Variations for piano before.
### TABLE 5

**SPEARMAN RANK COEFFICIENTS OF CORRELATION OF THE JUDGMENTS OF COMPLEXITY OF NON-MAJOR SUBJECTS**

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*Note. n = 16.*

The letters, A, B, C, and D denote the order subgroups.

Non-significant (r<.43) correlations are underlined.

An asterisk (*) marks those subjects who indicated that they had heard the "Eroica" Variations for piano before.
Subject D4 showed no agreement with other non-major subjects. Since there were three such subjects within a group of 19, they were not considered deviant and were not eliminated from the non-major sample. It is possible that they represent the extreme variability which may exist in the non-music major population.

After elimination of deviant subjects, the number of subjects in each group was 19. Within the sophomore group, there remained only two nonsignificant rank-order correlations; whereas, a number of nonsignificant rank-order correlations were contained in the graduate group (39) and the non-major group (61).

Within each group were four subgroups (A, B, C, D) differing only in the order in which the variations were heard. This counterbalancing was necessary to ascertain if there were order or sequence effects which influenced judgments of complexity. The rank-order correlation coefficients within a subgroup were compared with the rank-order correlation coefficients of other subgroups by calculating coefficients of concordance, the average of the correlation coefficients within a subgroup and between subgroups. The coefficients of concordance for all subgroups of all groups are presented in Table 6.

A comparison of within subgroup and between subgroup coefficients of concordance for each group of subjects shows
<table>
<thead>
<tr>
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<th>B</th>
<th>C</th>
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that the correlation within a subgroup is, with one exception, not greatly different from the correlations between the subgroups of a particular group. The exception is within Subgroup C of the non-major sample, the correlation .73 being clearly different from all other coefficients of concordance within the non-major group which range from .37 to .52. Reasons for this are unknown; speculations will be presented in Chapter 5 (pp.118-119).

It seemed reasonable to conclude that the order in which the variations were heard did not differentially influence the subjects' judgments of complexity, and the data from all subgroups within each group were combined for further analysis. The average rank-orders of judgments of complexity for each subgroup and each group are contained in Table 7.

The coefficients of concordance given in Table 6 indicate that the sophomore music majors were a highly homogeneous group, in that their judgments of complexity agreed to a much greater extent than did either those of the graduate music students or those of the non-music majors. The Mann-Whitney U Test was employed to test this conjecture. Since the within subgroup coefficients of concordance (the diagonal of the matrix, Table 6) were measures independent of each other, differences between groups were tested by comparing the four within subgroup coefficients of
### TABLE 7

**AVERAGE RANK-ORDERS OF THE JUDGMENTS OF COMPLEXITY BY ORDER SUBGROUPS AND BY GROUPS**

**FOR EACH VARIATION**

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<td>7</td>
<td>14</td>
<td>5</td>
</tr>
</tbody>
</table>
concordance of one group with the four within subgroup coefficients of concordance of another group. The results were:

1. A comparison of the sophomore group with the graduate group showed the coefficients of concordance of the sophomore group to be significantly higher ($U = 0$, $p = .014$).

2. A comparison of the sophomore group and the non-major group indicated that the coefficients of concordance of the sophomore group are significantly higher ($U = 2.5$, $p = .08$).

3. A comparison of the graduate group with the non-major group indicated no significant differences ($U = 4.5$, $p > .20$) in their coefficients of concordance.

There is evidence that prior familiarity with this set of variations had no significant influence upon subjects' judgments of complexity. Subjects who claimed to have previously heard this set of variations are marked with an asterisk in Tables 3, 4, and 5. There does not appear to be any sort of pattern in the rank-order correlation coefficients to distinguish those subjects who had previously heard the "Eroica" Variations for piano from those who had not (this is discussed further in Chapter 5, p.137).
Comparison of Subjects' Judgments of Complexity
According to Standardized Scores

The rationale for using standardized scores will be presented below, followed by a comparison of the three groups based upon these scores.

Due to the lack of experimental precedent, the first phase of this study, the experiment with graduate students, was considered to be exploratory in nature. Five different complexity scores were extracted from these subjects' raw scores:

1. average raw score
2. average standardized score
3. average percent score (score divided by maximum score)
4. average of score minus average, divided by range
5. average rank score

The intercorrelations of these complexity scores are presented in Table 8. Since these intercorrelations are so high, it seemed that one type of complexity score would suffice; standardized scores were chosen for the following reasons:

Of those complexity scores which correlated .99 with each other (all but rank score), the easiest to compute was the average raw score. However, it was expected that some subjects might have had problems using the type of ratio
<table>
<thead>
<tr>
<th>Variableᵃ</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.996</td>
<td>.998</td>
<td>.997</td>
<td>.956</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>.999</td>
<td>.999</td>
<td>.956</td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td></td>
<td>.999</td>
<td>.958</td>
<td></td>
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<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>.957</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. \( n = 16; p = .0001 \).

ᵃThe names of the variables corresponding to the numerals are:

1. average raw score
2. average standardized score
3. average percent score
4. average of score minus average score, divided by range
5. average rank score
scale that they were instructed to use and that, therefore, different subjects might have created scales that were not comparable. For these reasons raw scores were not used for further analysis.

Of the remaining complexity scores, the easiest to compute were standardized scores which had the advantage of minimizing differences caused by use of different scales. Tables 9 (Graduate), 10 (Sophomore), and 11 (Non-major) present the average raw scores and the average standardized scores and compare the ranks obtained from each with the average rank scores presented earlier (Table 7). It can be seen that for each group the three are quite similar, but there are differences. It was felt that these differences substantiated the use of standardized scores which, in addition to providing a standard scale, contain more information for purposes of investigating the relation between variables in music and subjects' perception of complexity than either rank or raw scores.

Table 12 contains the correlation coefficients of the standardized scores between groups. All correlations are significant at the .0001 level.

Table 13 contains the standard deviations of the standardized scores of each variation for each group. The Wilcoxon-rank sum test for a paired experiment was conducted to determine if there were significant differences among the
### TABLE 9

**COMPARISON OF GRADUATE SUBJECTS' RAW SCORES, STANDARDIZED SCORES, AND RANK SCORES DERIVED FROM JUDGMENTS OF COMPLEXITY**

Scores derived from judgments of complexity.

<table>
<thead>
<tr>
<th>Score</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>28</td>
<td>88</td>
<td>71</td>
<td>124</td>
<td>83</td>
<td>120</td>
<td>196</td>
<td>174</td>
<td>107</td>
<td>112</td>
<td>136</td>
<td>135</td>
<td>205</td>
<td>102</td>
<td>166</td>
<td>108</td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>10</td>
<td>3</td>
<td>9</td>
<td>15</td>
<td>14</td>
<td>6</td>
<td>8</td>
<td>12</td>
<td>11</td>
<td>16</td>
<td>5</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Standard</td>
<td>-1.65</td>
<td>-0.57</td>
<td>-0.90</td>
<td>0.12</td>
<td>0.64</td>
<td>0</td>
<td>1.12</td>
<td>0.88</td>
<td>0.24</td>
<td>0.08</td>
<td>0.23</td>
<td>0.20</td>
<td>1.49</td>
<td>-0.29</td>
<td>0.69</td>
<td>-0.36</td>
</tr>
<tr>
<td>Rank</td>
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<td>2</td>
<td>10</td>
<td>3</td>
<td>9</td>
<td>15</td>
<td>14</td>
<td>7</td>
<td>8</td>
<td>12</td>
<td>11</td>
<td>16</td>
<td>6</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Rank</td>
<td>Average</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>11</td>
<td>3</td>
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<td>8</td>
<td>10</td>
<td>12</td>
<td>16</td>
<td>5</td>
<td>13</td>
</tr>
</tbody>
</table>

**Note.** n = 19.
### TABLE 10

**COMPARISON OF SOPHOMORE SUBJECTS’ RAW SCORES, STANDARDIZED SCORES, AND RANK**

**SCORES DERIVED FROM JUDGMENTS OF COMPLEXITY**

<table>
<thead>
<tr>
<th>Variation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Raw</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Average</td>
<td>29</td>
<td>65</td>
<td>57</td>
<td>151</td>
<td>102</td>
<td>168</td>
<td>310</td>
<td>195</td>
<td>148</td>
<td>77</td>
<td>149</td>
<td>166</td>
<td>217</td>
<td>110</td>
<td>202</td>
<td>152</td>
</tr>
<tr>
<td>Rank</td>
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<td>2</td>
<td>9</td>
<td>5</td>
<td>12</td>
<td>16</td>
<td>13</td>
<td>7</td>
<td>4</td>
<td>8</td>
<td>11</td>
<td>15</td>
<td>6</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td><strong>Standard Average</strong></td>
<td>-1.51</td>
<td>-.99</td>
<td>-1.09</td>
<td>.14</td>
<td>-.48</td>
<td>.40</td>
<td>1.89</td>
<td>.62</td>
<td>.11</td>
<td>-.78</td>
<td>.09</td>
<td>.45</td>
<td>.93</td>
<td>-.39</td>
<td>.64</td>
<td>-.02</td>
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<tr>
<td>Rank</td>
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<td>2</td>
<td>10</td>
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<td>11</td>
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<td>8</td>
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<td>15</td>
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<td>14</td>
<td>7</td>
</tr>
<tr>
<td><strong>Rank Average</strong></td>
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<td>3</td>
<td>2</td>
<td>10</td>
<td>5</td>
<td>11</td>
<td>16</td>
<td>13</td>
<td>8</td>
<td>4</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td>6</td>
<td>14</td>
<td>7</td>
</tr>
</tbody>
</table>

*Note. n = 19.*
TABLE 11

COMPARISON OF NON-MAJOR SUBJECTS’ RAW SCORES, STANDARDIZED SCORES, AND RANK

SCORES DERIVED FROM JUDGMENTS OF COMPLEXITY

<table>
<thead>
<tr>
<th>Score</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>73</td>
<td>56</td>
<td>64</td>
<td>146</td>
<td>136</td>
<td>207</td>
<td>261</td>
<td>168</td>
<td>145</td>
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<td>141</td>
<td>205</td>
<td>200</td>
<td>152</td>
<td>191</td>
<td>111</td>
</tr>
<tr>
<td>Rank</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>6</td>
<td>15</td>
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<td>7</td>
<td>14</td>
<td>13</td>
<td>10</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Standard</td>
<td>-1.17</td>
<td>-1.07</td>
<td>-.95</td>
<td>.05</td>
<td>-.22</td>
<td>.63</td>
<td>1.39</td>
<td>.29</td>
<td>.04</td>
<td>-.53</td>
<td>.15</td>
<td>.65</td>
<td>.62</td>
<td>-.07</td>
<td>.60</td>
<td>-.39</td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>6</td>
<td>14</td>
<td>16</td>
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<td>10</td>
<td>15</td>
<td>13</td>
<td>7</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>6</td>
<td>13</td>
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<td>12</td>
<td>15</td>
<td>7</td>
<td>14</td>
<td>5</td>
</tr>
</tbody>
</table>

Note. n = 19.
TABLE 12

COEFFICIENTS OF CORRELATION OF THE STANDARDIZED COMPLEXITY
SCORES BETWEEN GROUPS

<table>
<thead>
<tr>
<th>Group</th>
<th>Graduate</th>
<th>Sophomore</th>
<th>Non-major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate</td>
<td>.878</td>
<td></td>
<td>.821</td>
</tr>
<tr>
<td>Sophomore</td>
<td>.955</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-major</td>
<td></td>
<td></td>
<td>.955</td>
</tr>
</tbody>
</table>

Note.  
$n = 16$ standardized complexity scores for each group.

All correlations are significant at $p = .0001$. 
<table>
<thead>
<tr>
<th>Group</th>
<th>Variation 1</th>
<th>Variation 2</th>
<th>Variation 3</th>
<th>Variation 4</th>
<th>Variation 5</th>
<th>Variation 6</th>
<th>Variation 7</th>
<th>Variation 8</th>
<th>Variation 9</th>
<th>Variation 10</th>
<th>Variation 11</th>
<th>Variation 12</th>
<th>Variation 13</th>
<th>Variation 14</th>
<th>Variation 15</th>
<th>Variation 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate</td>
<td>.528</td>
<td>.497</td>
<td>.438</td>
<td>.371</td>
<td>.535</td>
<td>.536</td>
<td>.919</td>
<td>.514</td>
<td>.490</td>
<td>.643</td>
<td>.750</td>
<td>.653</td>
<td>.629</td>
<td>.694</td>
<td>.396</td>
<td>.833</td>
</tr>
<tr>
<td>Non-major</td>
<td>.790</td>
<td>.355</td>
<td>.506</td>
<td>.488</td>
<td>.581</td>
<td>1.049</td>
<td>.729</td>
<td>.455</td>
<td>.713</td>
<td>.848</td>
<td>.954</td>
<td>.678</td>
<td>.647</td>
<td>.626</td>
<td>.682</td>
<td></td>
</tr>
</tbody>
</table>

Note. n = 19 subjects in each group.
standard deviations of the standardized scores of the three groups. Findings were:

1. The standard deviations of the standardized scores of the sophomores were significantly smaller than those of the non-majors (T = 5, p < .005) and those of the graduates (T = 20, p < .01).

2. The standard deviations of the standardized scores of the graduates were significantly smaller than those of the non-majors (T = 23, p < .01). This is further substantiation of the claim that the sophomore music majors were a more homogeneous group than either the graduate music students or the non-music majors, and this suggests that the graduate students were a more homogeneous group than the non-majors.

Comparison of the Judgments of Complexity

Among the Groups According to Logarithmic Scores

The high correlations of the standardized scores among the groups indicated that the groups were highly similar. However, correlations can only give information concerning ordinal relationships. An analysis of variance was used to determine whether the groups differed significantly from each other in the distribution of their judgments of complexity. The standardized scores of the judgments of complexity could not be used because in the process of
standardization all means had become zero. It was necessary, then, to use the raw scores, in particular, the logarithm, base 10, of the raw scores, in a 3 (groups differing in musical experience) by 16 (pieces of music) analysis of variance with subjects nested within the groups as replicates. Results are presented in Table 14. No significant variation among the groups was indicated ($F = 1.24$, $p = .30$), however, the members of the variation set (pieces of music) were found to differ significantly in complexity as judged.

**Summary**

Spearman rank-order correlation coefficients among subjects' judgments of complexity derived from subjects' raw scores were used to spot deviant subjects, to determine that there were no significant order and/or sequence effects, to conclude that the sophomore group was more homogeneous in their judgments of complexity than were either of the other groups, and to determine that prior familiarity with the "Eroica" Variations for piano had no discernable influence upon judgments of complexity.

From the standardized scores of the judgments of complexity, correlations between pairs of the groups were determined: Graduate / Sophomore, .89; Graduate / Non-major, .84; and Sophomore / Non-major, .96. Analysis of
TABLE 14
ANALYSIS OF VARIANCE OF LOGARITHMIC COMPLEXITY SCORES BY
3 GROUPS OF SUBJECTS FOR 16 PIECES OF MUSIC

<table>
<thead>
<tr>
<th>Sources of Variation</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>F</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piece of music</td>
<td>15</td>
<td>2.65</td>
<td>30.48</td>
<td>.0001</td>
</tr>
<tr>
<td>Group</td>
<td>2</td>
<td>.01</td>
<td>1.24</td>
<td>.302</td>
</tr>
</tbody>
</table>
the standard deviations of each group for each variation indicated that the groups differed significantly in homogeneity. From most to least homogeneous, they were: Sophomore, Graduate, and Non-major.

Using the logarithm, base 10, of the raw scores (original judgments of complexity), no significant variation was found among the groups in their judgments of complexity.

**Relation Between Physically Specified Variables in the Music and Subjects' Judgments of Complexity**

This section deals with the musical variables and their intercorrelations and the relation between the musical variables and subjects' standardized scores of complexity, as evidenced by correlation of musical variables with the standardized scores, analysis of variance, and stepwise regression.

Table 15 presents the correlation coefficients of the musical variables (detailed discussion of these correlations is contained in Chapter 5, pp. 121-124). Because of the high correlation (-.98) between variables X6 and X7, "number of measures of dominant harmony" and "number of measures of other harmony," variable X6 was disregarded in
### TABLE 15

COEFFICIENTS OF INTERCORRELATION OF MUSICAL VARIABLES

<table>
<thead>
<tr>
<th>Variable</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
<th>X10</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>.31</td>
<td>.17</td>
<td>.32</td>
<td>.19</td>
<td>.17</td>
<td>-.19</td>
<td>-.14</td>
<td>.47*</td>
<td>-.02</td>
<td></td>
</tr>
<tr>
<td>X2</td>
<td>.08</td>
<td>.36</td>
<td>-.06</td>
<td>.06</td>
<td>-.03</td>
<td>-.46*</td>
<td>.33</td>
<td>-.05</td>
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<td></td>
</tr>
<tr>
<td>X3</td>
<td>.37</td>
<td>-.74***</td>
<td>-.64***</td>
<td>.71***</td>
<td>.12</td>
<td>.18</td>
<td>-.08</td>
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<td>X4</td>
<td>-.12</td>
<td>-.24</td>
<td>.22</td>
<td>-.10</td>
<td>.52**</td>
<td>-.39</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>X5</td>
<td>-.70***</td>
<td>-.84***</td>
<td>.16</td>
<td>-.16</td>
<td>.03</td>
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</tr>
<tr>
<td>X6</td>
<td>-.98***</td>
<td>.09</td>
<td>-.29</td>
<td>.24</td>
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</tr>
<tr>
<td>X7</td>
<td>-.11</td>
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<td>X8</td>
<td>-.57**</td>
<td>.07</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>X9</td>
<td>-.45*</td>
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<tr>
<td>X10</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. n = 16.

*** p < .01
**  p < .05
*   p < .10

The names of the variables corresponding to the labels are:

X1: Regularity/irregularity of number of tones in vertical structures
X2: Number of independent parts
X3: Number of different harmonies
X4: Number of changes of harmony
X5: Number of measures of tonic harmony
X6: Number of measures of dominant harmony
X7: Number of measures of other harmony
X8: Number of changes in activity
X9: Rate of activity
X10: Length (seconds)
The correlation of the musical variables with the standardized complexity scores of each group for each variation is contained in Table 16. For all groups the correlation with X9: "rate of activity," was highly significant (p = .0001). Additional significant correlations (p < .10) were:

- Graduate -- X7: "number of measures of other harmony"
- X3: "number of different harmonies"
- Sophomore -- X4: "number of changes of harmony"
- Non-major -- X4: "number of changes of harmony"
- X1: "regularity/irregularity in vertical structures"

An analysis of variance for each group (see Table 17) with 9 musical variables and 16 pieces of music, showed that together all specified musical variables accounted for 94% of the variability in graduate music students' responses, 96% of the variability in sophomore music majors' responses, and 92% of the variability in non-music majors' responses (R² multiplied by 100 can be directly interpreted as percentage

---

5 There was no obvious reason for picking X7 instead of X6. Correlations of the two with other musical variables were highly similar, though generally one was positive and the other negative. Results were virtually identical when an analysis of variance or stepwise regression was run first with X6 and then with X7. X7 was chosen because it fits the knowledgeable musician's experience better to say, "the more non-tonic or non-dominant harmony there is within a piece of music, the more complex it is perceived to be;" rather than, "the less dominant harmony there is in a piece of music, the more complex it is perceived to be."
## TABLE 16

COEFFICIENTS OF CORRELATION OF THE MUSICAL VARIABLES WITH THE STANDARIZED COMPLEXITY SCORES OF EACH GROUP

<table>
<thead>
<tr>
<th>Variable&lt;sup&gt;a&lt;/sup&gt;</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
<th>X10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate</td>
<td>.34</td>
<td>.24</td>
<td>.46*</td>
<td>.37</td>
<td>-.32</td>
<td>.53**</td>
<td>-.36</td>
<td>.84***</td>
<td>-.32</td>
</tr>
<tr>
<td>Sophomore</td>
<td>.40</td>
<td>.33</td>
<td>.17</td>
<td>.46*</td>
<td>-.12</td>
<td>.27</td>
<td>-.42</td>
<td>.95***</td>
<td>-.43</td>
</tr>
<tr>
<td>Non-major</td>
<td>.44*</td>
<td>.31</td>
<td>.10</td>
<td>.53**</td>
<td>.02</td>
<td>.21</td>
<td>-.30</td>
<td>.88***</td>
<td>-.42</td>
</tr>
</tbody>
</table>

Note. n = 16 standardized complexity scores for each group.

*** p≤.0001  
** p<.05  
* p<.10

<sup>a</sup>Variable names are given with Table 15 and are in the text.
## TABLE 17

ANALYSIS OF VARIANCE OF THE STANDARDIZED COMPLEXITY SCORES
OF EACH GROUP OF SUBJECTS AND THE GROUPS POOLED,
WITH 9 MUSICAL VARIABLES AND 16 PIECES OF MUSIC

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Sources of Variation</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>SD</th>
<th>F</th>
<th>P&gt;F</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate</td>
<td>19</td>
<td>Model</td>
<td>9</td>
<td>8.805</td>
<td>.313</td>
<td>9.98</td>
<td>.005</td>
<td>.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Error</td>
<td>6</td>
<td>.588</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrected total</td>
<td>15</td>
<td>9.393</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sophomore</td>
<td>19</td>
<td>Model</td>
<td>9</td>
<td>10.679</td>
<td>.254</td>
<td>18.27</td>
<td>.001</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Error</td>
<td>6</td>
<td>.389</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrected total</td>
<td>15</td>
<td>11.068</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-major</td>
<td>19</td>
<td>Model</td>
<td>9</td>
<td>6.932</td>
<td>.318</td>
<td>7.59</td>
<td>.011</td>
<td>.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Error</td>
<td>6</td>
<td>.609</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrected total</td>
<td>15</td>
<td>7.540</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groups</td>
<td>57</td>
<td>Model</td>
<td>9</td>
<td>8.206</td>
<td>.274</td>
<td>12.07</td>
<td>.003</td>
<td>.95</td>
</tr>
<tr>
<td>Pooled</td>
<td></td>
<td>Error</td>
<td>6</td>
<td>.453</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrected total</td>
<td>15</td>
<td>8.659</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of variability accounted for). When the three groups were pooled (n = 57), 95% of the variability in subjects' responses was accounted for.

The results of a stepwise regression giving the best 1, 2, 3, 4, and 5 variable models are contained in Tables 18 (Graduate), 19 (Sophomore), and 20 (Non-major). The best one-variable model was, for all groups, X9: "rate of activity." With that variable alone, 71%, 90%, and 78% of the variability in the responses of graduates, sophomores, and non-majors, respectively, was accounted for. Note that this variable accounted for a much higher percentage of the variability of the responses of the sophomore subjects than it did with the other two groups of subjects.

The best two-variable model for the sophomore and non-major groups included X9: "rate of activity" and X8: "changes in activity"—both rhythmic variables. Whereas, the best two-variable model for graduate students was X9: "rate of activity," and X7: "number of measures of other harmony"—one rhythmic and one harmonic variable.

Although it is interesting to compare the 3, 4, and 5 variable models of the groups, the addition of each variable past the two-variable model did not account for enough additional variability to merit serious consideration. As is indicated by the graph in Figure 1, the graduate and non-major functions increased less sharply after the addition of
### TABLE 18

**STEPWISE REGRESSION ANALYSIS OF GRADUATES' STANDARDIZED COMPLEXITY SCORES**

<table>
<thead>
<tr>
<th>Number of Variables in Model</th>
<th>Objective Variables in Model</th>
<th>$F^*$</th>
<th>$R$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X9</td>
<td>34.23</td>
<td>.84</td>
<td>.71</td>
</tr>
<tr>
<td>2</td>
<td>X9, X7</td>
<td>27.96</td>
<td>.90</td>
<td>.81</td>
</tr>
<tr>
<td>3</td>
<td>X9, X7, X5</td>
<td>19.58</td>
<td>.91</td>
<td>.83</td>
</tr>
<tr>
<td>4</td>
<td>X9, X7, X5, X3</td>
<td>17.40</td>
<td>.93</td>
<td>.86</td>
</tr>
<tr>
<td>5</td>
<td>X9, X3, X7, X5, X4</td>
<td>19.96</td>
<td>.95</td>
<td>.91</td>
</tr>
</tbody>
</table>

*Note. $n = 16$ standardized complexity scores.*

$p = .0001$ for all $F$ values.
### TABLE 19
STEPWISE REGRESSION ANALYSIS OF SOPHOMORES' STANDARDIZED COMPLEXITY SCORES

<table>
<thead>
<tr>
<th>Number of Variables in Model</th>
<th>Objective Variables in Model</th>
<th>F*</th>
<th>R</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X9</td>
<td>131.15</td>
<td>.95</td>
<td>.90</td>
</tr>
<tr>
<td>2</td>
<td>X9 X8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>82.81</td>
<td>.96</td>
<td>.93</td>
</tr>
<tr>
<td>3</td>
<td>X9 X8&lt;sup&gt;a&lt;/sup&gt; X1</td>
<td>57.01</td>
<td>.96</td>
<td>.93</td>
</tr>
<tr>
<td>4</td>
<td>X9 X8&lt;sup&gt;a&lt;/sup&gt; X4 X2</td>
<td>45.88</td>
<td>.97</td>
<td>.94</td>
</tr>
<tr>
<td>5</td>
<td>X9 X8&lt;sup&gt;a&lt;/sup&gt; X2 X4 X1</td>
<td>43.34</td>
<td>.98</td>
<td>.96</td>
</tr>
</tbody>
</table>

Note. n = 16 standardized complexity scores.

*<sup>p = .0001</sup> for all F values.

<sup>a</sup>The variable has a negative correlation with the standardized complexity scores.
<table>
<thead>
<tr>
<th>Number of Variables in Model</th>
<th>Objective Variables in Model</th>
<th>F*</th>
<th>R</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X9</td>
<td>49.12</td>
<td>.88</td>
<td>.78</td>
</tr>
<tr>
<td>2</td>
<td>X9a X8</td>
<td>33.32</td>
<td>.92</td>
<td>.84</td>
</tr>
<tr>
<td>3</td>
<td>X9a X8 X5</td>
<td>24.08</td>
<td>.93</td>
<td>.86</td>
</tr>
<tr>
<td>4</td>
<td>X9a X5 X8 X7</td>
<td>20.70</td>
<td>.94</td>
<td>.88</td>
</tr>
<tr>
<td>5</td>
<td>X9a X5 X8 X7 X2</td>
<td>17.89</td>
<td>.95</td>
<td>.90</td>
</tr>
</tbody>
</table>

Note.  

n = 16 standardized complexity scores

*p = .0001 for all F values.

a The variable has a negative correlation with the standardized complexity scores.
Figure 1. Percentage of variability in subjects' responses accounted for by the stepwise regression models for each group.
the second variable, and the sophomore function did not increase greatly after the first variable model.

When the groups were pooled, the best one-variable model was $X_9$: "rate of activity;" the best two-variable model was $X_9$: "rate of activity," and $X_8$: "changes in activity;" the best three-variable model was $X_9$: "rate of activity," $X_8$: "changes in activity," and $X_7$: "number of measures of other harmony" (see Table 21).

Summary

Important findings from the analysis of the relation between physically specified variables in the music and subjects' standardized complexity scores included:

1. Musical variables which correlated significantly ($p < .10$) with judgments of complexity were:
   
   Graduates — $X_9$: "rate of activity"
   $X_7$: "number of measures of other harmony"
   $X_3$: "number of different harmonies"

   Sophomores — $X_9$: "rate of activity"
   $X_4$: "number of changes of harmony"

   Non-majors — $X_9$: "rate of activity"
   $X_4$: "number of changes of harmony"
   $X_1$: "regularity/irregularity in vertical structures"

2. The amount of variability in subjects' responses accounted for by all specified musical variables was:
### TABLE 21

**STEPWISE REGRESSION ANALYSIS OF THE POOLED STANDARDIZED COMPLEXITY SCORES OF ALL GROUPS**

<table>
<thead>
<tr>
<th>Number of Variables in Model</th>
<th>Objective Variables in Model</th>
<th>F*</th>
<th>R</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X9</td>
<td>83.10</td>
<td>.93</td>
<td>.86</td>
</tr>
<tr>
<td>2</td>
<td>X9, X8</td>
<td>52.02</td>
<td>.94</td>
<td>.89</td>
</tr>
<tr>
<td>3</td>
<td>X9, X8, X7</td>
<td>35.67</td>
<td>.95</td>
<td>.90</td>
</tr>
</tbody>
</table>

Note.  \( n = 16 \) standardized complexity scores averaged across all groups.

\( *p = .0001 \) for all F values.
Graduates -- 94%
Sophomores -- 96%
Non-majors -- 92%

3. The best two-variable models for the groups were:

Graduates -- X9: "rate of activity"
X7: "number of measures of other harmony" (accounting for 81% of the variability)

Sophomores -- X9: "rate of activity"
X8: "number of changes in activity" (accounting for 93% of the variability)

Non-majors -- X9: "rate of activity"
X8: "number of changes in activity" (accounting for 84% of the variability)
CHAPTER 5

DISCUSSION

Experimental results and their implications are discussed in this chapter. Topics considered are:
similarity of judgments of complexity, intercorrelations among musical variables, musical variables in future research, similarities and differences among groups in the relation between musical variables and judgments of complexity, support for a psychophysical theory, and conclusions.

Similarity of Judgments of Complexity

It is thought by many that listening to music is a unique, personal experience. Music literature contains an abundance of statements like the following one by Sessions (1950):

In following a performance [the listener] recreates it and makes it his own. He really listens precisely to the degree that he does this, and really hears to precisely the extent that he does it successfully. (p. 20)

This experimentation has shown that many persons have similar listening experiences based upon the same quantitatively specified musical variables.
Judgments of musical complexity within like groups of subjects were similar. Sophomore music majors were found to be a highly homogeneous group; there was a great deal of similarity among sophomore subjects in their judgments of complexity. The sophomore group was significantly more homogeneous than were either the graduate music students or the non-music majors. There was some evidence that the graduate students were a more homogeneous group than the non-music majors.

These results are not surprising. As was stated in the description of subjects (supra, pp. 74-5), sophomore music majors have a common interest and background in music, but have not yet specialized in a particular phase of music. Graduate music students, on the other hand, are more diversified, yet still have a common background. They have specialized in music theory, history, education, composition, or performance; and it would be expected that such specializations would influence how they perceive music.

Non-music majors are also a diversified group. All that is known about this particular group of non-music majors is that they met the established criteria: they professed a casual interest in music and were not music teachers, music majors, or professional performers. It is likely that the musical experiences of some of these
subjects included activities, such as, playing in the high school band, taking piano lessons, and singing in choirs, and that the musical experience of others was limited to listening to the radio. It is congruent with expectation that a large range in the coefficients of concordance for this group (.37 to .73) would result from the subjects' extremely diversified backgrounds. It is possible, for example, that all subjects in order Subgroup C (coefficient of concordance = .73) had studied music privately while in high school. Since no data (other than subjects' adherence to the criteria listed above) were gathered concerning subjects' musical experiences and background, this assertion can not be substantiated. The present study, the first of its type, has laid the groundwork for further experimentation with much larger groups of subjects utilizing a detailed questionnaire on musical experiences and background following the experimental situation. Through such experimentation it would be possible to study the relation of differences between subjects in responding and differences between subjects in musical background.

The judgments of complexity of all three groups were highly correlated, and no significant differences among groups were indicated by an analysis of variance. This finding of such a high degree of similarity among the groups is remarkable given the known differences among the
groups in musical background and training. The order of the correlations between the groups was, from highest to lowest: sophomore/non-major, sophomore/graduate, and graduate/non-major. Although this study has given no evidence that this order is meaningful, there is a rationale for the order. It was expected that the judgments of complexity of the graduates and the judgments of complexity of the sophomores would be more highly correlated than the judgments of complexity of the graduates and the judgments of complexity of the non-majors, because the graduates and the sophomores share similar musical training and experiences—the freshman and sophomore theory and history courses required by NASM. This expectation was substantiated. The finding of a higher correlation between the judgments of complexity of the sophomores and the non-majors than the judgments of complexity of the sophomores and the graduates was unexpected. When one considers, though, that non-music majors have had 0 years of college music training, sophomore music majors have had 2 years of college music training, and graduate music students (in this study) have had at least 6 years of college music training, this result does not seem so remarkable. In future investigations with larger groups of subjects and a greater variety of music, this order of the correlations between groups might be substantiated.
Although there was a great deal of similarity in the judgments of complexity of the three groups of subjects for most variations, the judgments of complexity for some variations were quite different. For example, those variations for which the judgments of the groups differed most markedly, as evidenced by differences of 4 or more between rank-orders and ranks of standardized scores, were: Variation 10 (Graduate/Sophomore, Graduate/Non-major) and Variation 6 (Graduate/Non-major). Careful study of these variations has yielded no discernable patterns which might be the basis for these differences among groups. It is possible that the differences in judgments were based upon variables which were not specified in this experiment and which I have been unable to discern.

**Intercorrelations Among Musical Variables**

A number of observations can be made concerning the relationships (intercorrelations) among the musical variables in the selected "Eroica" Variations:

1. The highest correlations among musical variables were for the harmonic variables, X3: "number of different harmonies," X5: "number of measures of tonic harmony," X6: "number of measures of dominant harmony," and X7: "number of measures of other harmony." These harmonic variable correlations (p ≤ .007) were:
2. The correlation between X6: "number of measures of dominant harmony" and X7: "number of measures of other harmony" was so high that it was felt that there was no reason to specify both, so in analysis of data, X6 was dropped. The strength of the relation between X6 and X7, in comparison to the relationships between the other harmonic variables, was even more obvious when the covariance \((r^2)\), which is a measure of degree of interrelation, for these harmonic variables was calculated. The coefficients of covariance were:

\[
\begin{array}{ccc}
  X5 & X6 & X7 \\
  X3 & -0.74 & -0.64 & 0.71 \\
  X5 & 0.70 & -0.84 \\
  X6 & & -0.98 \\
\end{array}
\]

The interrelationship between X6 and X7 of 96% was much higher than the interrelationships between any of the other harmonic variables.

Because harmony was categorized as either "tonic," "dominant," or "other," all three of these variables could not be independent of each other. For example, for there to be more "other harmony," there had to be less of either "tonic" or "dominant harmony" or both. The correlation, in music in general, between "number of measures of
dominant harmony" and "number of measures of other harmony" need not be this high and the two could even be uncorrelated. In such a case there would be a close relation between "number of measures of tonic harmony" and "number of measures of other harmony."

3. The additional harmonic variable, X4: "number of changes of harmony" was not significantly correlated with any of the other harmonic variables:

<table>
<thead>
<tr>
<th></th>
<th>X3</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
</tr>
</thead>
<tbody>
<tr>
<td>X4</td>
<td>.37</td>
<td>-.12</td>
<td>-.24</td>
<td>.22</td>
</tr>
</tbody>
</table>

X4 did, however, correlate significantly (.52) with X9: "rate of activity." It seems logical that music with a fast rate of rhythmic activity would often have a larger number of chord changes than would slow music. That is, the harmonic rhythm of fast music is often faster than the harmonic rhythm of slow music. Perhaps a better label for X4 would be "harmonic rhythm" rather than "number of changes of harmony," and it might be better categorized as a rhythmic variable than as a harmonic variable.

4. The three variables which had very low, nonsignificant correlations with many of the other variables (including X3: "number of different harmonies," X4: "number of changes of harmony," X5: "number of measures of tonic harmony," X6: "number of measures of dominant harmony," and X7: "number of measures of other harmony")
were: X2: "number of independent parts" and X8: "number of changes in activity" (which correlated significantly with each other) and X10: "length" (which correlated significantly with X9: "rate of activity"). These nonsignificant correlations were:

\[
\begin{array}{cccccc}
X3 & X5 & X6 & X7 & X10 \\
X2 & .08 & .06 & .06 & -.03 & -.05 \\
X1 & X3 & X4 & X6 & X7 & X10 \\
X8 & -.14 & .12 & -.10 & .09 & -.11 & .07 \\
X10 & X1 & X2 & X3 & X5 & X8 \\
& -.02 & -.05 & -.08 & .03 & .07 \\
\end{array}
\]

5. The variable X9: "rate of activity," correlated significantly (p ≤ .08) with more of the other musical variables (X1: "regularity/irregularity in vertical structures," X4: "number of changes of harmony," X8: "number of changes in activity," and X10: "length") than did any other musical variable:

\[
\begin{array}{cccc}
X1 & X4 & X8 & X10 \\
X9 & .47 & .52 & -.57 & -.45 \\
\end{array}
\]

For each of the above observations the following questions (which could be formulated into testable hypotheses) could be asked: How similar are these correlations of musical variables to correlations of musical variables in other music of Beethoven, in the music of other classical or romantic composers, in the music of other tonal composers, in other piano music?
Musical Variables in Future Research

The questions might be raised: What musical variables might have been specified but were not? Why weren't they? How might they be in further investigations? The following musical variables were considered for specification but were rejected because the measures would have been too subjective. As experimentation with music becomes more refined, methods for objective specification of these and similar variables may be discovered.

1. Prominence vs. obscurity of the theme.

This is a variable that might have been important to those who knew the Eroica theme or to those who were musically sophisticated enough to pick out the theme (Variation 1) from the 16 variations that they heard and to recognize the other pieces of music as variations on it. It would be possible to rate the complexity of the variations, then, based upon (relative to) the audibility of the theme.

There are numerous problems in the specification of this variable; Variation 5 (see p.55 for score) serves as an illustration. The Eroica theme is the bass line. This is obvious when one looks at the score but may not be obvious to a listener who is attending primarily to the soprano melody line. To make matters even more confusing and thus any decision concerning specification even more
subjective, Beethoven labelled this variation, "Thema," and it is preceded by "Introduzione col Basso del Tema" (the Eroica theme), "A due," "A tre," and "A quattro."

It seems unlikely that musical experts who had studied the score and listened to the music would agree on ratings of prominence vs. obscurity of the theme. However, such a means of specification could be attempted in future experimentation. Music which was rated high on the prominence/obscenity scale and music which was rated low on this scale could then be studied in an effort to discover psychophysical relationships.

2. Dynamics.

Because the dynamic level of most of the variations was constantly fluctuating, it was impossible to specify a single loudness level for each variation. Specification of changes in dynamic level was deemed too subjective. Questions which, at the time, seemed unanswerable were: Is a crescendo from piano to forte the same as a sudden change from piano to forte? Is a change from piano to a one beat sforzando and back to piano, the same as a change from piano to one measure of forte and back to piano? In general, what constitutes a significant change in dynamics?

It is possible that in future investigation criteria could be hypothesized and loudness levels could be
evaluated by meter readings from electronic equipment according to these criteria.

Another sort of question which might be asked relating to musical variables in future research is: Why is it that the whole scale of possibilities is not represented in the variable measurements? There is, for example, a large gap between the 20 measures of X7: "number of measures of other (than tonic or dominant) harmony" in Variation 13 and the "number of measures of other harmony" for all of the other variations, which ranges from 2 to 6.5 measures. Specific questions include: Is this group of variations unique or is this an ecological sample of patterns in music, in music of Beethoven, in music of the classic/romantic era?

In further investigations an attempt might be made to find and to utilize music or a set of pieces of music in which more of the scale of possibilities is represented by the musical variables.

It was hypothesized that the variables, "number of measures of tonic harmony" and "number of measures of dominant harmony," if applicable at all, would be inversely related to complexity, and that all other variables, if applicable at all, would be positively related to complexity. It is noteworthy that, contrary to expectation, the variables X8: "changes in activity" and X10: "length"
correlated negatively with judged complexity. These negative correlations might be explained by the correlations of X8 and X10 with X9: "rate of activity" (-.57 and -.45, respectively). Music with a greater rate of activity often has few changes in activity and often does not last as long as music with a lesser rate of activity.

In future research an attempt should be made to utilize music in which changes of activity and length are not highly correlated with rate of activity, so that the relation between these variables and judged complexity can be assessed.

**Similarities and Differences Among the Groups in the Relation Between Musical Variables and Judgments of Complexity**

Musical variables which were found to correlate significantly (p < .10) with the standardized judgments of complexity were:

**Graduates**
- X9: "rate of activity" (r = .84, p = .0001)
- X7: "number of measures of other harmony" (r = .53, p = .03)
- X3: "number of different harmonies" (r = .46, p = .07)

**Sophomores**
- X9: "rate of activity" (r = .95, p = .0001)
- X4: "number of changes of harmony" (r = .46, p = .07)
Non-majors -- X9: "rate of activity" (r = .89, p = .0001)
X4: "number of changes of harmony" (r = .53, p = .03)
X1: "regularity/irregularity in vertical structures" (r = .44, p = .09)

It is clear that X9: "rate of activity" was a powerful measure of complexity for all groups of subjects. Overall, judgments of complexity were based upon one, highly important variable, and this "rate of activity" variable accounted for a huge percentage of the variability in the responses of all groups--graduate, 71%, sophomore, 90%, and non-major, 78%. In all cases X9 accounted for more than twice the variability of that accounted for by the next most highly related variable, which accounted for 28% of the graduate variability, 21% of the sophomore variability, and 28% of the non-major variability.

There were differences between the graduate group and the sophomore and non-major groups in the variables which were of secondary importance as measures of complexity, but which correlated significantly with judgments of complexity. It is probable that the reasons for this contrast between the graduate and the sophomore and non-major groups lie in the correlations of X9 with the other musical variables. As was noted earlier, there were four musical variables which were significantly correlated (p ≤ .08) with
X9. These were X1: "regularity/irregularity in vertical structures" (.47), X4: "number of changes in harmony" (.52), X8: "changes of activity" (-.57), and X10: "length" (-.45). It can be seen, then, that X4, which was significantly correlated with the judgments of complexity of the sophomores and the non-majors, was significantly correlated with X9; and X1, which was significant for non-majors, as well, correlated significantly with X9. There was an important difference with the graduate group. The variables upon which judgments of complexity were based were independent measures; the significant variables in addition to X9 for the graduates had very low, nonsignificant correlations with X9 -- X7 (.27) and X3 (.18).

To summarize, the variable, X9: "rate of activity," had extremely high correlations with (and accounted for the largest percentage--71% or more--of the variance in) the judgments of complexity of all groups. It seems reasonable to conclude that the sensitivity to rate-of-activity information was not dependent upon musical training. For sophomores and non-majors the other variables which correlated significantly with complexity judgments also correlated significantly with the musical variable, X9. For graduate students the two additional variables which correlated significantly with complexity judgments had no significant correlation with X9.
Although the three groups of subjects reached similar conclusions in judging complexity, there is evidence that they did not reach these conclusions by identical means. A marked difference among the groups was evidenced by the stepwise regression. The two-variable model for graduate students included X9: "rate of activity," and X7: "number of measures of other harmony," two variables for which there is no evidence of a relationship, having a nonsignificant correlation of .27. The two-variable model for both sophomores and non-majors included X9: "rate of activity," and X8: "changes in activity," which were significantly correlated (-.57). X8 did not appear even in the five-variable model for graduates, nor did X7 appear in the five-variable model for sophomores. Variable X7 did appear in the four- and five-variable models for non-majors but with nonsignificant probability levels of .15 and .10, respectively.

It would be tempting to conclude that graduate music students, with their refined musical abilities, were able to pick up both rhythmic and harmonic information in judging the complexity of music. Whereas, sophomores and non-majors were capable only of picking up rhythmic information, which is easier to remember and compare. However, such conclusions might be erroneous. It is possible that sophomores and non-majors, for example, did pick up
harmonic information but rejected it as not being related to complexity. In further experimentation subjects could be asked to make rhythmic judgments and harmonic judgments. The accuracy with which these judgments were made would indicate the subjects' abilities to perceive the rhythmic and harmonic features of the music.

What can be concluded from the stepwise regression is that in further experimentation the musical variables to be considered important in accounting for the variability in subjects' responses are X9: "rate of activity" and X7: "number of measures of other harmony" for graduate students and X9: "rate of activity" and X8: "changes in activity" for sophomores and non-majors.

The pooling of the three groups of subjects resulted in a multiple correlation and a stepwise regression that seemed to be averages of the correlations and regressions of the individual groups. This indicated that the groups of subjects were indeed different in the means by which they reached their judgments of complexity. If the multiple correlation using pooled judgments had shown greater consistency, this would have indicated that any differences among the groups were random—three times as many subjects would have given a better multiple correlation.
Support for a Psychophysical Theory

This experiment lends support to the psychophysical theory of Gibson (1959) that perceptual responses, in this case, judgments of complexity, are determined by information in the stimulus object or event. Together, all specified musical variables accounted for 94%, 96%, and 92% of the variability in the responses of graduates, sophomores, and non-majors, respectively. Two variables, "rate of activity" and "changes of activity," accounted for 93% and 84% of the variability in sophomore and non-major responses; two variables, "rate of activity" and "number of measures of other harmony," accounted for 81% of the variability in the judgments of graduate subjects.

It is obvious that although a great deal of the variability in subjects' responses was accounted for by the specified musical variables, some of the variance was not accounted for. Arnoult (1960) addressed the problem of the variance which is not accounted for. It is possible, he stated,

that the unexplained variance is related to associational processes which are largely unique to each S, and which can be identified only through a knowledge of S's particular past experience . . . . On the other hand Gibson and Gibson have proposed that every perceptual response is to some discriminable physical property of the stimulus, and there is no reason to believe that the possible stimulus cues have been exhausted by the set used in this experiment. (p. 267)
According to Gibson's theory, there are unlimited kinds of potential stimulation in the environment. It seems possible that when listening to music we never isolate all of the possible higher-order variables and invariants—there may always be new patterns and new relationships to hear. It is possible, as well, that there are attentional factors which are largely unique to each subject. This could explain the basis of the responses of the deviant subjects in all three groups, who, in their judgments of complexity, did not agree with any other subjects. These attentional effects, which are most likely a product of past experience, may be idiosyncratic but may still be psychophysically specifiable.

Poland (1971) demonstrated the discovery of new patterns and new relationships in music with a section near the end of Tchaikovsky's Nutcracker Ballet, which on first hearing sounds like "a simple waltz melody [in 3,4 time] with a simple accompaniment and . . . the melody is congruent with that accompaniment" (p. 13). However, the bass line can be heard in patterns of 2+2+2, and listening to the melody in reference to that bass line organization is an entirely different experience from the first hearing of a simple waltz. Poland concluded to his group of listeners,
The physical signal at your ear was the same each time. Each time you heard different music. Always the same piece; never the same music. I have permanently changed your perceptions of this composition, for you can never have not perceived the patterns I showed you. (p. 14)

Once one has attended to the bass line organization, it is, in Poland's experience, impossible for one to make the bass pattern recede, and although the music may still be a waltz, it is no longer simple.

It is the concept of an unlimited amount of potential stimulation that explains, within a psychophysical framework, why there were differences in this experiment among groups differing in musical background and experiences in the bases of their judgments of complexity. Owen (1977) noted that traditionally a distinction has been made between physical determinants of perception—those "arising from changes in stimulation" and organismic determinants of perception—those "arising from changes in the perceiver as a function of his past history of stimulation" (p. 2). Owen, in conjunction with Gibson, considered this to be a false dichotomy. Perception is the name for the relationship between what goes on in the organism and what goes on in the environment. It is a reciprocal contingent relationship. Therefore, because of prior experiences, that is, because of previous contacts with physically specifiable
variables in the environment, a perceiver learns to attend
to new (different) or additional variables in a musical
event. The perceiver becomes prepared to hear these new
musical variables and can listen for (anticipate) their
occurrence—he has a new skill. As Gibson stated,

Perceptual learning is . . . the activity
of achieving and improving contact with
the environment—of discovering new prop­
erties of the world by discriminating new
variables in the stimulus flux. (1959,
p. 486)

The observer learns to look for the critical
features, to listen for the distinctive var­
iations . . . . This is an education of at­
tention to the information in available stim­
ulation. (1966b, p. 270)

This education of attention is not confined to the
detection of progressively finer details.

The span of attention is increased with prac­
tice. It can (within limits) be enlarged in
scope. It can also be extended in time.
This increase of the span of apprehension
over both space and time is very suggestive.
It is probably a matter of detecting pro­
gressively larger forms composed of smaller
ones, and progressively longer episodes com­
posed of shorter ones. The spatial relations
in an array, and the temporal relations in a
sequence, permit the information to be taken
in progressively larger and longer units or
"chunks." One can finally grasp the simul­
taneous composition of a whole panel of instru­
ments or a panorama, and apprehend the succes­
sive composition of a whole production line or
a whole symphony. Note that this extension and
protension of grasp is not inconsistent with
the concentration of attention on smaller
details of an array, or briefer details of an episodic sequence. (1966b, p. 270)

E. Gibson (1969) suggested that there are three different aspects to perceptual differentiation, "abstraction of differential properties of stimuli, filtering out of irrelevant variables of stimulation, and selective attention of the kind described as exploratory activity of sense organs" (p. 117). According to E. Gibson, "These three processes . . . operate together in producing the kind of modification referred to as perceptual learning" (p. 117).

Consistent with this theory are two somewhat surprising experimental observations:

1. Prior familiarity with this set of variations did not influence subjects' judgments of complexity. This conclusion is based on the observation that within each group, subjects who claimed to have previously heard this set of variations did not differ significantly in judgments of complexity from those who had not been familiar with the music. In addition, the three groups of subjects were quite similar in their judgments of complexity in spite of the fact that there were large differences in the percentage of subjects in each group who had previously heard the variations—graduate, 58%, sophomore, 16%, and non-major, 5%. A possible interpretation for the lack of influence of
prior familiarity is that subjects were able to ignore (filter out) the irrelevancy--familiarity--and to attend to the determinants of complexity.

2. The order in which the variations were heard did not influence subjects' judgments of complexity. Subjects were sensitive to particular variables in the music, and the particular vehicle for those variables, as well as its relation to the previous vehicle, was not important.

Conclusions

This study answered the specific experimental questions posed in Chapter 1 (p. 35) as follows:

1. What are the relationships between physically specified variables in the music and judged complexity? Physically specified variables in the music were differentially related to judgments of complexity. There were three levels of relationship: The judgments of complexity of all groups were most highly correlated with the "rate of activity" of the music--this was the only variable significantly related to the judgments of complexity of all three groups. Another class of variables including, "regularity/irregularity in vertical structures," "number of different harmonies," "number of changes of harmony," and "number of measures of other harmony," was significantly related to the judgments of one or two of the groups. A third class
of variables composed of, "number of independent parts," "number of measures of tonic harmony," "number of changes in activity," and "length," was not significantly correlated with the judgments of complexity of any of the groups. Together, the specified variables in the music accounted for over 90% of the variability in subjects' responses.

Do groups differing in musical background and training differ in this regard? Although the groups differing in musical background and training were remarkably similar in their judgments, their judgments were, to some extent, based upon different variables in the music. The judgments of complexity of graduate music students were most highly correlated with "rate of activity," "number of measures of other harmony," and "number of different harmonies." The best two-variable model for this group included "rate of activity" and "number of measures of other harmony." The judgments of complexity of sophomore music majors were most highly correlated with "rate of activity" and "number of changes of harmony." The best two-variable model included "rate of activity" and "changes in activity." The judgments of complexity of non-music majors were most highly correlated with "rate of activity," "number of changes of harmony," and "regularity/irregularity in vertical structures." The best two-variable model was "rate of activity"
and "number of changes in activity." Sophomores and non-majors were quite similar in this regard, and the variables upon which their judgments were based were highly correlated with each other. The variables upon which the judgments of complexity of graduate students were based were relatively independent.

2. Within like groups of subjects are judgments of complexity similar? Judgments of complexity within like groups of subjects were similar.

Do groups differing in musical background and training differ in this regard? Sophomores were a more homogeneous group than were graduates or non-majors. Analysis of variance and correlation of judgments of complexity among the groups indicated that the three groups were highly similar to each other in their judgments of complexity.

Three more general questions were posed at the outset of this study:

1. Can variables in "real" music be quantitatively specified?

2. Can "real" music be successfully used as a source of stimulation in a psychophysical experiment?

3. Can new tools and ideas for analysis be discovered through experimentation with music?
This experiment has given clear evidence that the quantitative specification of variables in music is possible and that "real" music, music that has stood the test of time, music that has not been composed for experimental purposes, can successfully be used as a source of stimulation in a psychophysical experimental situation. This experimentation has shown relationships among variables which may be formulated as testable hypotheses in future analytic work.

This study was the first attempt to use real music in an experimental situation and to specify quantitatively variables in the music. In comparison to earlier psychophysical studies in complexity (Attneave, 1957, Arnoult, 1960, Owen and Brown, 1970, and others cited, supra, pp. 19-20) the present experiment used stimuli which were carefully selected, but which could not be controlled--only measured. Yet a comparable or larger percentage of the variability in subjects' responses was accounted for by variables specified in this study than was accounted for in the precisely controlled experimentation with generated forms cited above.

Other benefits of this study are as follows:

1. This study has shown that it is possible through an experimental investigation to determine the meaning of a term or concept, used in talking about music, that had
previously been undefined or only vaguely defined. This study may serve as a model for exploration of various musical dimensions.

2. This study has indicated that an adequate theory of musical perception must focus on the relation between the subjects' responses and the musical stimulation. More specifically, this study has provided a test for a psychophysical theory of musical perception and has substantiated that theory.

3. This study has provided an elegant solution for controlling for order and/or sequence effects in experimentation with a large number of stimulus objects or events that must be presented sequentially and has provided a number of other statistical procedures which may be of value in other experimentation with music, or of value, in general, in experimentation with any stimulation that occurs sequentially, such as speech and dance. It has also furnished information about scales and their transformations for use in statistical treatments.

Lest critics argue that I am over-emphasizing or over-valuing the importance of both the validity and the generality of this investigation, the following arguments support the claim that I am dealing with central, not peripheral, issues:
1. Beethoven was a central, not a peripheral, composer; he was ranked first or second in all ratings of eminent composers reviewed by Farnsworth (1969). Although the "Eroica" Variations used in this study are rarely performed and are unfamiliar even to many of the musically educated (and are therefore on the periphery when one considers Beethoven's output), Beethoven was obviously entranced with the Eroica theme and many of his developments and variations of it. He used the Eroica idea four times: in this set of piano variations (1802), in the last movement of his third symphony, Op. 55 (1803), in the finale of the ballet, "The Creatures of Prometheus," Op. 43 (1800-01), and in one of a set of 12 Country Dances (published 1802-03). Therefore, although this set of variations is peripheral, the basic musical material is central.

2. The study of form complexity has been a central area of investigation for the past 20 years in the field of psychology. This has been a particular area of interest for, though not limited to, those working within a psycho-physical framework (Attneave, 1957, Arnoult, 1960, Owen and Brown, 1970). Other psychologists, such as, Berlyne (1974) and Crozier (1974), working within a mechanistic theoretical framework have been preoccupied with form complexity as well.
Suggestions for further experimentation include:

1. Determining the physical bases for judgments of similarity or pleasingness or interestingness and relating these bases to the bases for judgments of complexity.

2. Allowing subjects to listen to each of these variations (or perhaps reducing the number of variations) for as long as they wish (an exploratory listening situation) and investigating the relationships among these listening times, the variables in the music, and the judgments of complexity.

3. Allowing subjects in another experimental situation to choose which of two variations they would like to hear again. Information gained would relate to such ecologically valid situations as choosing between two radio stations. The questions could be addressed: how are such choices made; what is the physical basis for such choices?

Suggestions for musical analysis include: looking at other music of Beethoven, at music of other composers of that era, at music of other eras and types to answer the questions: (1) what musical variables can be quantitatively specified, (2) what are the correlations among the variables. It is possible that such investigations will illuminate general style traits that were previously difficult to describe or compare.
The present study has laid a basis for these kinds of research. It has demonstrated a workable experimental method, using "real" music and elegant experimental controls. It has produced not only interesting results but also support for a psychophysical approach to musical problems which will generalize beyond the study of complexity, beyond this set of variations, and beyond the music of Beethoven. Because of the success of this investigation it will now be easier to grapple with music that was previously viewed as too intractable for use in experimental investigations. Music whose complexity might now be investigated includes: orchestral variations, such as, Elgar's "Enigma" Variations, Op. 36 and Brahms' Variations on a Theme of Haydn, Op. 56a, pieces of identical form, such as minuets by Mozart, and chorale harmonizations by various composers.

We in music can not depend on psychologists working in visual perception, or even auditory perception, to answer our musical questions for us. The following excerpts from Neisser's (1976) discussion of the psychologist studying chess are analogous to situations in which psychologists study music:

What would we have to know to predict how a chess master will move his pieces, or his eyes? His moves are based on information he has picked up from the board, so they can
only be predicted by someone who has access to the same information. In other words, an aspiring predictor would have to understand the position at least as well as the master does; he would have to be a chessmaster himself! If I play chess against a master he will always win, precisely because he can predict and control my behavior while I cannot do the reverse. To change this situation I must improve my knowledge of chess, not of psychology. (p. 183)

To understand and predict musical behavior one must be a musical expert, but one also needs to consult with experts in other fields. In this study I depended upon my psychological training and upon experts in the fields of psychology and statistics as well as music. I have illustrated the necessity of a multi-disciplinary approach dependent upon theories from these three different fields. It is hoped that the present study has demonstrated the sort of experimentation that can be done with music by a musical expert in conjunction with experts in other disciplines in solving musical problems.


Beethoven, Ludwig van. 15 Variations with Fugue in E-flat on a Theme from "Prometheus" ("Eroica" Variations), Op. 35, performed by Sviatoslav Richter. Angel S-40183.


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