THE PERCEPTUAL PROCESSING OF RHYTHMIC

AUDITORY PATTERN TEMPORAL ORDER

By

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ABSTRACT

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Traditional theories about the perceptual processing of auditory patterns have generally followed one of two approaches. One approach has been to portray the perceived auditory sequence as an associative chain, the elements of which are processed as a concatenated string. The second approach has focused upon overall pattern context with the individual elements being perceived in relation to the total pattern.

An alternative to these approaches is possible through an explanation of auditory pattern structure in terms of relations among individual elements. Based on this concept, Martin (1972) developed rules of relative accent level and relative timing which may be used to describe the regularity of patterns.

In the present study, an original perceptual model was proposed in an attempt to illustrate how the perceptual system may make use of temporal structure in the encoding, decoding, and recoding of auditory events. The model accommodates the concepts of relative accent level and relative timing, and deals explicitly with the effect of redundancy reduction on the perceptual processing of serially ordered patterns. Model formulation also included the development of a calculus whereby levels of relative redundancy in rhythmic patterns can be quantified.

The study investigated the effect of pattern regularity on the discrimination of auditory patterns. Sixteen pairs of experimental and "dummy" rhythmic patterns (eight regular, eight irregular) were used. For half of the regular and irregular patterns, accent was marked through variation in frequency; for the remaining patterns, accent was marked through variation in event durations.

Fifty-two, normal hearing subjects were evenly divided into two groups (high musical experience vs. low musical experience) on the basis of performance on a musical ability test. Subjects were tested twice (Trial 1 and Trial 2) under each of the two conditions of accent mode (frequency vs. duration) and each of the two conditions of pattern type (regular vs. irregular). Within each trial, ABX paradigm discrimination judgments were obtained in two counterbalanced blocks which differed in terms of accent mode. Each block consisted of four replications of the eight different pairings of experimental and dummy stimuli.

The dependent variable was identified as percent-correct pattern discrimination. The data were examined to determine the effect of (1) musical training, (2) pattern type, and (3) accent mode on pattern discrimination. A supplemental analysis which compared the proposed relative redundancy level quantification method with listener discrimination scores.

Mean discrimination scores differed significantly as a function of each of the three main effects. Scores were higher for subjects with high levels of musical training than for those with little or no musical training. Similarly, scores for the frequency accent mode were higher than those for the duration accent mode.

Mean discrimination scores for regular rhythmic patterns were, in all instances, higher than those for irregular patterns. This suggests that the degree of regularity, as defined by the rules of relative timing and relative accent level, significantly influenced rhythmic pattern discrimination.

Values resulting from the proposed relative redundancy quantification of relative redundancy displayed a monotonic correspondence with percent-correct discrimination scores. This result suggests that the quantification method may provide a useful measure of redundancy levels in rhythmic patterns.

The findings were sufficiently encouraging to justify additional research concerning the effect of levels of rhythmic pattern regularity on pattern discrimination, the usefulness of the proposed relative redundancy quantification procedure, and the accuracy of the perceptual model.

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CHAPTER I

INTRODUCTION

Music is experienced by the listener as sound moving through real time. Unlike most other genres of art, music requires of the listener an ability to evaluate and apprehend the meaning of an "object," the elements of which are in a constant state of motion. Thus, a capacity to perceptually organize the temporal ordering of events in a musical pattern is a fundamental prerequisite for listening activities. Peters (1975) states that the detection, discrimination, and recognition processes of listening hinge upon temporal factors of both the musical and perceptual organization of the musical sequence (p. 157).

It has been noted on numerous occasions that there is often a discrepancy between what a listener reports hearing and the musical sound source presented to the listener. That is, there are differences between the subjective assimilation of music and the actual music itself. Concerning these discrepancies between subjective and objective temporal arrangement, Sternberg and Knoll (1973) assert, "that the perceived temporal order of a pair of stimuli might not correspond to their actual order . . . and the source of errors in judgments of order . . . is one of the oldest of our unsolved problems" (p. 630).

A crucial task, then, is to achieve a clearer understanding about the relationship between a musical sequence and the manner in which that sequence is organized and assimilated in perception. Of particular interest to the present study is how the listener orders or organizes the temporal arrangements of musical events in relation to the temporal characteristics of the sound source itself.

Background

Many theories have been proposed to explain the perceptual process of organizing auditory events. These theories can be divided into two general categories. The first (and oldest) category includes those theories which portray the perceived auditory sequence as an "associative" chain. Advocates of this point of view describe the perceptual system as treating the "sequence of elements in a pattern as a concatenated string" (Sturges and Martin, 1974, p. 378). In effect, the perceptual process is conceived of as being similar in operation to that of a computer which "easily solves a serial pattern by storing events in order as they occur, then reading out the results in the same order" (Restle, 1970, p. 483). This facility is a result of the computer's ability to generate serial order "by placing events in successive locations of memory. Given that capacity, a computer can learn any one serial arrangement of a given set of elements as easily as any other" (Restle, 1970, p. 483).

That human beings are incapable of processing every auditory sequence with the same facility underpins the main objections to associative chain theories. Although the listener makes use of the event-by-event arrangements of the sound sequence, his ordering of the elements is also affected by the overall context of individual events. Restle (1970) indicates further that "since human Ss are not at all indifferent to content, it follows that when they learn a serial pattern they do not impose the order by sequential storage of elements, but instead generate order from a system of rules" (p. 483), the characteristics of which are dependent upon the pattern as a whole. Lenneberg (1967) refutes associative chain theories on the basis of neurophysiological studies. He states that if behavioral associationists (or "connectionists") were to search for "corroborative data produced by the new neuroanatomical 'connectionism,' they would actually find results that are more likely to contradict their own theories of connections than support them" (p. 210).

A second, and opposing, category of theories suggests that the perceptual organizing of an auditory pattern is determined primarily by the overall context of the sound sequence. The view that a pattern is not a "simple sum of the individual parts" has its origins in Gestalt psychology. Jones (1978a) describes this theoretical position as follows:

> When single events form a sequence, effects of the collective context on the perception of individual members are so overwhelming that Gestalt psychologists argue that "patternness" can only be understood in terms of the total pattern and not isolated members. (p. 11)

As with associative chain theory, there are many offshoots to the view outlined above. The main premise, however, is that the perceptual process of organizing auditory events depends upon the makeup of the whole sound sequence; that a single event is perceived only in relation to the total pattern. This is to assume "that processing of the sequence consists in first accepting the whole string simultaneously upon reaching the end of the unit, the occurrence of which has just been signalled by a pause or some other terminal cue" (Sturges and Martin, 1974, p. 378). The overall context of an auditory pattern influences the perceptual organization of the sound sequence, but the Gestalt theories discourage investigation of the internal structure of patterns.

An alternative to the Gestalt and associative chain theoretical approaches is realized through an explanation of the structure of whole patterns in terms of special combinations of the individual parts "if the parts themselves are conceived of as relations" (Jones, 1978a, p. 11). This concept of the perception of temporal order in auditory events as a set of relations was first outlined by Lashley (1951). In presenting his views on inherently temporal types of human behavior (such as speech and music), Lashley stressed not only the need to discover cognitive representations of relations that define the auditory pattern in time, but also the need to understand how these relations are detected and finally come to guide pattern reproduction. In other words, it is necessary to develop a theory concerning the structure of an auditory pattern which not only takes into account the temporal relations within the overall context of the sequence, but that it does so in such a way as to show how the listener detects these relations and manipulates them perceptually.

Lashley's interpretation of the perceptual processing of serial auditory patterns is based on the concept of continuously active, centrally located cerebral mechanisms which flexibly move amidst preplanned schemes (Jones, 1978a, p. 8). This is to imply that the perceptual system does not passively accept incoming auditory information for subsequent reflexive processing. Rather, as the auditory sequence unfolds, certain locales ("units") are "primed" to receive the ensuing elements of the pattern. The perceptual system, therefore, is seen as actively establishing expectancies about future sequence events, including anticipation of temporal order.

Lashley goes on to speculate that "rhythmic activity" (that is, all motor functioning), as well as the neural systems which control such behavior, constitute the simplest timing mechanisms. He further suggests that these central regulatory mechanisms which control motor function also affect perception as well as behavior (p. 128), thus providing a "natural link" between the temporal organizing process in perception and in the production of man-made serial activities. The simple timing mechanisms are seen as forming "a sort of substratum" upon which behavioral and perceptual activity are built (Lashley, 1951, p. 128). Lashley labels this connection, "rhythmic action."

This concept implies that the expectancies which are established in perception are subject to the same timing constraints as those which control motor behaviors. One of the predominant features of serially ordered human behavior is the regularity with which important temporal characteristics recur; that is, the temporal arrangement is highly redundant. According to Lashley's premise, then, it is expected that redundancy will be a primary feature of the perceptual organizing process.

Recent development in neurophysiological theory and experimentation allows for elaboration and modification of Lashley's thesis. Most studies concur with his placement of the organizing perceptual process in the cerebrum. Konorski (1967) states that the "cerebral cortex is the main organ for perception of complex . . . stimulus patterns" (p. 508). It has also been established that the cerebrum, like all other neural systems, is constantly active. Thus, Lenneberg (1967) can state summarily,

> Stimulation, processing input, and responding are not signalled by a change from a passive to an active state. Instead, there are alterations in the firing patterns of the cells. All aspects of behavior may be considered to be based upon modulation of activity in neuronal nets. (p. 215)

Lashley's proposal concerning central regulatory mechanisms which coordinate motor functioning (including the production of speech and music) is also supported by "an impressive array of experimental findings" (Lenneberg, 1967, p. 15). Luria (1966) states, "all the evidence indicates that motor coordination requires a special cerebral mechanism which brings about the inhibition of the motor impulse into a single stereotype that has developed over a period of time" (p. 174).

As yet, there is no conclusive experimental evidence which supports Lashley's notion that the cerebral mechanisms involved in perceptual processing are "primed" to receive incoming stimuli. Bishop's (1961) studies of the somaesthetic and visual systems, however, has resulted in an interpretation of the functional organization of the central nervous system which accomodates Lashley's "priming" concept. Bishop suggests that there is a progressive increase in specificity of central coordination and of motor control from the lower to the higher cerebral levels. The higher levels successively dominate those below with respect to afferent coordination and to motor control. Two processes are employed in the upward extension of the afferent paths. One is a simple relay of activity from a lower to a next higher level. The other involves parallel paths of larger fiber systems that bypass a given relay station and reach a higher level more directly.

Assuming that the primary auditory projection system from the medial geniculate of the thalamus to the superior portion of the temporal lobe contains these larger, rapidly conducting fibers, it can be expected that the more direct pathways will deliver the impulses quickly to the cephalic end of the brain (Goldstein, 1963, p. 188).

> The higher centers receive their signals quickly, presumably before the signals delivered to some of the lower centers by slower . . . paths are relayed to the higher centers by less direct routes. The earlier signal to the higher centers . . . probably acts as an alerting signal for the higher centers to act discriminately on the signals coming from the lower, more diffusely-behaving centers. (Goldstein, 1963, p. 188)

Neurophysiological theory also allows for modification of Lashley's proposal concerning the existence of preplanned schemes in perceptual processing. At the lower sensory levels, systems are predisposed to receive incoming stimuli in certain ways. Abbs and Sussman (1971) refer to these sensory systems in the auditory periphery as "feature detectors." Feature detectors are defined as organizational configurations consisting of neurosensory receptive fields which are "innately structured to detect, and respond to, the various distinguishing physical parameters of the acoustic stream" (Abbs and Sussman, 1971, p. 23). The feature detectors are simultaneously sensitive to many characteristics of complex auditory stimuli and are not restricted to isolated details of the sound stream; that is, stimulus processing is not the result of limited dimensional sampling of the information embedded in the signal.

Generalization of information about the stimulus is obtained by summating the inputs from the lower sensory levels. At the higher levels, specificity is achieved by selective restriction (inhibition) of particular classes of inputs (Barlow, 1969, p. 219). Selectivity is organized hierarchically through the higher sensory levels with each level progressively dominating the selective process. Lashley's concept of preplanned schemes can, therefore, be modified such that the perceptual process is seen to include receptive fields which are predisposed to receive incoming information about the auditory stimulus, and higher sensory levels which are hierarchically organized with regard to selectivity and specificity of information. At each higher level, stimulus information can be placed in larger and larger units due to the selective restriction of certain inputs and to increased generalization. The process is interrupted at certain stages while various aspects of the signal are combined and compared with information from other sense organs and from stored information. The additional inputs increase the accuracy of the selective process (Young, 1978, pp. 127-128).

Barlow (1969) suggests that the selective process consists of recoding messages about the stimulus into a less redundant form at the higher sensory relays and centers (p. 209). Redundancy is defined as that fraction of a stimulus which is "unnecessary in the sense that if it were missing the message would still be essentially complete, or at least could be completed" (Shannon and Weaver, 1949, p. 13). In terms of information theory, if the incoming stimulus is highly organized (that is, repetitive or regular), then it is considered to be highly redundant. Redundancy refers to that portion of the stimulus which is controlled by structural considerations. In a very regular auditory stimulus, a large percentage of the physical features is controlled by the demands of structure. Redundancy, therefore, is a property of stimulus structure.

Barlow's redundancy reduction concept has received increasing support from integrative brain theory. It is also consistent with the known physiological predisposition for cell preservation. It is expected that the sensory systems are organized such that the typical sensory environment will result in low average cell firing rates. If the environment is changed due to the introduction of an additional stimulus, the average sensory activity rises. The lower mean firing rate, however, is restored in a short period of time (Grastyan, 1959). This return to normal, or lower, activity rates is described as "economy of impulses." The redundancy reduction coding at the higher sensory levels has the effect of "reducing the number of impulses required to transmit sensory messages while reducing as little as possible the efficiency or accuracy with which the message is transmitted" (Barlow, 1969, pp. 223-224). It follows that, if the higher sensory levels are hierarchically organized to reduce redundancy, then incoming auditory stimuli which are regular or repetitive will be more easily and economically processed by the perceptual system.

In the production of speech and music, as in perception, active use of redundancy is a main feature of pattern structure. In English, for example, the redundancy level is about fifty percent, "so that about half of the letters or words we choose in writing or speaking . . . are controlled by . . . the structure of language" (Shannon and Weaver, 1949, p. 13). In music, structure is referred to as, "form." Apel (1969) states that "music, like all art, is not a chaotic conglomeration of sounds but consists of elements arranged in orderly fashion" (p. 326). Form is the overall structure in a composition; it is the "structural outline" (Apel, 1969, p. 327). Redundancy is a primary feature in musical structure and is manifested in such compositional techniques as restatement and repetition.

Speech and music are, therefore, similar to all other motor behaviors in that both are systems or structures of relationships (Young, 1978, p. 177). Redundancy is one of the main features of these structural relations. Likewise, it is this even distribution especially of temporal characteristics which facilitates the neural processing of stimulus information in perception. Redundancy, rather than the effect of some central timing mechanism, would seem, therefore, to more parsimoniously describe the "natural link" between the perception and production of serial behavior. It is redundancy in stimulus structure which shapes periodicity and gives definition to relations between events. The regularity of relations is, in turn, necessary (1) to develop descriptions from the incoming data, (2) to test inferences as to what the data "mean," and (3) to respond accordingly (Young, 1978, p. 123).

The Problem

In the comparatively new field of auditory patterning, those experimental studies which include *a priori* concepts of auditory stimuli temporal structure have tended to emphasize the overall aspects of a pattern at the expense of details concerning the pattern's internal structure (Gestalt), or have concentrated upon the individual elements within the pattern at the exclusion of overall temporal order (associative chaining). Other experimental paradigms have neglected *a priori* temporal structure models altogether and have focused solely upon listener responses to arbitrary temporal arrangements of sound sequences. As Jones (1978a) indicates, "experimental progress in understanding perception of auditory patterns is only interpretable if some framework exists for understanding what a pattern is" (p. 19). It is also necessary for experimental models to incorporate information about the temporal characteristics within the pattern in such a way as to illustrate their relation, not only one to another, but also to the overall temporal structure of the pattern. And, because extensive evidence tends to support the notion that perception is an active, anticipatory process, these experimental models which deal with the perception of the temporal aspects of the auditory stimulus must demonstrate how this process makes use of the temporal structure present in the sound sequence.

Two important issues must be confronted if a clearer understanding of the perception of temporal structure in auditory (specifically, musical) patterns is to emerge. First, what is it about the temporal relations of event characteristics in a musical pattern that facilitates the perceptual processing of that sound sequence? Although the question pertains to such musical aspects as accent and durational change in the auditory pattern itself, the concern here is not in defining the physical qualities of these features. Rather, the question addresses itself to the temporal function of these features and the manner in which they define temporal order in the pattern. The second question concerns the perceptual process which takes place when the listener comes in contact with the auditory pattern: How does the perceptual system make use of these temporally defining characteristics so as to assimilate and organize the overall temporal structure of the auditory pattern? Taken together, these two questions pertain to the inter-relationship of the objective arrangement of the temporal elements in the sound sequence and that structure as it is organized subjectively in perception.

Purpose of the Study

It is not yet possible to measure and evaluate the various neurophysiological functions which make up the perceptual process. It is possible, however, to construct rhythmic auditory patterns which are temporally redundant and to analyze behavioral responses to such stimuli. The purpose of this study, therefore, was to investigate the effect of certain temporal structures present in rhythmic auditory stimuli on the discrimination of temporal pattern. To achieve this objective, it was necessary to use a theoretical grammar or set of "rules" as a structural framework within which sound sequences could be developed and manipulated. Two rules concerning relative accent level and relative timing (Martin, 1972) were incorporated in order to provide such a grammar. These rules allow for systematic manipulation of the elements of patterns (via changes in pitch or duration), and the regularity of sequences of patterns. Listener responses to these temporal arrangements were then observed in hopes of clarifying the effect of specific aspects of the auditory pattern's predetermined temporal structure upon pattern perception. A perceptual model was also proposed in an attempt to illustrate how the perceptual system may make use of temporal structure in the encoding, decoding, and recoding of auditory events. This model accomodates Martin's relative accent and relative timing concepts, and deals explicitly with the redundancy of serially ordered patterns.

The primary agents employed in pattern construction were relative accent level (pitch variation) and relative timing (duration variation). For each mode of manipulation, eight specific questions were asked.

1. With what consistency do normal hearing persons with and without musical training discriminate rhythmic auditory patterns which differ in regularity (that is, regular vs. irregular)?

2. Does pattern regularity significantly influence discrimination of rhythmic auditory patterns?

3. Does musical training significantly influence discrimination of rhythmic auditory patterns?

4. Does accent mode (that is, pitch variation vs. duration variation) significantly influence discrimination of rhythmic auditory patterns?

5. Do the factors of pattern regularity and musical training interact to significantly influence discrimination of rhythmic auditory patterns?

6. Do the factors of accent mode and musical training interact to significantly influence discrimination of rhythmic auditory patterns?

7. Do the factors of accent mode and pattern regularity interact to significantly influence discrimination of rhythmic auditory patterns?

8. Do the factors of musical training, accent mode, and pattern regularity interact to significantly influence discrimination of rhythmic auditory patterns?

Need for the Study

As Jones and others have indicated, there has yet to be developed an adequate description of how the listener organizes pattern structure in regard to its temporal characteristics. Martin (1972), in speaking specifically about musical rhythm, says,

> Rhythm appears to be taken so much for granted in music training that there is only one book on rhythmic theory (Cooper and Meyer, 1960) although there are many on melody, harmony and counterpoint. The latter are culturally determined to a far greater extent than is rhythm. (p. 491)

In all previous studies dealing with the perception of auditory pattern temporal structure, the longest pattern used was nine elements in length (Royer and Garner, 1970). Further, no study has included patterns in which the elements are of different relative durational value. Peters (1975), in his review of the measurement of temporal factors in auditory perception points to a need for greater concern and more investigation of longer temporal patterns (p. 158).

Limits of the Study

The present study was limited to an investigation of certain temporal characteristics of musical pattern structure only, at the same time realizing that such musical features as pitch, timbre, harmony, and counterpoint have a definite influence upon the perceptual ordering of sound sequences (Ward, 1970).

All of the auditory patterns used in the study were based on an "eight-beat" arrangement of events. Thus, some patterns contained only eight elements. Others, however, incorporated changes in durational values, thus increasing the number of events in the pattern while still remaining within the eight-beat framework. Patterns of this type usually occur in musical passages of some form of duple (or quadruple) meter. No attempt was made to include musical patterns which are common rhythmically in the various forms of triple meter. Variations in relative time values was limited to either 1:1 or 2:1 ratios (♩: ♩ or ♫:♩).

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Ward (1970), in his comprehensive review of musical studies in perception, states that, while the last few decades have produced important new procedures and results in regard to the perceptual process, "advances in knowledge about the perception of music during the same period have, by and large, been much less spectacular" (p. 405). This observation seems especially true for musical time perception, for Ward does not include a discussion of any kind concerning rhythm, nor does he report a melody study that involves the temporal properties of music. There are, however, a large number of psychological studies in the general area of auditory pattern temporal structure and the perceptual organization of processing order.

The following discussion focuses on two approaches to the temporal aspects of pattern structure and the perceptual process. The first approach, represented by the experimental and theoretical work of Garner and others (1962, 1974), tends to place less emphasis on the internal temporal structure of the auditory stimulus itself and more upon the subjective descriptions of the organizing process. Responses are then defined in terms of Gestalt principles. The second approach, to which the present study closely adheres, is represented by the theoretical views of James G. Martin (1972, 1974). Methodologically, this approach differs from Garner's reliance upon subjective description of the organizational process in that the listener is confronted with predetermined "easy" and "hard" pattern structures. Pattern quality is designated according to invariant temporal relations, or rules. The rules used by Martin are, in turn, based upon the concept of rhythmic action as first outlined by Lashley (1951).

Although Garner's views and methodologies are not directly related to the approach followed in the present study, a discussion of experimental findings and theoretical conclusions is included for several reasons. First, because investigations of this nature do not attempt to predetermine the "quality" of auditory stimulus temporal structure, all possible permutations of sequence character and order must be presented in experimentation to avoid bias. Definition of pattern structure is based solely upon subject response to the various arrangements of element order. Of all the possible permutations presented to listeners, Royer and Garner (1970) found that only a small number of these arrangements were used for organizational purposes by the experimental subjects.

Further, the temporal makeup of these "usable" patterns, in most cases, coincide with the structure predetermined by Martin's rules. Also pertinent to the present study are Garner's findings in regard to the relationship between presentation rate (fast or slow) and the learning of auditory pattern order.

Subjective Determination of Pattern Structure

Generally, studies investigating the perceptual organization of temporal order have used fixed-sequence stimuli made up of dichotomous (binary) elements. Different pattern structures can be generated by simply rearranging the serial order of the two types of events. Royer and Garner (1970) state that "when sequences of dichotomous elements are repeated indefinitely without interruption, there are as many possible beginnings to the perceived pattern as there are events in it" (p. 115). If, for example, the binary sequence, XXO were to be repeated three times (XXOXXOXXO), then the original three-event sequence is not distinguishably different from XOX or OXX except for starting point. It is, therefore, possible for the listener to use any one of the three organizations (XXO, XOX, or OXX) in apprehending or "learning" pattern serial order. This repeated binary arrangement, through analysis of listener response, allows for determination of preferred types of pattern organization.

Royer and Garner (1966) presented listeners with eight-element, fixed binary sequences in an attempt to define the organizing principles used in the learning of serial patterns. Because the experimental design focused upon subjective response with no _a priori_ determination of pattern "goodness," it was necessary to use 256 binary sequences so as to include every arrangement possible in an eight-element pattern (XXXXXXXO, XXXXXXOX, XXXXXOXX, and so on). Two buzzers were used to produce the dichotomous elements which, in turn, generated the sequences. Subjects were asked to reproduce the patterns motorically through key-tapping in synchrony with the stimulus, and were free to begin the task at whatever serial point they wished.

Results of the experiment indicate that only a small number of the possible alternative organizations were used "when measured by the point at which subjects start to track the sequences manually" (Royer and Garner, 1970, p. 115). This was also found to be true in listener response to sequences at various presentation rates (Garner and Gottwald, 1968). Royer and Garner (1970) state, "with this approach, the nature of the preferred organization is expected to shed light on the psychological processes that enable the organism to deal with repeating sequences" (p. 115).

Based on these and other findings, Garner (1974) has developed a theory concerning the perceptual organization of temporal auditory patterns. Upon learning a binary sequence, a listener is assumed to hear one of the two sounds as the "figure" and the other as the "ground" (Garner, 1974, pp. 62-63). Garner suggests that two organizing principles govern the manner in which a listener then structures the sequence according to "figure" and "ground" features. These two operants are labelled, the Run Principle and the Gap Principle (Garner, 1974, pp. 59-61). Both principles involve the perceptual <u>reorganization</u> of the dichotomous elements. According to the Run Principle, a listener reorganizes incoming events so that the longest string of identical events (that is, a run) of the "figure" elements begins the pattern, while the Gap Principle has the listener reorganizing the pattern so that the longest string of "ground" events is last. Jones (1978a) illustrates this concept as follows:

> If B becomes the figure in the repeating pattern, ABBBAAB . . . , the "Run" principle yields the representation BBBAABA, while the "Gap" principle gives BABBBAA. Activity, in this view comes in pattern reorganization. (p. 9)

The perceptual reorganization, according to Garner, will be more difficult if Run and Gap rules conflict, resulting in many alternative organizations, than if they were compatible.

Sequences used by Royer and Garner (1966) demonstrate both Run and Gap principles as they affect perceptual organization of a binary pattern. Because every possible serial combination was included in experimentation (256), a variety of pattern structures, as defined by the Run and Gap principles, were presented to the listener. Royer and Garner predicted that patterns with conflicting Run-Gap arrangements (that is, those patterns with increased numbers of alternative organizations) would be more difficult. Jones (1978a) states,

> If a listener revealed a "Run" organization of one of these patterns by beginning to tap at the onset of the longest run of the figure element, the longest run of the ground element would not end the pattern, thus violating the "Gap" principle. However, patterns with compatible "Run" and "Gap" principles (e.g. 11111110) offer few alternatives and should be easy. (p. 12)

Because subjects demonstrated variability in initiating motoric response (key-tapping) at each of the pattern's serial locations, a subjectively weighted measure of alternative organization called, Response Point Uncertainty (RPU) also had to be determined. Jones (1978a) reports that "the impact of Run-Gap compatability upon subjective organizations was supported by the finding that RPU correlated highly with performance difficulty as measured by the median delay in responding averaged over serial start locations" (p. 12).

These conclusions have also been supported by findings in other related studies (Preusser, 1972), including those which used fast and slow presentation rates (Garner and Gottwald, 1968). Garner, therefore, interprets perceptual organization of pattern structure as being guided by human predisposition about the relative placements of strings of identical events. Royer and Garner (1970) state,

> One result from all research on temporal auditory patterns . . . is that the psychologically meaningful unit for Ss in such experiments is the run of identical elements, not the individual elements themselves. Rarely is a pattern perceived as organized with a break in a run of identical elements, so that the number of possible alternative organizations is more properly specified by the number of runs of identical elements than by the number of elements themselves. (p. 115)

Predetermination of Pattern Structure

A second approach to auditory pattern temporal order and perceptual organization interprets listener activity as seeking out invariant relations against a flux of constant change (Jones, 1978a, p. 9). Impetus for this view comes from the work of Gibson (1969) and Gibson (1966) who argue that "object perception arises from the organism's detection of invariant higher-order physical relationships given by the object" (Jones, 1978a, p. 10). Studies in audition have also supported this interpretation (Kubovy, Cutting, and McGuire, 1974). Restle (1970) has proposed that a listener detects higher-order invariant relations existing between successive events in temporal patterns.

Martin's (1972) interpretation of the perceptual organization of pattern temporal structure is likewise based on the detection of invariant temporal relations in the auditory sequence. Methodologically, Martin's approach to binary sequence structure is quite different from that of Garner and others. Whereas Garner relies on listener description to reveal organizing principles, Martin confronts the listener with objectively selected "easy" and "hard" patterns; that is, *a priori* determination of auditory sequence temporal structure.

Martin's view of real-time information processing is based on Lashley's (1951) suggestion that the perception and production mechanisms underlying temporally unfolding behavior are "linked" by what is called, "rhythmic action." This concept sets forth two postulates. First, it is assumed that speech and music are subclasses of all motor functioning and are, therefore, subject to the same temporal constraints as act upon other types of serial behavior (e.g., respiration and movement). Martin refers to these simpler motor functions as "natural" patterns and suggests that their temporal features are "rhythmic." Speech and music are also assumed to be patterned rhythmically and to possess a hierarchical organization that has a coherent internal structure at the sound level.

Rhythmic patterns are described by Martin as being sequences of "accented" and "unaccented" elements temporally organized such that the locus of each sound element in the time dimension is <u>relative</u> to the locus of each other element in the series. Martin identifies the primary temporal constraint to which all motor functioning is subject and which is manifested in the element-element relations of "natural" rhythmic patterns as, "relative timing" (Martin, 1972, p. 488).

Jones (1976) concurs with this interpretation of rhythmicity in serial behavior. Indeed, Jones has expanded this view to include all pattern-making. She states,

> Patterns in the physical world (world patterns) consist of energy changes defined within three space dimensions and a time dimension. All dimensions are most simply conceived as having nested, or hierarchical, structure. (p. 328)

Further,

> The hierarchical structure of world patterns is described in terms of invariant relations along changing physical dimensions. (p. 328)

Agreement with this viewpoint can also be found in Schillinger's (1946) theory of musical rhythm. Schillinger has designated his treatise, "the theory of regularity and coordination; it represents an effort to set down the basis of all pattern-making in the universe" (p. xii). Schillinger suggests that musical patterns, when viewed in the context of all biological, physical, and aesthetic objects, "are really only special cases of the general process of pattern-making" (Schillinger, 1946, p. xii).

The second postulate generated by the concept, "rhythmic action" proposes that perception as well as the production of auditory sequences is affected by the timing mechanisms which coordinate motor functioning, thus forming a temporal "substratum" for both motor and perceptual behavior. Martin suggests that it is the continual presence of "natural" rhythmic patterns which affect perception.

> If auditory stimulus sequences normally occurring in the natural environment are characteristically organized in a certain way, e.g., they are rhythmic, then one might reasonably expect that the perceptual mechanisms as they have evolved will be biased to listen for sounds organized in this certain way. (Sturges and Martin, 1974, p. 377)

Jones (1976) also agrees with Martin's view of perception as being essentially rhythmic. She states, "the human system in general and the perceptual system in particular depend upon the properties of endogeneous rhythmic processes in the nervous system" (Jones, 1976, p. 328).

In considering the process of perception, Jones (1978b) has extended this concept of rhythmicity to include perceptual expectation. Upon encountering initial temporal factors in the stimulus, simple "expectancy schemes" concerning the temporal arrangement of future events are formulated. These expectancy schemes, according to Jones, are temporally redundant; the listener "expects" regularity. If succeeding pattern events do not exhibit regular temporal relations, then the expectancy scheme must be revised. The greater the revision necessary, the more difficult it becomes to perceptually organize the auditory pattern (Jones, 1978b, p. 6).

Based on the assumption that perception is affected by the constancy of "natural" rhythmic patterns in the typical sensory environment, Martin (1972) has formulated a descriptive rule (Relative Accent Rule) which characterizes the temporal organization of normally occurring auditory sequences and "shows their structure as based upon relative timing constraints which go beyond the simple ordering (concatenation) of elements" (Sturges and Martin, 1974, p. 377). Temporal redundancy is the main feature of those rhythmic patterns which Martin's rule identifies as "natural." It is the regularity of accent placement and relative timing which, according to Martin, create the invariant temporal relations that facilitate the perceptual processing of the pattern.

Sturges and Martin (1974) tested the hypothesis concerning temporal redundancy, relative timing, and perceptual processing of temporal order. Using eight- and seven-element patterns identified as either "good" or "poor" according to the Relative Accent Rule, the authors presented subjects with each individual auditory sequence, continuously sounding, but repeated only once. Because of predetermination of pattern quality, the number of stimuli used could be limited to eight of each type. Subjects were asked to indicate whether the patterns heard were the same or different (repeating or non-repeating), and, in each instance, were asked to write the pattern. The experiment was carried out on three different occasions under three separate conditions. In the first and second experimental situations, different presentation rates were used. Experiment III included a built-in response delay interval before subjects were allowed to record their answers.

Results of the study showed that, in all experiments, there were more correct judgments for good patterns than for poor patterns ($p\alpha < .01$ and $p\alpha < .001$) as judged by mean proportions of correct judgments (Sturges and Martin, 1974, p. 380). Written recall for good patterns was also better than that observed for poor patterns (Experiment I, $p\alpha < .001$; Experiment II, $p\alpha < .01$; Experiment III, $p\alpha < .001$).

The study also revealed that accent structure and temporal order are also related to pattern length. Most theories on perceptual organization assume that the shorter the auditory sequence, the easier it is perceived. Contrary to this belief, Sturges and Martin, in almost all cases, found the eight-element "good" pattern to be recognized with greater facility than were the seven-element patterns (p. 380). The authors state that a "repeating 7-element pattern with accents on Elements 1 and 5, or on 1, 3 and 5, generates expectancies during listening for an 8-element pattern which, however, will be violated since the expected pattern begins repeating one element too soon" (Sturges and Martin, 1974, p. 379). Consequently, it is more difficult for subjects to recognize the seven-element pattern as repeating because relative accent level is not in synchrony with pattern length. Jones (1978a) says,

> Martin's hypothesis parsimoniously predicts an interaction of accent structure with pattern length . . . That is, accents must equally divide a whole sequence in time and such a division is unlikely with patterns of length 7, but not with patterns of length 8. (p. 13)

It should be noted in passing that Restle (1970), in his studies of serial pattern learning, has also used auditory sequences with inherent hierarchical structures as described by structural "trees" (pp. 481-495). These structures, however, were designed to establish pitch relations and not temporal structure. Pauses introduced during presentation, in some cases, facilitated pattern learning, as is typical of serial order apprehension. Martin (1972) points out, however, that the pauses were helpful only when introduced at moments appropriate to the pattern. That is, the pauses assisted listener apprehension of the stimulus only when they were in synchrony with the relative timing characteristics of the pattern and thus divided temporal "subunits" within the sequence (Martin, 1972, p. 506).

In summary, evidence would indicate that the temporal regularity with which certain events recur (as defined by relative timing) is important in the perceptual processing of auditory patterns. In Martin's view, the recurrence of accented sounds defines an invariant property, or "rule," that relates to the time dimension.

Presentation Rate

Several studies have identified presentation rate as a stimulus property which may affect the degree of difficulty with which a listener learns a serially ordered auditory pattern. In their analysis of preferred organizations, Royer and Garner (1966) used stimulus presentation rates too fast for the learning of individual elements to occur, but not too fast for the listener to apprehend pattern structure as a whole. Key-tapping response, while identifying preferred organizations through analysis of frequently used starting points, also indicated pattern difficulty as measured by the length of time occurring before subjects began to respond.

In a similar study using both fast and slow presentation rates, Garner and Gottwald (1968) found that "even though the learning of slow patterns involves some different psychological processes from the perception of faster patterns, similar principles of perceptual organization operate for both types of performance" (Royer and Garner, 1970, p. 115). The authors concluded that patterns which are difficult to learn at slow rates are also difficult to perceive in an organized fashion at higher (faster) rates (Royer and Garner, 1970, p. 115). Jones (1978a) states that, even though this "temporal transposition" has its limits, a pattern will retain its temporal character when shifted up or down (fast or slow) on the time dimension (p. 15).

Summary

The Run-Gap principle (Garner, 1974) and the accent structure hypothesis (Martin, 1972), although contrasting theoretically and methodologically, often agree as to which temporal patterns are easy or difficult to perceptually organize. Garner's presentation rate investigations tend to refute the associative chain theories of pattern learning, and stress the importance of overall pattern structure in the learning of serially ordered event sequences. Aside from identifying strings of similar elements as primary organizing agents, however, the Run-Gap principle gives little information concerning the temporal relations within the pattern structure which facilitate sequence apprehension.

Martin's hypothesis allows for a more detailed inspection of pattern temporal characteristics and their effect on the perceptual process. Temporal constraints present in all motor functioning produce certain invariant relations in temporal order. Based upon this assumption, rules which define these invariant properties can be generated against which listener response to predetermined patterns structures can be analyzed. The hypothesis also allows for speculation concerning the nature of the organizational process which has developed in the perceptual system.

While Martin's theory of accent structure makes certain implications concerning the interrelatedness of accent placement and relative timing, his experimentation has not included an investigation of patterns which incorporate actual variations in relative time durations. Studies have also neglected patterns with greater numbers of elements thereby limiting the inferential strength of the theory.

CHAPTER III

THE MODEL

Introduction

Discussion of the model is divided into four major sections. First, terms associated with the temporal features of auditory patterns are defined. The definitions are not intended to be all-encompassing. Rather, they delineate the temporal concepts attached to each term as it is employed in the model. Second, those aspects of redundancy which are developed in the model are defined. Third, a grammar consisting of two formal descriptive rules is proposed. The rules pertain specifically to rhythmic pattern construction and generate hierarchically structured temporal arrangements of pattern elements. The rules are not associated with the perceptual processing of rhythmic auditory patterns. Finally, a model is proposed which attempts to illustrate how redundancy reduction may influence the perception of rhythmic patterns.

Definitions

In the following schema, three terms are accepted as undefinable primitive concepts. These are, (1) similarity, (2) dissimilarity, and (3) underlying principle. The third concept ("underlying principle"), in general, refers to a rule or set of rules determined prior to pattern development and to which pattern structure adheres. Properties of the "underlying principle" become manifest in various pattern characteristics. These characteristics are defined below.

Element

An element is an auditory event which may exhibit physical features such as frequency, timbre, and intensity (as well as other less prominent attributes such as attack and decay), or which may consist of silence. There is no fixed real-time unit to which all elements must conform durationally. All elements, however, do display some durational characteristic. Certain types of elements are bipartite, consisting of sound followed by silence.

Temporal Sequence

A temporal sequence is a succession of distinct elements which may or may not be separated from each other. Temporal sequences may or may not be rhythmic. Temporal sequence is synonymous with "temporal array."

Interstice

An interstice is a space between elements in certain types of temporal sequences. It is not synonymous with the silence portion of a bipartite element. Rather, the interstice may be likened to the "ground" aspect of the sequence, whereas the element, both sound and silence, is the "figure."

Temporal Pattern

A temporal pattern is a sequence the elements of which are bipartite. The sound, silence, and/or interstices may or may not exhibit relations of similarity or dissimilarity to each other. These relations may or may not be evident to an observer. Two major subsets of all temporal patterns are rhythmic patterns and concatenations.

Concatenation

A concatenation is a temporal pattern in which there is no underlying principle to govern element relations. Rather, the temporal arrangement is the product of successiveness of elements only.

Rhythmic Pattern

A rhythmic pattern is a temporal pattern the element-element relations of which exhibit greater or lesser degrees of regularity. Regularity in a rhythmic pattern is a function of some underlying principle which governs pattern construction or form. Element relations are said to be regular when they occur or recur at uniform intervals as determined by the underlying principle. Conversely, the underlying principle is manifest and, therefore, discernible in the degree of regularity of inter-element relations.

Rhythmic Patterning

Rhythmic patterning is defined as the act of constructing or discerning the regularity of relations in a rhythmic pattern.

Relative Timing

Relative timing is a primary constraint on rhythmic patterning (Martin, 1972, p. 488); that is, the essential underlying principle which governs the temporal arrangement of elements in a rhythmic pattern. Relative timing refers to the distribution of element durations within the pattern. Jones (1978a) states, "within some unit time [that is, real time], successive elements may all be of equivalent duration and equally spaced in time or their durations may differ" (p. 2). Martin (1972) defines relative timing as the relation between the locus of any rhythmic pattern element and the loci of all other elements, adjacent or nonadjacent along the time dimension (p. 488).

The degree of regularity in rhythmic patterns is discerned, in part, through analysis of inter-element durational relations. Thus, it is possible to describe greater or lesser degrees of regularity in terms of relative timing.

The six-element pattern in Figure 1 illustrates the analysis of relative timing. Each element consists of those attributes previously ascribed to rhythmic pattern elements. The standard rhythmic notation indicates that there are two types of durational value present in the rhythmic pattern. Let "n" equal the durational value of one quarter note (♩). Assuming that one eighth note (♪) is equal to half the durational value of one quarter note, the relation between the two durational values can be described by the equation, $\frac{n + n}{2} = n$; that is, ♫ = ♩ .

Using this equation, the total duration of the pattern and the inter-event relations can be expressed as:

$$n + n/2 + n/2 + n + n/2 + n/2,$$

where n = the durational value of one quarter note.

The string describes the relative timing of each element; for example, serial event 1 is twice as long as serial event 5. The degree of regularity in the rhythmic pattern can be partially ascertained through analysis of the uniformity of durational recurrence.

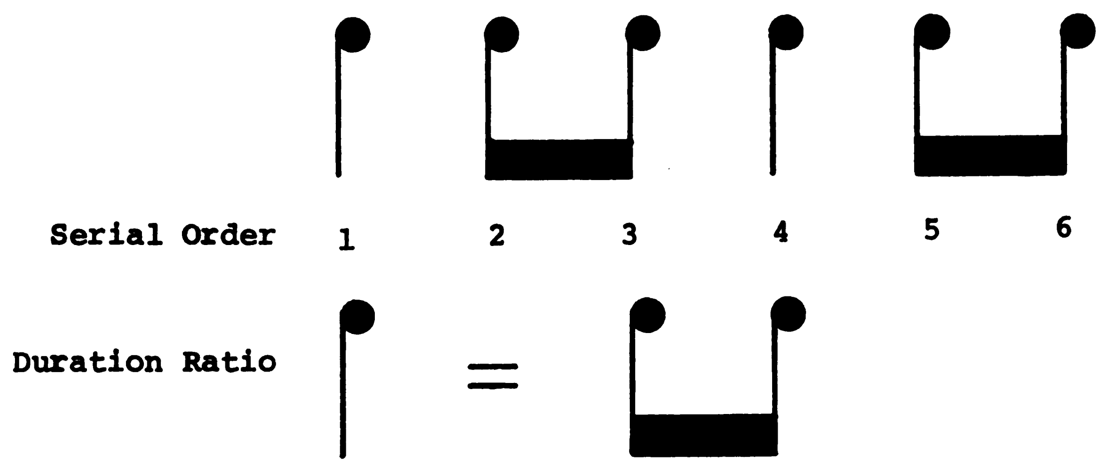


Figure 1. Example of a six-element rhythmic pattern in which there are two types of durational value.

Presentation Rate

Temporal sequences and the temporal relations among sequence elements exist in real time. Presentation rate is a function of event duration, referring to the total number of events per unit of time, and is closely analogous to music tempo. Presentation rate, therefore, refers to whether a sequence is moving rapidly or slowly and can be measured as a number of elements per unit of time.

Although presentation rate is affected by relative timing, the reverse is not necessarily true. This is so because relative timing depends upon the relations among events and not upon the speed at which the pattern is presented.

Presentation rate is characteristic of an entire pattern, whereas relative timing describes events in relation to each other. If, for example, it has been established that eighth-note elements are equal to half the durational value of quarter-note elements, then the element-element temporal relations will remain constant at different presentation rates.

Royer and Garner (1970) demonstrated experimentally that relative timing is, for the most part, independent of presentation rate. Jones (1978a) equates this phenomenon with relative pitch in that, just as the "integrity" of a pattern of pitches is preserved when a melody shifts an octave, so also the rhythmic character of the pattern remains unchanged as pattern temporal arrangement is "transposed" in the time dimension (p. 15). There are, of course, limits to this aspect of relative timing. At very fast rates (e.g., in excess of 20 events per second), elements may not be discernible, and at very slow rates, the listener may forget the relative timing of successive elements. Musical patterns usually occur at rates between four and eight elements per second. The listener is, therefore, capable of perceiving temporal order with events of about one hundred msec in duration.

Using the relative timing of a pattern, an internal temporal structure can be ascertained. The details of inter-event temporal relations are largely independent of presentation rate.

Physical Accent

Physical accent is defined as any physical variation among elements (e.g., frequency, intensity, duration) which demarcates certain elements in the rhythmic pattern resulting in a grouping of events (Cooper and Meyer, 1960). Physical accent, like relative timing, is a relational concept; the accentual value of one element is described in relation to the accentual value of all other elements in the pattern. Physical accent is synonymous with the term, relative accent level.

In rhythmic patterns, the degree of regularity present is described, in part, through (1) analysis of interelement accentual relations, and (2) the relation between accent placement and relative timing. The six-element pattern in Figure 2 illustrates the analysis of relative accent level. Each element is assumed to consist of those attributes ascribed to rhythmic pattern elements. The artificial accent marking (>) denotes physical accent placement. The number above each accent marking indicates the relative accent level for that event with 6 being the strongest accent and 1 the weakest. The degree of regularity of relative accent level is measured initially by observing the uniformity of accent placement relations (serial event 1 through serial event 6), and secondly, by analyzing the regularity of relationship between accent locations and the two durational values (that is, relative timing).

Perceived Accent

Perceived accent is the sensory impression of physical variations in the pattern (e.g., changes in pitch, loudness, protensity, quality, and attack). Perceived accent is not necessarily dependent upon or in alignment with the physical accent present in the auditory pattern. Woodrow (1951) notes that listeners, when presented with a continuous series of evenly spaced,

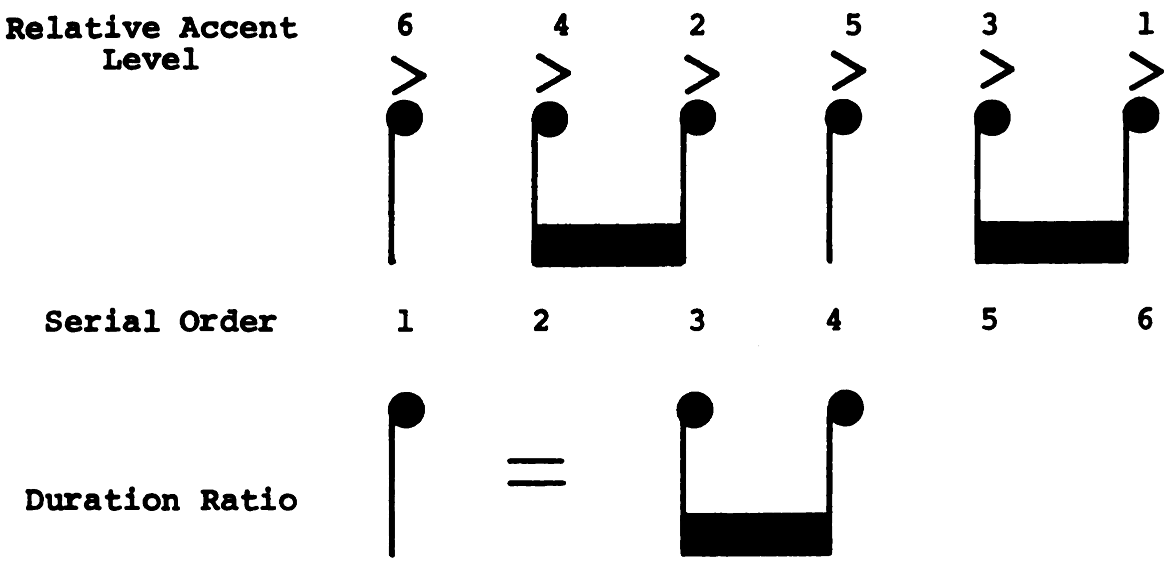


Figure 2. Example of a six-element rhythmic pattern in which each event is accented. Relative accent levels for pattern events are indicated above the notation with 6 being the strongest accent location and 1 the weakest.

identical elements, often report a subjective grouping of elements into fours, with stronger perceived accent on the first element in the group.

Transmissive Redundancy

Transmissive redundancy is defined as that fraction of the signal which is determined by the rule or rules which govern signal construction; it is that portion of the signal which is not free to vary randomly. As such, transmissive redundancy exists independently from the perceptual process and is properly considered as a characteristic of the stimulus.

In rhythmic patterns, transmissive redundancy can be described in terms of the degree of regularity present. Regularity, in turn, is manifest in (1) the inter-element durational relations (relative timing), (2) the relative accentual arrangement, and (3) the relation between relative timing and relative accent level. As will be shown, these three factors can be quantified and combined to produce a numerical representation of transmissive redundancy. For a rhythmic pattern with a specified number of elements, such a measure of transmissive redundancy can be compared (via a ratio) to the total transmissive redundancy possible for that pattern. This ratio (expressible as a proportion or percentage) is defined as relative redundancy in the present model.

Receptive Redundancy

Receptive redundancy is a characteristic of a listener which depends upon information available to the listener through past learning and experience. A listener who has had many years of musical training will possess higher levels of receptive redundancy in association with rhythmic patterns than a listener who has had no musical exposure. The ability to perceive the temporal arrangement in a rhythmic pattern is a function of both relative redundancy (a signal property) and receptive redundancy (a listener property).

Rules for the Construction of Rhythmic Patterns

Introduction

The definitions dealing with relative timing and relative accent level describe where degrees of regularity of relations are to be analyzed in a rhythmic pattern. Martin (1972) has proposed a formal system of rules which allow for a description of these relations in serially ordered auditory patterns in terms of relative accent and relative timing. His system illustrates the interdependence of relative accent level and relative timing as presented in the definitions, and makes possible the classification of auditory patterns as regular or irregular. In this sense, Martin's formulation serves an analytic role; application of the system's rules to existing patterns facilitates characterization of rhythmic regularity. Rhythmic regularity is indexed by the degree to which arbitrarily assigned accent in a specific sequence corresponds to relative accent levels derived from a tree structure which describes the sequence.

Martin has implied that this system also has prescriptive utility; that is, it can be applied to the task of generating rhythmic patterns. It is emphasized that the system's rules pertain to stimulus description only and not to the perception of rhythmic patterns.

Although Martin's formulation is not a perceptual model per se, features of that formulation have been incorporated into the model proposed here. For this reason, an explanation of his system is necessary. Those rhythmic patterns, either pre-existent or derived, which adhere to the rules are labelled, regular rhythmic patterns.

Relative Accent Level Rule

The relative accent level rule describes maximum regularity of accentual values among rhythmic pattern events. This is accomplished by determining uniform temporal recurrence for accent relations. The uniformity of recurrence is described independent of presentation rate.

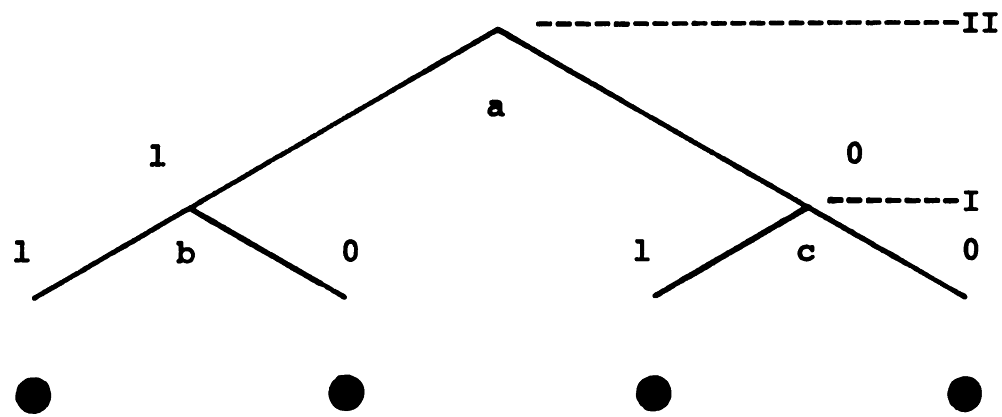
Figure 3 represents four auditory events which, except for accent level, are identical. The accent can be produced by any physical alteration (e.g., frequency). Serial order is indicated by the numbers 1 to 4 below the dots. The hierarchical "tree" is used to ascertain the relative accent level for each event in such a manner as to show maximum regularity among accent relations. The construction of the tree is governed by the number of events in the pattern.

Each left branch of the tree is labelled, "1," each right branch, "0." By reading up the tree and combining the branch labels, a binary number is obtained for each event. The binary numbers are used to determine the relative accent level for each serial position by using the following rule: to compute accent level, convert the obtained binary number to a decimal number and add one (Martin, 1972, p. 490).

The second serial event in Figure 3 will be used to illustrate the rule. By reading up the tree, the binary number, 01_b is derived. Binary-to-decimal conversion is accomplished through the formula,

$$a_n \times 2^n + a_{n-1} \times 2^{n-1} + . . . a_1 \times 2^1 + a_0 \times 2^0;$$

where "a" is either 0 or 1, and 2 represents the power of two to the digit, "a" (Schmid, 1974, p. 2).



Serial Order:	1	2	3	4
Binary Value:	11	01	10	00
Decimal Value:	3	1	2	0
Relative Accent Level:	4	2	3	1

Figure 3. Determination of relative accent levels for a four-event auditory pattern. The two-node level tree is used to show maximum regularity among accent relations. The derived binary number for each event is converted to a decimal number. The relative accent level is obtained by adding 1 to each conversion.

For the second event, designation of the relative accent level according to the hierarchical tree would be as follows:

1. Determine the event's binary value (01_b);

2. Convert the binary value to a decimal value ($0_b \times 2^1 + 1_b \times 2^0 = 1_d$);

3. Add one to the derived decimal value to obtain the relative accent level (1 + 1 = 2).

Binary values, decimal values, and relative accent level for each event in Figure 3 appear beneath each dot. The strongest relative accent (4), according to the tree structure, will fall on serial position 1 with the second strongest (3) occurring at serial event 3, indicating an equal division of the total pattern as well as a regularity of relative accent placement.

Also important in Martin's system is the number of nodes present in a tree structure. A single node consists of a left and right branch converging on a point. The tree structure given in Figure 3 has three nodes designated, "a," "b," and "c" in the figure. The relative accent levels of elements are influenced by the number of nodes in the tree structure.

The number of node levels (Figure 3 has two, designated as I and II) depends upon the number of events included in the sequence. Note that the stronger relative accent levels are described by the left branch of each node level.

Relative Timing Rule

The primary feature of the relative accent level rule is the described regularity of stronger accent occurrence resulting in equal subdivision of the total pattern. Martin's formulation proposes that variation in relative durational values, in order to be categorized as regular, must also exhibit a uniformity of temporal occurrence which is directly linked to the relative accent levels.

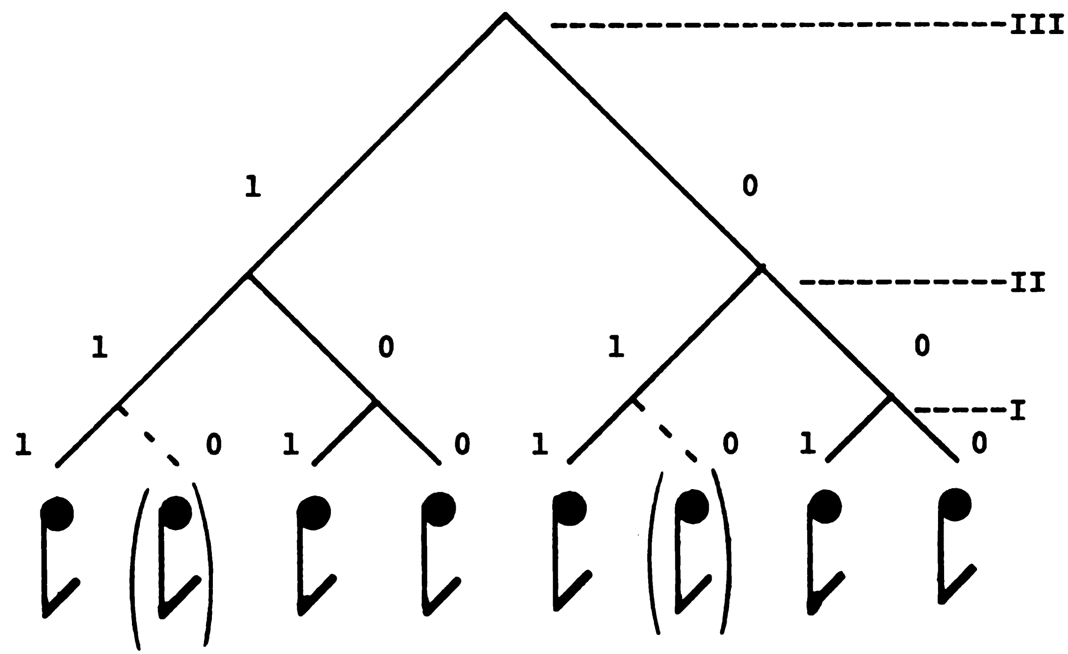
The relative timing rule is essentially a subrule of the relative accent level formulation. It asserts that events with relatively longer durational values will coincide temporally with the stronger relative accent locations, especially those which are designated by higher node level left branches of the hierarchical tree. Events occurring at weaker accentual positions will either be equal to or less than the durational value of those events occurring at strong relative accent points. If more than one type of durational value is used in the rhythmic pattern (e.g., ♩ and ♪), then the number of node levels required in the hierarchical design will depend upon the element with the shortest duration.

The Interdependence of Relative Accent Level and Relative Timing

Figure 4 will be used to illustrate the relative timing rule and to describe the interdependence of relative accent level and relative timing. On the lowest node level (node level I), there are two null branches. Because they are independent of seriation, relative accent levels remain unchanged by these absences, "since accent level is determined . . . by location along the time line, whether or not the event in question is actually realized" (Martin, 1972, p. 490).

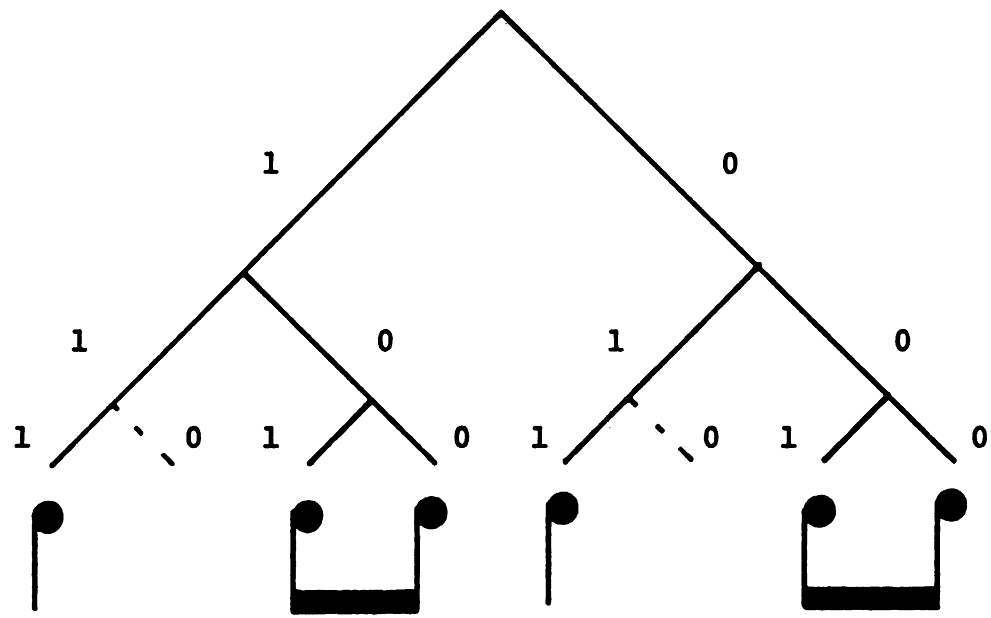
The two null branches follow the two strongest accent locations (relative accent levels 8 and 7) as described by the tree. Absence of elements at these points in effect increases the relative durational value of those events occurring at accent points 8 and 7. The resultant bi-level durational relations are more clearly illustrated in Figure 5 by using quarter (♩) and eighth (♪) notes. It is assumed that the usual 2:1 relation exists between the two note types (that is, ♫ = ♩).

The interrelationship between relative accent level and relative timing is explicit here in that the longer durational value of serial events 1 and 4 *is* the accent-producing agent. The sequence in Figure 5 would, according to the two rules, be labelled regular since, (1) the



Serial Order:	1		2	3	4		5	6
Relative Accent Level:	8	(4)	6	2	7	(3)	5	1

Figure 4. Representation of relative accent levels as described by a three-node level hierarchical tree. The two null branches (dashed lines) on node level I indicate the absence of event.



Serial Order:	1	2	3	4	5	6
Relative Accent Level:	8	6	2	7	5	1

Figure 5. Representation of the rhythmic pattern shown in Figure 4 using two musical note types to indicate changes in durational value.

relative accent levels evenly divide the total pattern, and (2) longer durational values coincide temporally with stronger accent location.

The synchrony between relative accent level and relative timing described by the two rules can be further illustrated if an additional accent-producing agent is introduced into the rhythmic pattern. In the following examples, it is assumed that the artificial accent sign (>) indicates a considerable increase in the intensity level for those marked events. In Figures 6 (a) and (b), there is no change in relative durational values, thus allowing for a comparison of the relative accent levels described by the trees with the artificial accent locations. In Figure 6 (a), the imposed accents fall with a certain regularity at the stronger relative accent points (serial positions 1, 3, and 5). Rhythmic grouping of the events is almost uniform with respect to overall pattern content. In Figure 6 (b), however, the artificial accent has been irregularly placed on serial positions 1, 4, and 6. Subdivision of the total pattern is not uniform. Accent locations in Figure 6 (a) result in sub-groupings of two's and four's which are regular with respect to the pattern's temporal content. In Figure 6 (b), imposed accent results in unequal subdivisions of two's and three's.

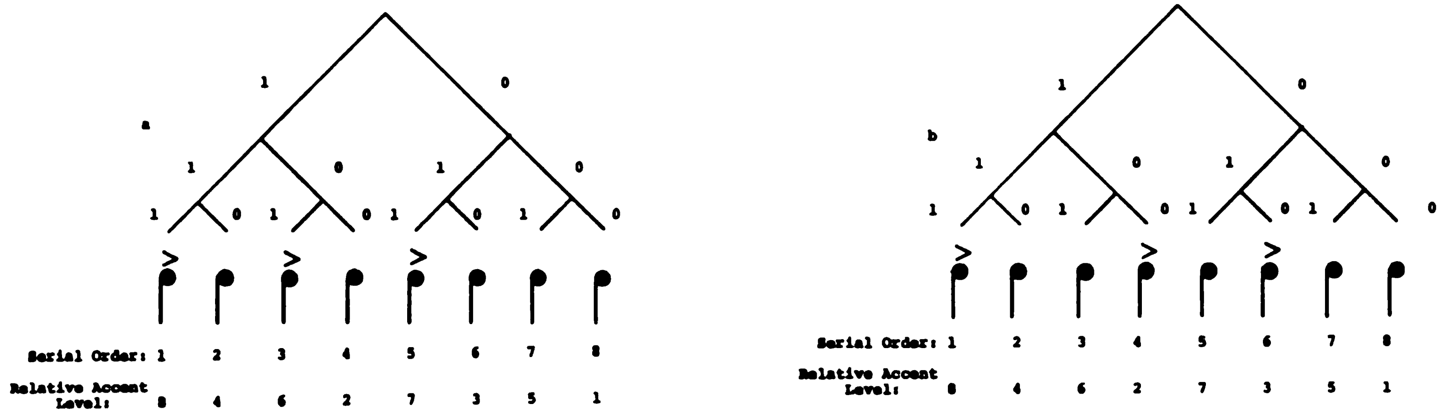


Figure 6. Eight-event rhythmic patterns with regular (a) and irregular (b) accent locations as defined by the rule of relative accent level. The artificial accent sign (>) denotes accent location.

Figure 7 (a) represents an irregular rhythmic pattern in that the longer durational values are not consistent with the important relative accent locations. Although imposition of artificial accent at the designated stronger accentual points of 16, 15, and 14 (Figure 7 (b)) tends to diminish the irregular quality of the pattern, the improper alignment of relative timing and accent still results in an unequal or irregular subdivision of the total pattern.

Figure 8 (a) illustrates a regular rhythmic pattern in which the intensity level accent corresponds with both the stronger relative accent locations and the relative durational values as determined by overall pattern content. Even when artificial accent is shifted to irregular locations, as illustrated in Figure 8 (b), the regularity of temporal order in the pattern, although somewhat compromised, remains intact due to the correct correspondence of longer durational values with designated strong accent locations.

Use of the Two Rules in the Analysis of a Relative Redundancy Level

Martin's schema allows for a gross determination of regularity (that is, regular vs. irregular). It would be desirable to quantitatively describe the degree of

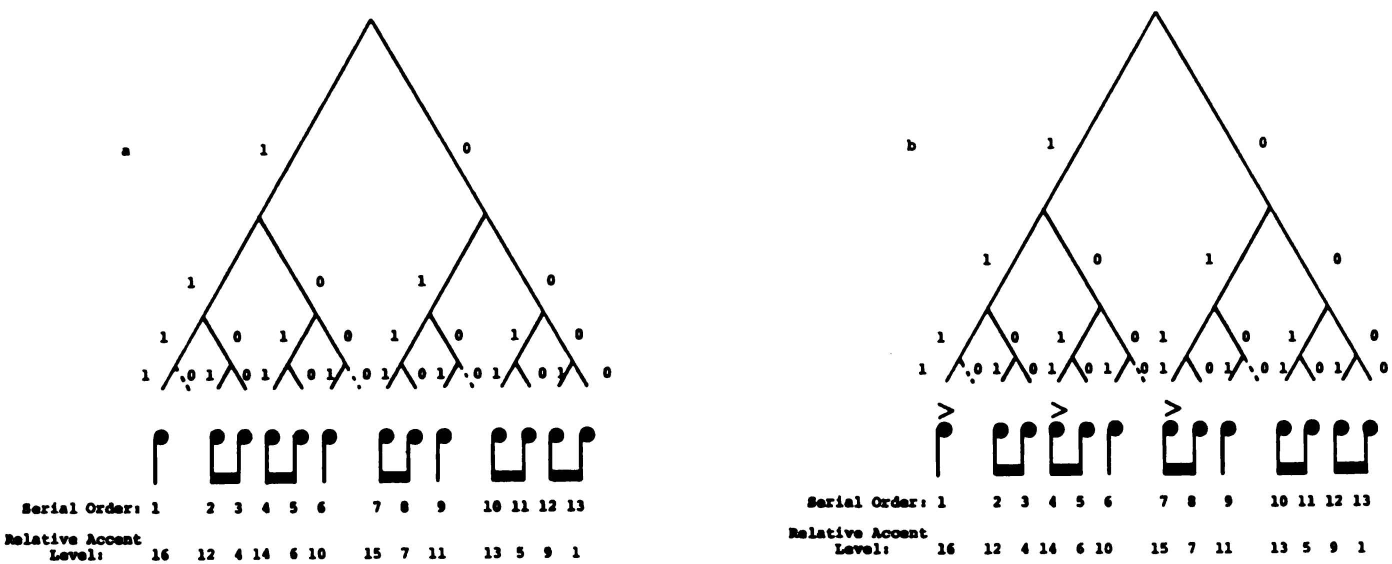


Figure 7. Thirteen-event rhythmic patterns with irregular arrangements of two types of event durations. Pattern irregularity is described by the rule of relative timing. The artificial accent sign (>) denotes location of additional accent-producing agent (e.g., intensity change).

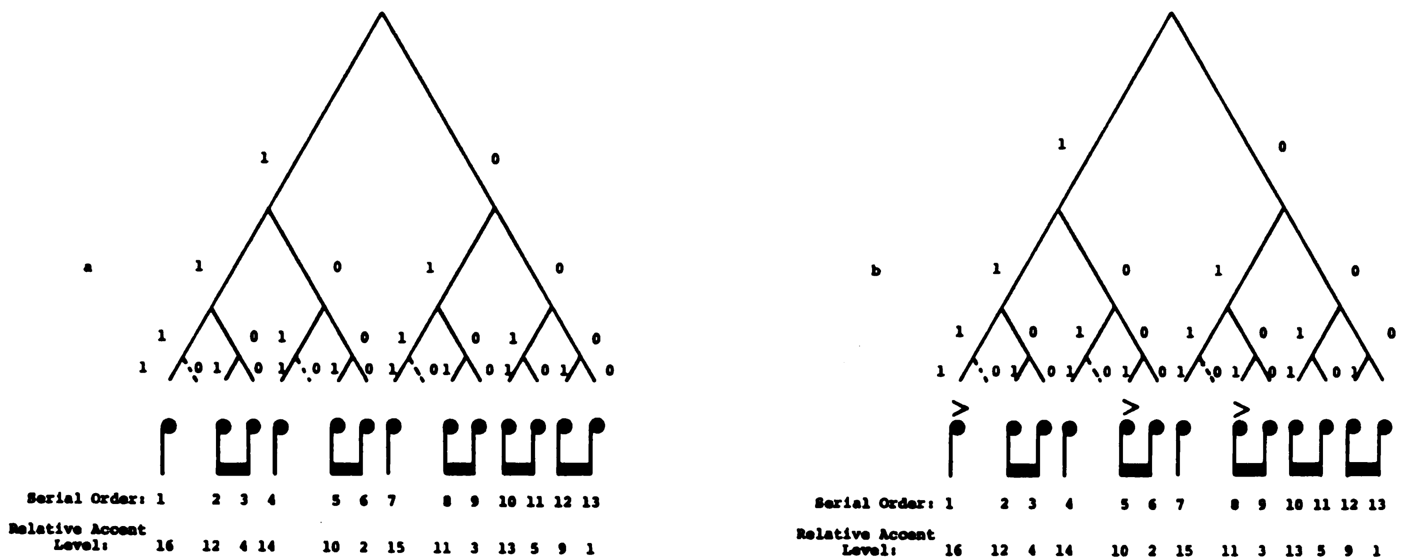


Figure 8. Thirteen-event rhythmic patterns with regular arrangements of two types of event durations. Pattern regularity is described by the rule of relative timing. The artificial accent sign (>) denotes locations of an additional accent-producing agent (e.g., intensity change).

regularity present in a rhythmic pattern. Quantification[1] of regularity would facilitate description of relative redundancy levels because regularity directly influences redundancy in pattern temporal structure.

The relative accent level and relative timing rules describe maximum regularity for four types of relations. These described regular relations can be discovered through analysis of the hierarchical tree structures, the means by which relative accent level is derived. An example of such a tree structure is presented in Figure 9. The resultant relative accent levels (RAL) and the serial order positions labelled in Figure 9 are properties of the tree. Similarly, the four relations are associated with the maximum regularity properties of the hierarchical tree.

Relations 1 and 2 pertain to the described regularity of relationships along the relative accent level (RAL) continuum. Note that this continuum extends from strongest RAL to weakest RAL and retrogresses from weakest RAL to strongest RAL. Progression along the RAL continuum is movement from a large-valued RAL to a small-valued RAL; retrogression proceeds in the opposite direction. In Figure 9, for example, the RAL continuum progresses

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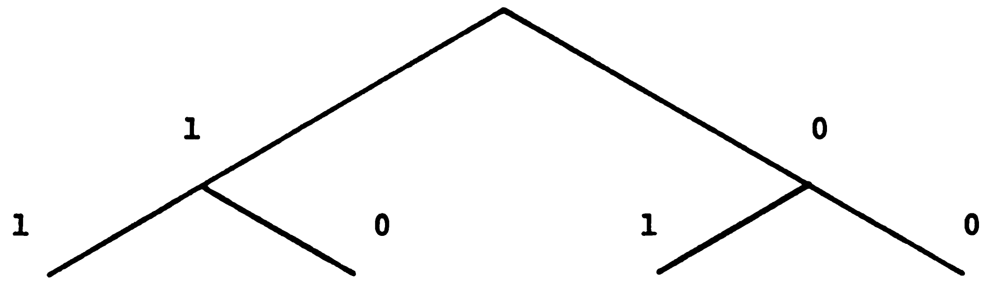
[1]The quantification procedure about to be described is the result of interactions with M. R. Chial (Spring, 1980).



Serial Order: (TSO)	1	2	3	4
Relative Accent Level: (RAL)	4	2	3	1

Figure 9. Serial Order (TSO) and relative accent level (RAL) continua for a two-node level hierarchical tree. Maximum regularity described by the relative accent level and relative timing rules is discovered through analysis of relations along the two continua.

from RAL_4 to RAL_3 to RAL_2 to RAL_1. Because RAL is not monotonic with serial order, it must be thought of as a separate continuum.

Relations 3 and 4 pertain to the described regularity of relationships in accent and duration along the serial order (TSO) continuum. This continuum progresses from smallest (that is, initial) to largest (that is, terminal) integer and retrogresses from largest to smallest integer. In Figure 9, for example, the TSO continuum progresses from 1 to 2 to 3 to 4. Note that the successive progression and retrogression of the two continua do not correspond, for while the TSO continuum progresses successively from left to right across the hierarchical tree, the RAL continuum alternates. For each TSO position, however, there is an associated RAL. The regularity described by Relations 3 and 4 pertains to the relationship between the associated RALs for the various TSO positions.

Following is an outline of the described maximum regularity for the four Relations.

<u>Relation 1</u>

Relation 1 involves <u>progression</u> along the RAL continuum; in other words, a comparison of the value of a specific accent level, RAL_x, and the value of the next smaller relative accent level, RAL_{x-1}. The relation of these two RALs is such that RAL_x is greater than RAL_{x-1}

with regard to accent strength and durational value. Symbolically,

$$RAL_x > RAL_{x-1}.$$

Relation 2

Relation 2 involves retrogression along the RAL continuum. The value of a particular relative accent level (RAL_x) is compared to the value of the next largest relative accent level (that is, RAL_{x+1}). The described regularity is such that RAL_x is less than RAL_{x+1} in accent strength and durational value; that is,

$$RAL_x < RAL_{x+1}.$$

Relations 1 and 2 may be summarized as follows:

$$RAL_{x+1} > RAL_x > RAL_{x-1}.$$

Relations 3 and 4

The regularity of relations described by the two rules results in an even distribution of the relatively strong and weak RALs across the hierarchical tree. In Figure 9, for example, a stronger-weaker-stronger-weaker (RAL_4, RAL_2, RAL_3, RAL_1) alternation results from even distribution of RALs. Based on this even distribution of described relative accent levels, regularity of relationships between the corresponding RAL for any serial order position (RAL_{TSO_n}) and the next RAL progressing along the TSO continuum (that is, $RAL_{TSO_{n+1}}$) can be determined.

Likewise, the regularity of relation between RAL_{TSO_n} and the next RAL retrogressing along the TSO continuum (that is, $RAL_{TSO_{n-1}}$) can be ascertained. According to the two rules, the corresponding RALs for TSO_{n+1} and TSO_{n-1} will both be either greater than or less than the RAL corresponding to TSO_n. Symbolically,

$$\left\{RAL_{TSO_{n+1}} < RAL_{TSO_n} > RAL_{TSO_{n-1}}\right\} \cup \left\{RAL_{TSO_{n+1}} > RAL_{TSO_n} < RAL_{TSO_{n-1}}\right\},$$

$$\overline{\left\{RAL_{TSO_{n+1}} > RAL_{TSO_n} > RAL_{TSO_{n-1}}\right\} \bullet \left\{RAL_{TSO_{n+1}} < RAL_{TSO_n} < RAL_{TSO_{n-1}}\right\}}.$$

In Figure 9, for example, RAL_{TSO_2} is bracketed by two larger (that is, stronger) RALs at TSO_1 (RAL_4) and TSO_3 (RAL_3). In contrast, RAL_{TSO_3} progresses and retrogresses to smaller (that is, weaker) RALs along the TSO continuum.

Rules for Comparing Described Regular Relations with Rhythmic Pattern Temporal Relations

If the maximum regularity described by the Relations is used as a standard, an index of relative redundancy for actual patterns can be determined by comparing the accentual and durational relationships present in the actual pattern with those maximally regular Relations described by the relative accent level and timing rules. In the proposed procedure, comparisons of relationships among events of an actual pattern and the described regular Relations is accomplished by "mapping" an appropriate hierarchical tree structure onto the actual pattern. Comparisons can then be made between (a) the relations among events of an actual pattern, and (b) the relations among events of the hierarchical tree invoked to analyze that actual pattern. An example of this mapping operation is presented in two-dimensional form in Figure 10. The serial order continuum of the actual pattern is labelled, PSO to distinguish it from the serial order continuum of the hierarchical tree (that is, TSO). The mapping operation results in a correspondence between specific RALs and TSOs with rhythmic pattern events. In Figure 10, for example, PSO_1 corresponds to TSO_1 and RAL_4, PSO_2 corresponds with TSO_2 and RAL_2, and so on.

Based on the described regular Relations, a set of rules can be generated which will govern the comparisons between the regular relation properties of the hierarchical tree with the temporal relations present in the actual pattern. In this procedure, if a positive comparison is observed (that is, the regularity of a described Relation is mirrored in the actual pattern), then the temporal relation in the actual pattern is labelled, regular. If a negative comparison is observed, then the actual pattern's temporal arrangement for that comparison is labelled, irregular.

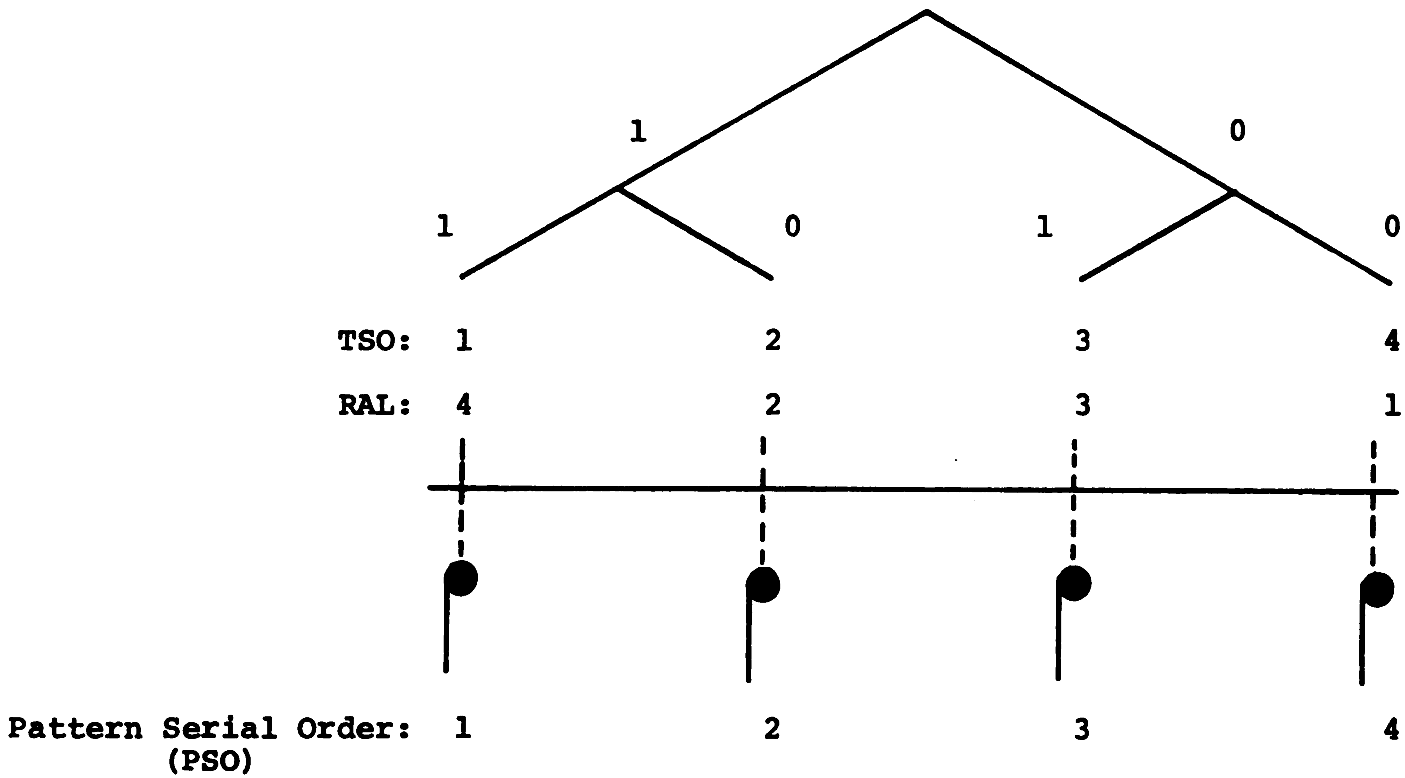


Figure 10. Mapping operation (indicated by the vertical dashed lines) used to compare relations among pattern events with maximum regularity described by a hierarchical tree. Serial order continuum of the pattern is labelled, PSO to distinguish it from the serial order continuum of the hierarchical tree (TSO).

A slight modification of the Relation formulae has been made in the comparisons rules to allow for analysis of a larger number of orders of rhythmic patterns. In the hierarchical tree structure, there is a different RAL for each branch, indicating many unique levels of relative accent level and duration. In Figure 9, for example, there are four unique levels of RAL, such that $RAL_4 > RAL_3 > RAL_2 > RAL_1$. Thus, $RAL_4 > RAL_2$, $RAL_3 > RAL_1$, and so on.

In certain rhythmic patterns, for which the tree illustrated in Figure 9 would be the appropriate structure for relation comparison, it is possible that there may be less than four unique accent levels present. For this reason, regular Relation statements of "greater than" and "less than" have been changed to "greater than or equal to" and "less than or equal to" in order to facilitate regular Relation comparison with rhythmic patterns containing smaller numbers of accent levels.

Following is an outline of the rules for comparison.

Rule 1

The first rule is used to compare the accentual and durational relation of an actual pattern event (PSO_n) and its corresponding RAL with that pattern event which corresponds to RAL_{x-1}. Thus, Rule 1 is based on Relation 1. In Figure 10, for example, the mapping operation indicates that PSO_3 corresponds with RAL_3. In the hierarchical tree, $RAL_{3-1} = RAL_2$. Note that PSO_2 corresponds with RAL_2. The modified version of Relation 1 states that,

$$RAL_x \geq RAL_{x-1}.$$

Rule 1 states, therefore, that if the accentual and durational relations of two actual pattern events compares positively with the regular relation of the two corresponding RALs progressing along the RAL continuum of the tree, then the relation between the two PSOs is regular. If the accentual and durational relation of the two actual pattern events presents a negative comparison with the regular relation of the two corresponding RALs, then the relation between the two PSOs is irregular. In Figure 10, for example, if the accent strength and durational value of PSO_3 equals or exceeds that of PSO_2, then the relation between PSO_3 and PSO_2 is regular, because it mirrors the regular relation described by the corresponding RALs in the hierarchical tree.

Rule 2

The second rule is used to compare the accentual and durational relation of an actual pattern event and its corresponding RAL with that rhythmic pattern event which corresponds with RAL_{x+1}. In Figure 10, for example,

$RAL_{3+1} = RAL_4$, and PSO_1 corresponds with RAL_4. Thus, a comparison between PSO_3 and PSO_1 can be made using the second rule. The modified version of Relation 2 states,

$$RAL_x \leq RAL_{x+1}.$$

Rule 2 states, therefore, that if the accentual and durational relation of the two actual pattern events (e.g., PSO_3 and PSO_1) compares positively with the regular relation of the two corresponding RALs retrogressing along the RAL continuum of the tree, then the relation between the two PSOs is regular. If the accentual and durational relation between the two actual pattern events presents a negative comparison with the two corresponding RALs, then the relation between the two PSOs is labelled, irregular. In Figure 10, for example, if the accent strength and durational value of PSO_3 is less than or equal to that of PSO_1, then the relation between PSO_3 and PSO_1 is regular because it mirrors the regular relation described by the corresponding RALs in the hierarchical tree.

Rule 3

Rules 3 and 4 are based on Relations 3 and 4, and are used to compare the relation of actual pattern events with the corresponding RALs along the TSO continuum. Note that the PSO continuum is identical to the corresponding TSO continuum; that is PSO_n corresponds with TSO_n, PSO_{n+1} corresponds with TSO_{n+1}, and PSO_{n-1}

corresponds with TSO_{n-1}. In Figure 10, PSO_1 corresponds with TSO_1, PSO_2 corresponds with TSO_2, and so on.

The modified version of Relations 3 and 4 state that,

$$\frac{\left\{RAL_{TSO_{n+1}} < RAL_{TSO_n} > RAL_{TSO_{n-1}}\right\} \cup \left\{RAL_{TSO_{n+1}} > RAL_{TSO_n} < RAL_{TSO_{n-1}}\right\},}{\left\{RAL_{TSO_{n+1}} > RAL_{TSO_n} > RAL_{TSO_{n-1}}\right\} \bullet \left\{RAL_{TSO_{n+1}} < RAL_{TSO_n} < RAL_{TSO_{n-1}}\right\}.}$$

Rule 3 states, therefore, that if the accentual and durational relation between two actual pattern events compares positively with the regular relation of the RALs for the corresponding TSOs progressing along the TSO continuum (that is RAL_{TSO_n} to $RAL_{TSO_{n+1}}$), then the relation between the PSOs is labelled, regular. If the accentual and durational relation between the two actual pattern events presents a negative comparison with the regular relation of the two RALs for the corresponding TSOs, then the relation between the two PSOs is labelled, irregular. In Figure 10, for example, if the accent strength and durational value of PSO_3 is greater than or equal to that of PSO_4, then the relation is regular because it mirrors the regular relation described by the RALs for the corresponding TSOs in the hierarchical tree.

Rule 4

Rule 4 states that if the accentual and durational value of two actual pattern events compares positively with the regular relation of the RALs for the corresponding TSOs retrogressing along the TSO continuum (that is, RAL_{TSO_n} to $RAL_{TSO_{n-1}}$), then the relation between the two PSOs is labelled, regular. If the accentual and durational relation of the two actual pattern events presents a negative comparison with the regular relation of the two RALs for the corresponding TSOs, then the relation between the two PSOs is labelled, irregular.

Missing Comparisons

The rules for comparison proposed here are designed to analyze relations among events of non-repeating patterns as they correspond to finite hierarchical tree structures. As a result, two of the four comparisons will be missing for both the initial and terminal actual pattern events. In Figure 10, for example, there are no Rule 2 and Rule 4 comparisons available for PSO_1. Similarly, Rule 1 and Rule 3 comparisons are missing for PSO_4.

The missing comparisons may be completed through analysis of the relation between the initial and terminal pattern events as a function of those rules for which a comparison is incomplete. In other words, PSO_4 is "followed" by PSO_1, and PSO_1 is "preceded" by PSO_4 in Figure 10.

Relative Redundancy Levels

Introduction

In the quantification procedure proposed here, a positive comparison between an actual pattern relation and corresponding RALs or RAL_{TSO_n} for any of the four Rules (that is, a regularity of actual pattern relation) is assigned the number, 1. If a pattern relation presents a negative comparison in any of the Rules (that is, the pattern relation is irregular), then the relation is assigned a 0. Cumulative frequency of regularity (R_{tot}) for each actual pattern event is obtained by adding the results derived from the comparisons. The R_{tot} for each event is then multiplied by a weighting factor dictated by the corresponding RAL for that serial event. The result is a weighted R_{tot}, or WR_{tot}. Finally, the relative redundancy level (RRL) for the actual pattern is obtained by summing the values of WR_{tot} across serial elements.

An additional rule is used in this method and pertains to the location of accent in the actual pattern. This additional accent rule is defined as follows.

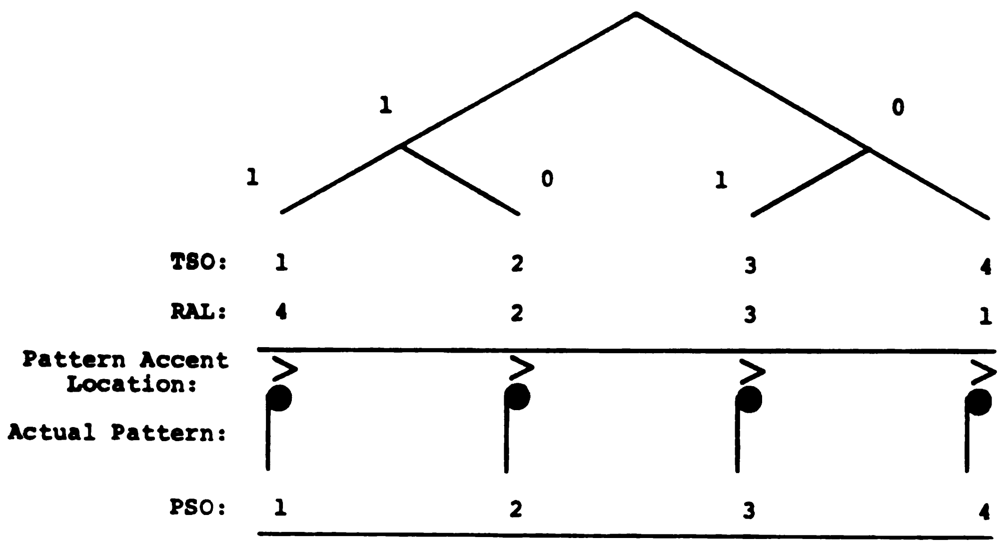
Rule 5

If an actual pattern event is accented, and if all other analysis shows a positive comparison with the regularity of the hierarchical tree, then the accented actual pattern event is assigned the number, 1. If the pattern event is unaccented, or if any of the analysis shows a negative comparison with the regularity of the hierarchical tree, then that pattern event is assigned a 0.

Example

Four-event patterns in which all of the elements are equal in duration will be used to illustrate quantification procedures. It is assumed that a binary frequency (pitch) change is used to produce accent in the actual pattern (the same result could be obtained by marking accented elements with an increase in intensity). The artificial accent sign (>) is used to denote accent location.

According to the quantification method proposed here, maximum redundancy will result when each of the rhythmic events is accented and all actual pattern temporal relations show a positive comparison for each of the comparison Rules. Figure 11 presents such a pattern, together with a comparison matrix. Each cell of the matrix identifies either a positive or negative comparison between any actual pattern event (PSO_n) and the hierarchical tree as a function of each of the five comparison Rules. Each cell, after completion of comparisons, will contain either a 1 or a 0 value. In Figure 11, note that all cells in



Comparison Matrix

PSO:	1	2	3	4
Rule 1	1	1	1	1
Rule 2	1	1	1	1
Rule 3	1	1	1	1
Rule 4	1	1	1	1
Rule 5	1	1	1	1
R_{tot}:	5	5	5	5
Weighting Factor:	X 4	X 2	X 3	X 1
WR_{tot}:	20	10	15	5

$RRL = \sum WR_{tot} = 50$

Figure 11. Example of a four-event pattern exhibiting a positive comparison with all regular relations described by the tree. Positive comparisons are indicated by a "1" in each cell of the Comparison Matrix. The R_{tot} for each event is obtained by summing the respective column. Weighting factors are determined by the corresponding RALs, and RRL for the pattern is obtained by summing WR_{tot} values across serial elements.

the comparison matrix contain the number, 1, indicating that the temporal relations in the rhythmic pattern are all regular, or maximally redundant.

The rhythmic pattern event, PSO_3 in Figure 11 will be used to illustrate quantification procedure according to the Rules for comparison. As indicated by the mapping operation, PSO_3 corresponds with the TSO_3 and RAL_3 properties of the hierarchical tree. According to Rule 1, if the accentual and durational value of PSO_3 is greater than or equal to that of the actual pattern event which corresponds to RAL_2 (that is, PSO_2), then a positive comparison exists between the regularity of the hierarchical tree and the temporal relation in the actual pattern. The pattern event, PSO_3 is equal in accent and duration to PSO_2. Thus, there is a positive comparison for Rule 1, and PSO_3 has been assigned the number, 1 in the PSO_3-by-Rule 1 cell of the comparison matrix.

Rule 2, when applied to PSO_3, states that if the accentual and durational value of PSO_3 is less than or equal to that of the actual pattern event which corresponds with RAL_4 (that is, PSO_1), then a positive comparison exists between the regularity of the hierarchical tree and the temporal relation in the pattern. The pattern event, PSO_3 is equal in accent and duration to PSO_1. Thus, there is a positive comparison for Rule 2, and PSO_3 has been assigned the number, 1 in the PSO_3-by-Rule 2 cell of the comparison matrix.

Rule 3, when applied to PSO_3, states that if the relation between the accentual and durational value of PSO_3 and PSO_4 compares positively with the corresponding regularity of the RALs progressing along the TSO continuum, then the relation between PSO_3 and PSO_4 is regular. In Figure 11, the accentual and durational value of PSO_3 is equal to that of PSO_4. Thus, there is a positive comparison for Rule 3, as indicated by the number, 1 in the PSO_3-by-Rule 3 cell of the comparison matrix. A positive comparison also exists between PSO_3 and PSO_2 for Rule 2. Because all four comparisons for PSO_3 proved to be positive, and because PSO_3 is accented (>), the number, 1 has been assigned to the PSO_3-by-Rule 5 cell of the comparison matrix.

The relative redundancy level (RRL) for the rhythmic pattern in Figure 11 is obtained by multiplying the R_{tot} for each pattern element by a weighting factory as indicated by the corresponding RAL for that element and then summing the WR_{tot} values across serial elements. For the actual pattern in Figure 11,

$$
\begin{aligned}
RRL &= \Sigma WR_{tot} \\
&= (4 \times 5) + (2 \times 5) + (3 \times 5) + (1 \times 5) \\
&= 50.
\end{aligned}
$$

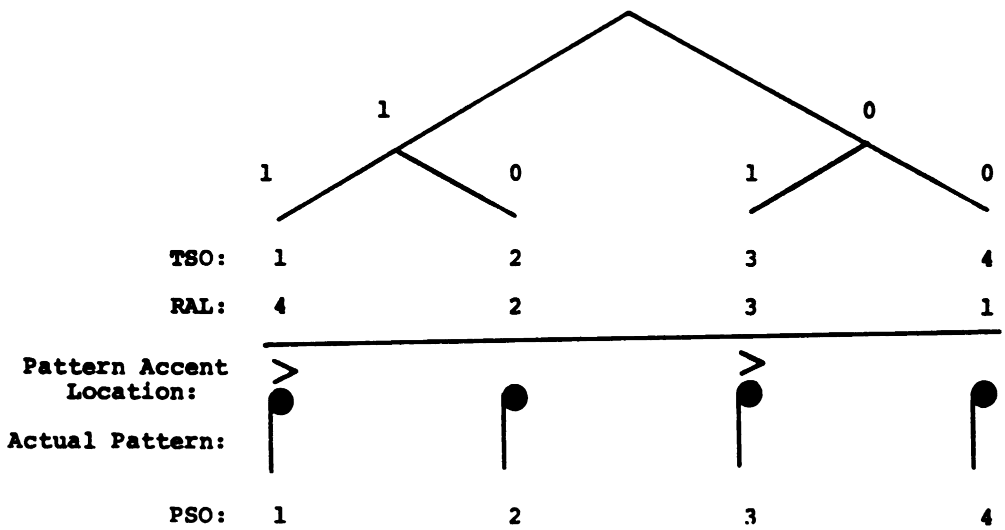
Because all comparisons showed a positive correspondence, the RRL for the actual pattern in Figure 11 (50) represents maximum redundancy (R_{max}) for this type of four-event pattern. An index of relative redundancy (IRR) for other patterns of this order (that is, four-event patterns) is obtained by dividing the computed RRL by R_{max}. Figure 12 will be used to illustrate computation of IRR. In this rhythmic pattern, the events, PSO_2 and PSO_4 are unaccented, and the absence of accent has resulted in the assignation of a 0 in the PSO_2-by-Rule 5 and PSO_4-by-Rule 5 cells of the comparison matrix. The RRL for this pattern is

$$\begin{aligned} RRL &= \Sigma WR_{tot} \\ &= (4 \times 5) + (2 \times 4) + (3 \times 5) + (1 \times 4) \\ &= 47, \end{aligned}$$

and IRR is given by,

$$\begin{aligned} IRR &= RRL/R_{max} \\ &= 47/50 \\ &= .94. \end{aligned}$$

Table 1 presents values for R_{tot}, RRL, and IRR for all possible four-event patterns. The quantification method described here can be generalized to patterns of other orders (element numbers) found in simple duple and quadruple meter settings. Because R_{max} is equal to the highest RRL for a given order of rhythmic patterns, the R_{max} for each pattern order will be different.



Comparison Matrix

PSO:	1	2	3	4
Rule 1	1	1	1	1
Rule 2	1	1	1	1
Rule 3	1	1	1	1
Rule 4	1	1	1	1
Rule 5	1	0	1	0
R_{tot}:	5	4	5	4
Weighting Factor:	X 4	X 2	X 3	X 1
WR_{tot}:	20	8	15	4

$$RRL = \sum WR_{tot} = 47$$

Figure 12. Computation of the index of relative redundancy (IRR) for a four-event pattern in which two events are unaccented. Absence of accent is denoted by a 0 in the Rule 5-by-PSO_2 and Rule 5-by-PSO_4 cells of the Comparison Matrix. IRR for the pattern is determined through a comparison of the RRL (47) with the R_{max} for four-event patterns (50).

TABLE 1. Quantification of temporal regularity for four-event patterns as described in text. Accent placement in pattern serial order is denoted by the number, "1." Absence of accent is marked by a "0." Maximum redundancy (R_{max}) for this order of pattern is 50. The index of relative redundancy (IRR) is obtained by dividing relative redundancy level (RRL) by R_{max}.*

Pattern Serial Order				R_{tot} Pattern Event					
1st	2nd	3rd	4th	1	2	3	4	RRL	IRR_4
1	1	1	1	5	5	5	5	50	1.00
1	1	1	0	5	5	5	4	49	.98
1	0	1	0	5	4	5	4	47	.94
1	0	1	1	5	3	5	3	44	.88
1	0	0	0	5	4	4	4	44	.88
1	0	0	1	5	3	3	2	37	.74
1	1	0	0	5	2	2	4	34	.68
0	0	1	0	3	4	3	4	33	.66
1	1	0	1	5	2	1	3	30	.60
0	1	1	0	2	3	3	4	27	.54
0	1	0	0	3	1	2	4	24	.48
0	0	0	1	2	3	3	0	23	.46
0	0	1	1	1	3	3	1	20	.40
0	1	1	1	0	3	3	2	17	.34
0	1	0	1	0	1	1	1	6	.12

*Because of the absence of accent, the pattern, 0000 is considered to be a concatenation and is, therefore, not included in the table.

The Perceptual Model[2]

Introduction

Martin's system succinctly describes relative accent and durational regularity, but is insufficient as a perceptual model because it deals exclusively with pattern structure. In general, an adequate model must also account for the processes by which the listener responds to the pattern. This can be accomplished by identifying and segmenting the various subprocesses known and/or thought to operate in auditory perception. The model also should be sufficiently flexible to account for the perception of a variety of patterns.

The model proposed here focuses on the redundancy reduction aspects of perceptual processing. In general, redundancy reduction allows for optimum efficiency in the transmission of stimulus information due to an increase in the informational capacity of the perceptual system (Barlow, 1969).

Although the model is based, in part, on neurophysiological findings, it (the model) is intended to be neither quantitative nor neurophysiological. Rather, it is a conceptual model which attempts to illustrate how redundancy reduction may operate in the perception of rhythmic auditory patterns. As such it provides a means

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[2]The present form of the model is the result of interactions with M. R. Chial (1979-1980).

for dealing with the known and presumed elements involved in auditory perception.

Formal modeling of perceptual processes presents certain additional advantages, and the success of the present effort will be determined by the extent to which these advantages can be realized. It is hoped that the model will serve a mnemonic function through explicit identification of the processes and subprocesses involved in the perception of rhythmic auditory patterns. It should also contribute explanations of the cause-effect relations which operate in the perception of these phenomena. Ideally, the model will motivate predictions of outcomes susceptible to experimental inquiry.

Discussion of the model is divided into three sections. First, a set of assumptions concerning the perceptual system and perceptual processing is outlined. Second, several features of the model derived from the assumptions are presented. Third, components of the model are identified and described.

Assumptions

The following assumptions refer both to the perceptual system and to perceptual processing. Three types of assumptions are incorporated, including (1) those based on facts, (2) those which are "borrowed" from other areas viewed as pertinent to the central issue of redundancy reduction, and (3) additional enabling assumptions which may not be strongly supported by experimental evidence but which allow for a fuller delineation of certain concepts.

Assumptions Concerning the Perceptual System

The first three assumptions pertain to the perceptual system and are based on (1) statements by Lashley (1951) and Lenneberg (1967) about continuous cerebral activity, (2) Bishop's (1961) concept of parallel afferent neural pathways, and (3) Barlow's (1969) views concerning the effect of redundancy reduction on the informational capacity of the neural pathways.

<u>Assumption 1</u>. The neuro-perceptual system consists of continuously active mechanisms hierarchically organized into levels. These levels are ordered with regard to control of various system functions.

<u>Assumption 1a</u>. The neural mechanisms consist of fixed sets of impulse-carrying nerve pathways which increase in number toward the cortex. In the visual system, for example, there are five thousand cortical cells for every one cell in the lateral geniculate body of the thalamus (Young, 1978, p. 124).

<u>Assumption 1b</u>. There are two types of parallel afferent pathways. One is a simple relay of activity

from lower to higher levels. The other consists of larger fiber systems that bypass "relay centers," thus reaching a higher level more rapidly.

Assumption 2. Above the level of peripheral transducer systems, information is carried by all-or-nothing impulses in the nerve fibers. Impulse rate varies as a function of stimulation, but fibers always exhibit some base firing rate.

Assumption 2a. The informational capacity of any neural pathway depends upon (1) the number of nerve fibers present, and (2) the rate of impulses being carried by the nerve fibers.

Assumption 2b. There is a physiological predisposition for cell preservation. Changes in the environment will result in an increase or decrease in cell activity, but the base firing rate will soon be restored (Grastyan, 1959). This return to base rate is described by the phrase, "economy of impulses."

Assumption 3. Memory (that is, the storing of information) is a bi-modal process consisting of short-term and long-term components. Long term memory is responsible for the retention of information which has been received in the more distant past while short term memory deals with the recording of information received in the immediate past (less than one minute).

Assumptions Concerning Perceptual Processing

Assumptions 4 and 5 refer to perceptual processing and are based on Young's (1978) concepts of search "programs" in the brain and perceptual reconstruction.

Assumption 4. Perception is a continuously active process of reconstruction involving the classification of information through the subprocesses of encoding, decoding, and recoding.

Assumption 4a. Encoding is a pre-cognitive, non-intellectual process which operates in response to "questions" previously posed by a cognitive perceptual function.

Assumption 4b. Decoding is a cognitive function of an immediately higher perceptual level.

Assumption 4c. Recoding is the result of inhibition of selected information in the input signal and is mediated at yet a higher perceptual level.

Assumption 4d. Classification of pattern information is not entirely simultaneous. Alerting signals reach a higher level search "program" more rapidly and thus coordinate the process of reconstruction.

Assumption 5. Perceptual reconstruction is initiated and coordinated by search programs. A search program is a higher level, cognitive perceptual function designed to discover "meaningful clues" about a stimulus and to preserve stimulus regularity. In a rhythmic auditory pattern, the search is concentrated on regular temporal relations occurring amidst a flux of change.

Assumption 5a. The search program has access to and can coordinate the memory systems. Sets of expectancies about auditory patterns are established based on both memories and are affected by the preservation of regularity for which the search program is designed.

A sixth assumption refers both to perceptual processing and to the perceptual system.

Assumption 6. Random neural activity (noise) produces random errors of perception. Noise can occur at any point or points in the neural and perceptual system. Noise increases ambiguity about signals and messages.

Features of the Model

The form of the proposed model is based upon those operations assumed to occur in the perceptual processing of rhythmic auditory patterns. The primary function of the model is to describe reduction of redundant information in auditory perception. Features of the model include (1) classification of information through a reconstructive process, (2) coordination of the various classificatory operations, and (3) the effect of prior knowledge on perceptual processing.

Reconstruction

Perception is viewed as an active process of reconstruction involving subprocesses of encoding, decoding, and recoding. These three subprocesses form the framework of the present model.

Search program. The search program is a relatively high level cognitive function which initiates and controls the reconstructive process. In the model proposed here, the search program directly or indirectly coordinates all classificatory and memory operations. Search programs are described as being optimally designed to discover regularity. Barlow (1969) suggests that neural connections are such that the discriminatory capability of the system is greatest for those stimuli which are "uniform" (that is, regular), thus allowing for greater sensitivity in the analysis of departures from uniformity (p. 212). In a rhythmic auditory pattern, uniformity is manifest in the degree of regularity of inter-event relations. Rhythmic patterns displaying high levels of temporal regularity will, therefore, be processed quickly because they conform closely to those signal structures for which the search program analysis is optimally designed.

Alerting Signal

A search program must receive stimulus information rapidly in order to coordinate the reconstructive process. Bishop's (1961) concept of two types of parallel nerve pathways accomodates this need. Larger, faster fiber systems probably transmit alerting signals which allow the higher level operations to continue maximum efficiency in the coordination of classification procedures.

Memory and Expectancy

The degree of redundancy in an auditory pattern is, in part, a product of what is already known; that is, receptive redundancy. Based on previously stored information, sets of expectancies about the temporal arrangement of pattern events are established by the search program. The expectancies pertain to the degree of regularity present in the pattern; that is, the search program "expects" regularity. For example, if initial pattern event, A is succeeded by event B then a set of regular expectancies, $\left\{E_C\right\}$, based on the relation AB will be developed for the temporal "location" of event C. The more precisely event C coincides with the expected temporal regularity, the greater the redundancy reduction possible. Departures from regularity in later pattern events can be analyzed more easily through an increase in the informational capacity of the system by redundancy reduction.

Redundancy Reduction

A central feature of the present model is redundancy reduction, a process which allows for an increase in the carrying capacity of fibers due to a reduction in the number of impulses needed to carry the information. At the same time, the message being transmitted is minimally reduced (Barlow, 1969, p. 224). Elaboration of the network at higher levels, coupled with a reduction in impulse rate suggests that information can be represented by fewer and fewer impulses moving through more and more fibers. Barlow (1969) states, "it is as if the number of letters in the alphabet was being increased, and the number of letters per word decreased."

In order to accomodate redundancy reduction, an operation described in automata theory as "channel redundancy," or parallel processing, has been incorporated in the model. Spira (1968) has shown that the fastest computations are achieved by networks using highly redundant coding. Instead of a single channel transmitting n bits of information successively, n channels are used to transmit the n bits simultaneously (Arbib, 1964, p. 78).

A modification of channel redundancy is used in the present model, which is given in simplified form in Figure 13. An inhibitor has been added which restricts the transmission of redundant features R_1 and R_2 from the encoder to the decoder, thus increasing the informational capacity of channels C_1, C_2, and C_3.

Components of the Model

The model is presented graphically in Figure 14. The stimulus is considered to be an auditory pattern consisting of physically describable events. The peripheral multistage transducer represents middle ear and cochlear functions by which time-varying pressure changes are converted to neural impulses "with intermediate processes of mechanical deformation and electrochemical events" (Dallos, 1978, p. 125).

The perceptual functions can be subdivided into two categories. The first category includes encoding components which are considered to be pre-cognitive, non-intellectual processes operating in response to direct or indirect control by a search mechanism. The encoder consists of a five-stage, parallel system which accepts information from the transducer. The differentiators respond to changes in the transduced input signal and commence the redundancy reduction process. The pitch differentiator measures frequency modulation, while the

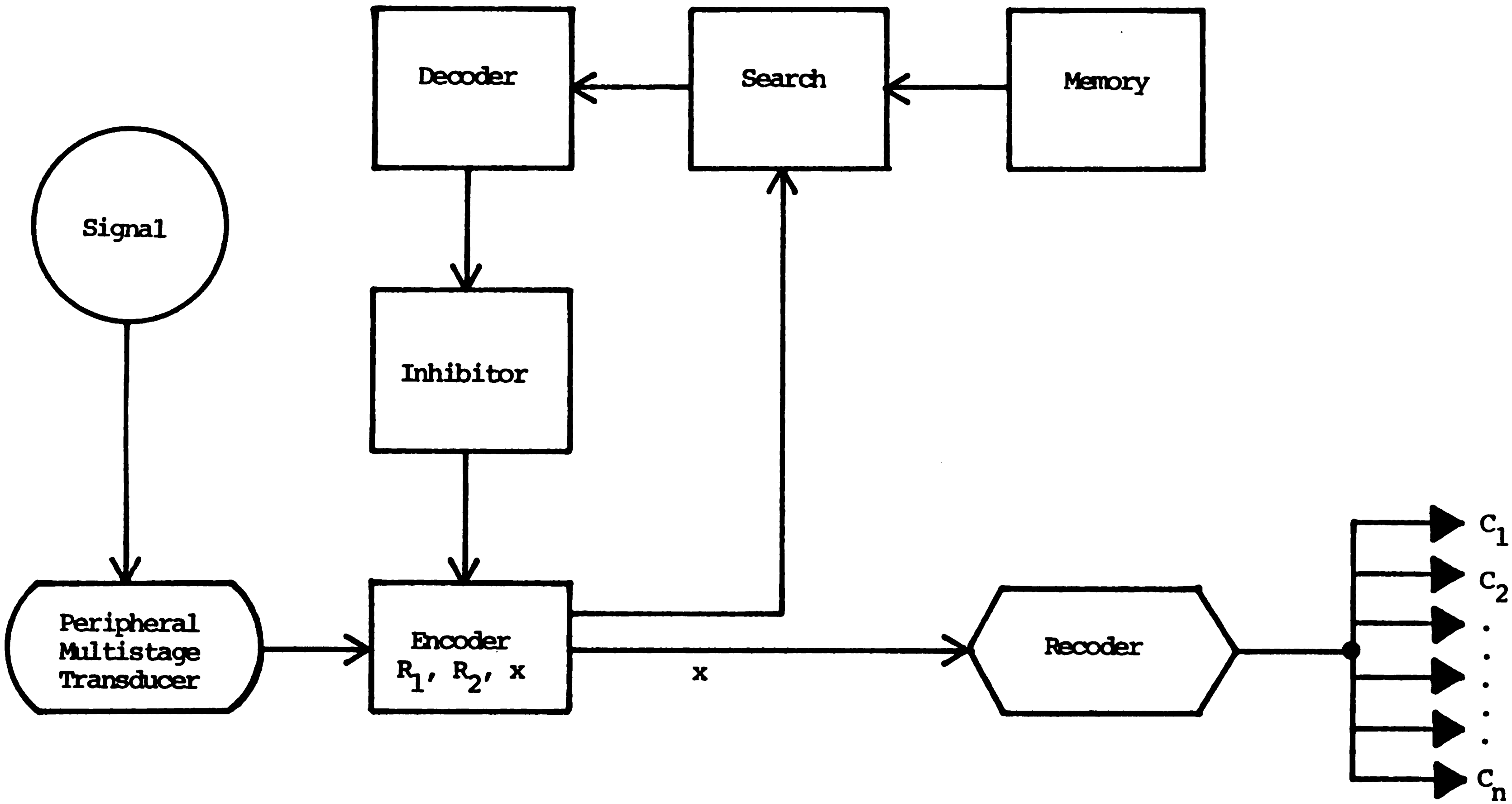


Figure 13. Overview of the perceptual model displaying the channel redundancy concept. The inhibitor restricts transmission of redundant features R_1 and R_2 from the encoder to the recoder, thus increasing the information capacity of channels C_1 through C_n.

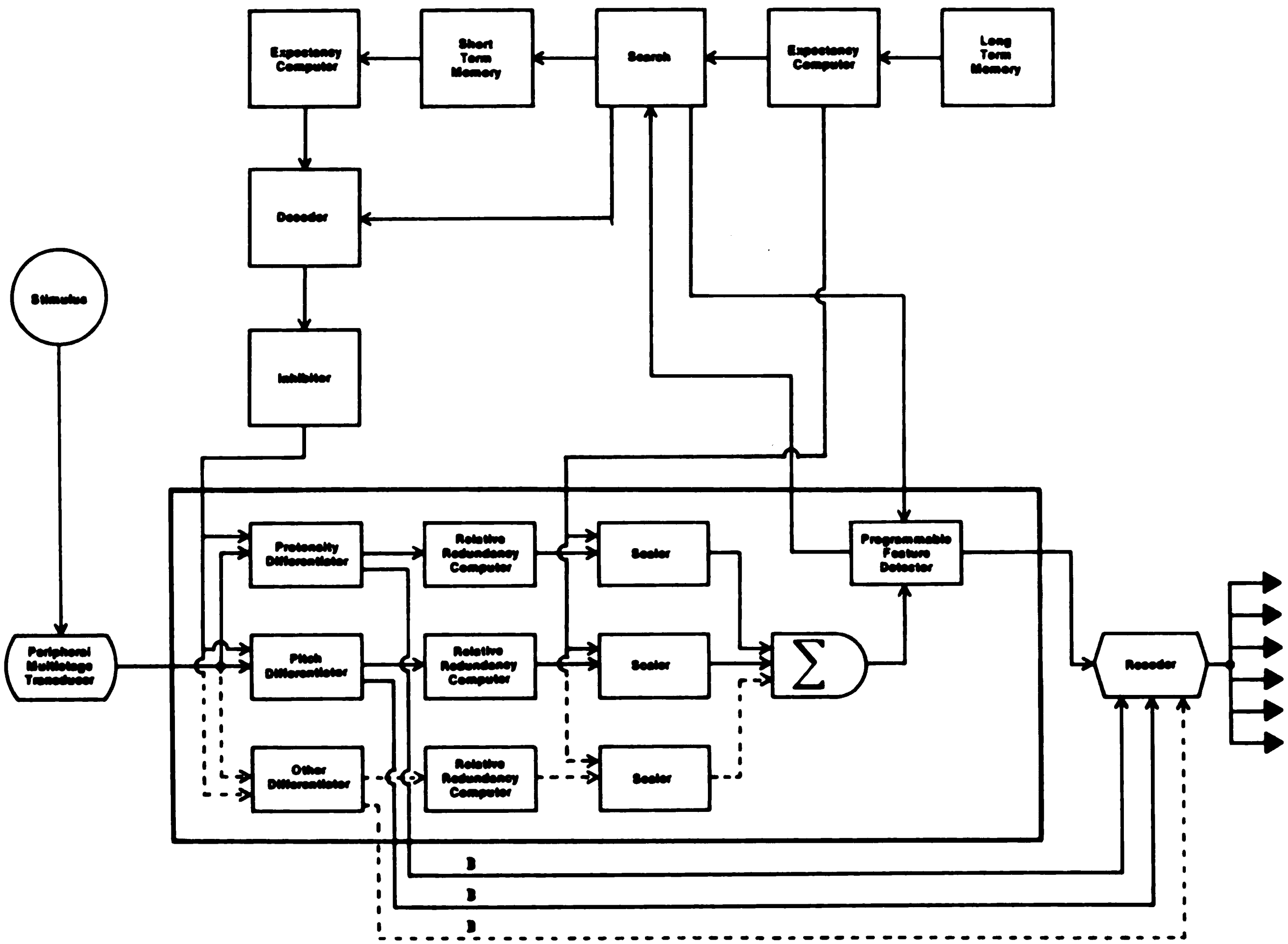


Figure 14. Graphic representation of the perceptual model.

protensity differentiator operates on the stimulus time domain; that is, durational change. Other types of differentiators respond to changes in timbre, intensity, and (perhaps) other features of the signal. The several differentiators act simultaneously.

A set of relative redundancy computers (one for each differentiator channel) extract information about the regularity of changes in the signal. The relative redundancy computers are considered to compute indices of relative redundancy (IRR) as described above.

The three scalers represent a selective attention mechanism and can be considered similar to a set of internal volume controls. The scalers adjust for the relative importance of the different inputs, thus focusing more or less attention on certain aspects of the incoming temporal features. The scaler component is capable of dealing with various characteristics of individual elements.

Like the scaler, the programmable feature detector is a selective attention device. Whereas the scalers operate on individual characteristics of events, the programmable feature detector deals only with summed (Σ) relative redundancy levels. The programmable feature detector is a modifiable system controlled by the search mechanism.

The search component represents a higher level (perhaps cognitive) function which has both direct and indirect control over the encoding process. It directly coordinates revisions of the programmable feature detector, and thus controls the input to the recoder. The search mechanism also indirectly affects initial signal differentiation in the encoder by coordinating decoding and, subsequently, inhibition.

The search operation is affected by the memory components. The long term memory component represents prior knowledge, and the short term memory component represents the immediate temporal relations recognized in the stimulus. The memory systems account for musical experience and training. Advanced musical experience results in (1) an increase in the redundancy reduction possible, and (2) greater precision in the expected temporal relations of pattern events. The effect of prior knowledge on redundancy reduction is represented in the model by the long term memory expectancy computer's control of the encoding scalers. The effect of memory on the immediate analysis of temporal relations in the rhythmic pattern is represented by the short term memory expectancy computer's input into the decoder mechanism.

The decoder is controlled by the search mechanism and consequently coordinates inhibitor activity. The inhibitor operates on the encoding differentiators by restricting the transmission of redundant temporal information directly to the recoder. Such redundancy reduction increases the informational capacity of a set of alternative (β) differentiator outputs which progress to the recoder. The temporally redundant information reaches the recoder only after summation and programmable feature detector revision. The five-channel output of the recoder represents an increase in the size of the neural network at some higher level.

CHAPTER IV

METHOD

Introduction

The purpose of this study was to investigate the effect of accent structure and relative timing in rhythmic auditory patterns on the discrimination of temporal order. Two rules concerning relative accent level and relative timing (Martin, 1972) were used as a structural framework for developing sound sequences. Listener responses to these temporal arrangements were observed in the form of percent-correct discrimination scores in an attempt to more clearly understand perceptual processing in relation to specific aspects of the auditory pattern's predetermined temporal structure.

Subjects

Subjects were unpaid undergraduate students enrolled in two introductory music courses offered to non-majors at Michigan State University. Because it was desired to differentiate students on the basis of musical experience, the students enrolled in the courses (N = 130) were given a test of musical ability and two questionnaires designed to determine prior training. Appendix A presents copies of the musical ability test and questionnaires. The ability test allowed for observation of subjects' aural and cognitive musical skills, and included rhythmic, intervallic, melodic, and harmonic discrimination tasks, as well as musical notation identification and error detection. The test, although not standardized, had been used in undergraduate courses for three years and was assumed to accurately estimate students' prior musical training. The questionnaires probed for information concerning (1) the nature of previous formal music instruction, (2) duration of involvement in formal instruction, (3) performing ensemble participation, and (4) musical style preferences.

Subjects were classified as high or low in musical ability on the basis of musical ability test scores. Students whose Z scores were greater than .81 above the mean were classified as "high" in ability (N = 26); those whose Z scores were less than -.81 below the mean were classified as "low" in musical ability (N = 26). Thus, a total of 52 subjects served in the study. Of these, 40 were female and 12 were male. Subject age data were not gathered, but most subjects were assumed to be between 18 and 21 years old. Subjects who (1) knew they had a hearing loss, (2) were suffering from head colds or ear infection, or (3) had served in the military were discharged from test procedures.

Stimulus Materials

Introduction

Sixteen rhythmic auditory patterns with different levels of temporal regularity were developed for the experiment. Patterns were categorized as regular or irregular according to their compliance with or violation of the relative accent level and relative timing rules.

Each of the experimental patterns was paired with a "dummy" rhythmic pattern. Dummy patterns were identical to the corresponding experimental patterns except for alteration of one event.

An ABX paradigm comparison format (A = experimental pattern; B = dummy pattern; X = either experimental or dummy pattern) was used for each experimental-dummy pattern pairing. Thus, each stimulus event consisted of three patterns ordered according to one of four possible combinations allowed by the comparison paradigm (ABB, ABA, BAB, BAA). To avoid experimental bias, all four combinations for each pattern pair were used.

Accent was marked either through variation in frequency (frequency accent mode), or through variation in event duration (duration accent mode). Development of test items is outlined in Figure 15. The frequency accent mode stimulus patterns were similar in temporal arrangement to those used by Sturges and Martin (1974).

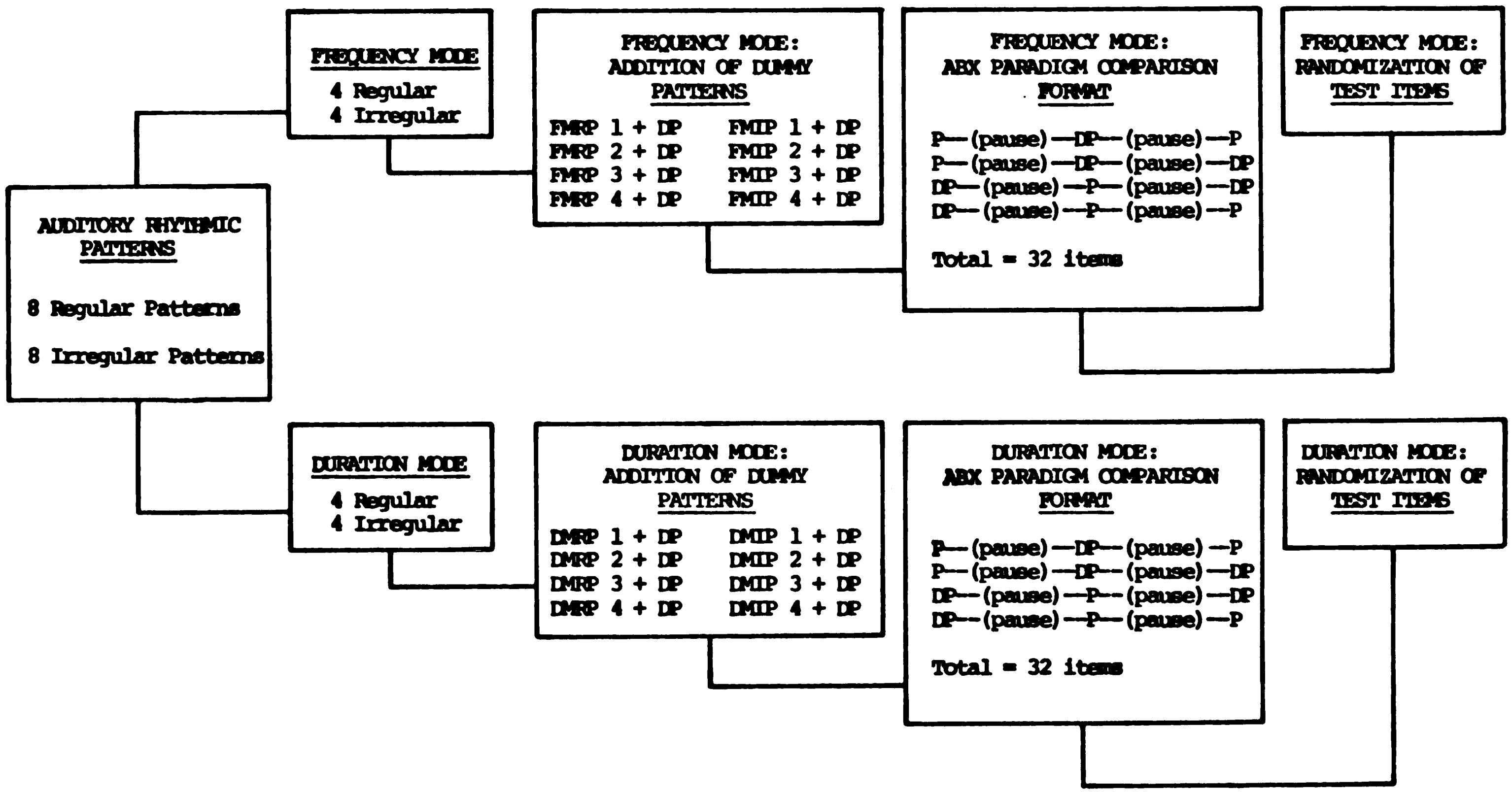


Figure 15. Development of frequency and duration accent mode test items. Eight pairs of experimental and dummy patterns (four regular, four irregular) were used in each mode. "FMRP" and "FMIP" denote regular and irregular patterns respectively in the frequency mode; "DMRP" and "DMIP" represent regular and irregular patterns in the duration mode. "DP" denotes dummy patterns.

<u>Generation Equipment</u>

Experimental and dummy rhythmic patterns were electronically produced with a modular stimulus programming system (Starkey Laboratories). This system allowed for control of both the frequency and duration of each element in a rhythmic pattern.

Figure 16 presents the apparatus used to produce frequency accent mode test stimuli. Figure 17 presents the same information for duration accent mode test stimuli. The signal-generating equipment displayed in the two diagrams are components of the modular stimulus programming system.

Sine wave generators were used to produce sinusoidal signals having a uniform magnitude across test frequency range. The same wave-form was used for both frequency and duration accent mode test stimuli. The sine wave signals were routed to calibrated step attenuators which controlled signal level. Attenuation for all test stimuli generation was set for a 20 dB loss. Signals were routed from the attenuators through programmable electronic gates (switches) which were used to modify signal duration and rise/fall time.

The electronic gates were controlled by a digital programmer which manipulated signal onset, offset, and duration by means of instructional commands stored in the memory section of the event programmer.

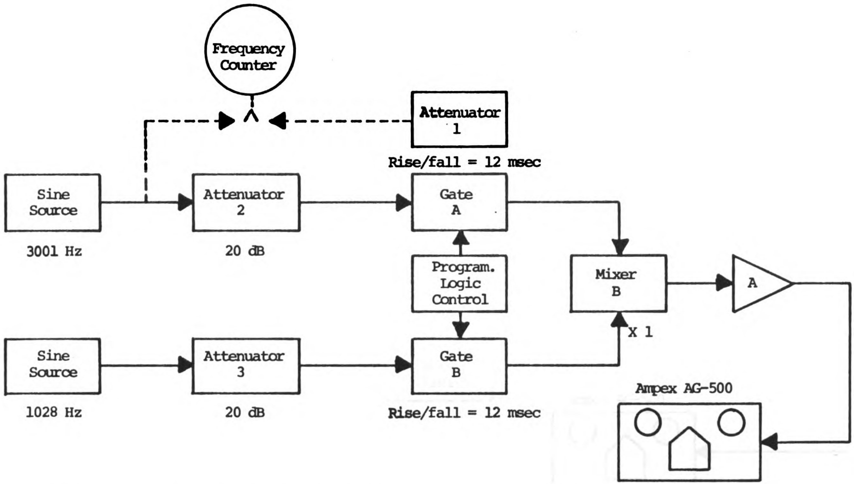


Figure 16. Apparatus used to generate frequency accent mode test stimuli.

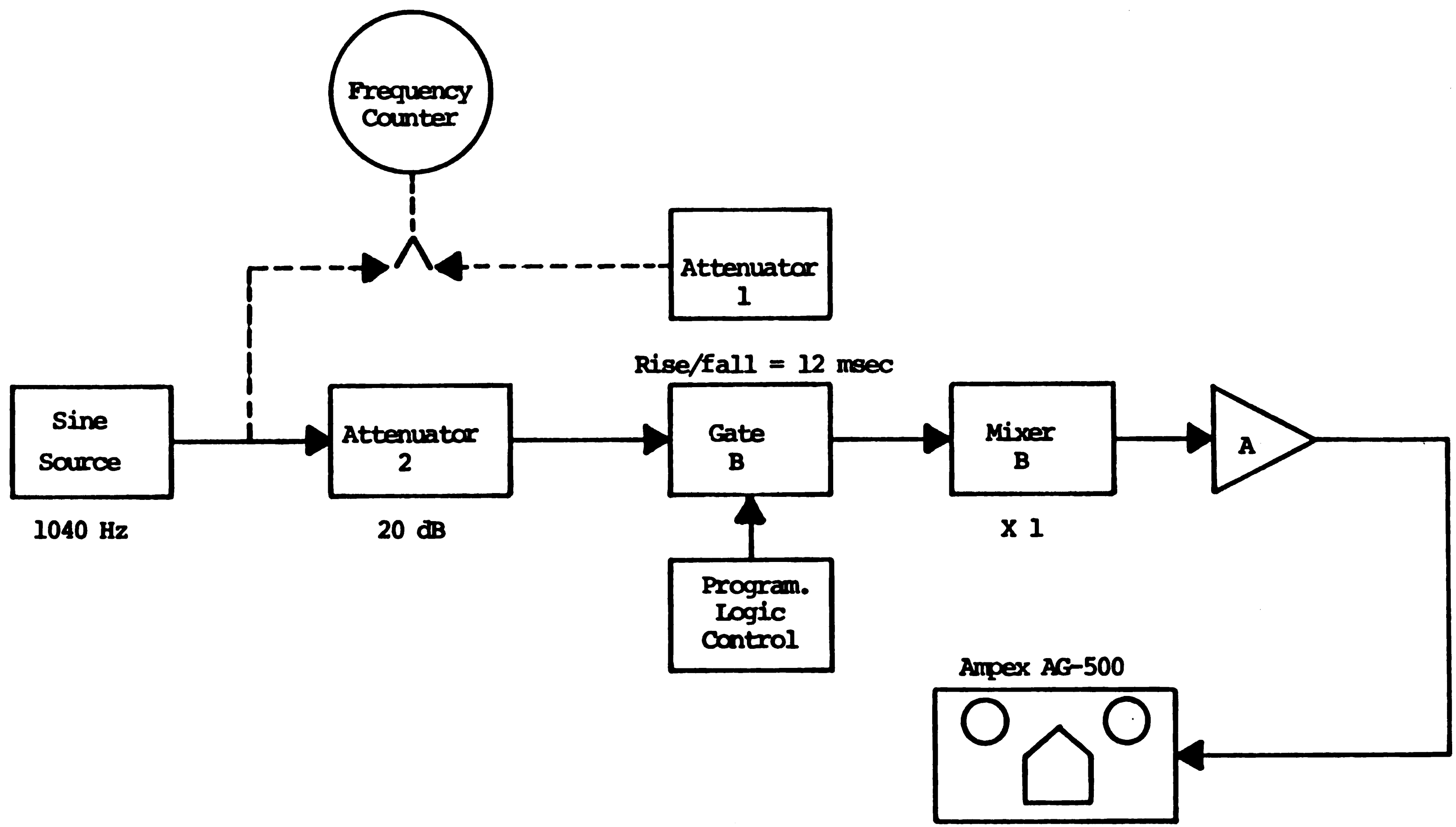


Figure 17. Apparatus used to generate duration accent mode test stimuli.

A variable duration clock controlled the duration assigned to each programmed event. A "response delay" component was used to stop the programmer between patterns.

Signals were routed from the electronic gates through a mixer and an amplifier to an output jack. All patterns were recorded on tape (3M-206) using a reel-to-reel recorder (Ampex AG-500) which conformed to the calibration standards of the National Association of Broadcasters (1965). Tape speed was set at 7.5 ips. A steady-state level calibration signal was generated by the modular stimulus programming system prior to taping. The tape recorder input level control was set to produce a 0 VU for the calibration signal.

Signal frequency was calibrated by means of a frequency counter (Heath Schlumberger, Model SM-4100). Signal durations were verified after generation and recording using a storage oscilloscope (Techtronics 564B). A storage oscilloscope was required in order to "freeze" the image of the time-varying signal.

Generation Procedures

Frequency Accent Mode

For four of the regular rhythmic patterns and four of the irregular rhythmic patterns, accent was produced through a binary frequency change. Two sine wave generators were used, one for each frequency. The higher of the two frequencies was set at 3001 Hz (± 1 Hz), the lower at 1028 Hz (± 1 Hz). The higher frequency was positioned at those temporal points designated for stronger accent placement (Royer and Garner, 1970).

These particular frequencies were selected in order to minimize the impact of confounding incidental effects. Specifically, they were chosen to avoid (1) instrumental effects arising from frequency nonlinearities in the earphones used to present signals (the test frequencies fall within the linear portion of the frequency response for the earphones); (2) perceptual effects resulting from minor departures from normal hearing (the test frequencies fall within the most sensitive region of the auditory range; Sivian and White, 1933); (3) perceptual effects resulting from differences between two signals in terms of loudness level (the test frequencies would be expected to produce similar loudness levels, and this similarity would be expected to be unchanged over a wide range of intensity; Fletcher and Munson, 1933); (4) perceptual effects arising from variations among listeners in the ability to discriminate differences in frequency (the difference between the test frequencies widely exceeds the difference limen for frequency; Shower and Biddulph, 1931; Henning, 1966); (5) perceptual effects resulting from the interactions between signal duration and the frequency difference limen (the difference between test frequencies exceeds the range within which duration influences discrimination; Doughty and Garner, 1948; Chih-an and Chistovich, 1960); (6) perceptual effects arising from interaction between loudness and the frequency resolving ability of the cochlea (the difference between test frequencies exceeds the critical bandwidth for each tone; Scharf, 1970); and (7) perceptual effects resulting from the use of a musically turned interval which might serve as a cue for some listeners but not for others (the test frequencies do not conform to a tuned interval).

The regular and irregular rhythmic patterns (and the corresponding dummy patterns) consisted of eight events. Rise/fall time for each event was measured at 12 msec. Signal on-time for each event was nominally set at 200 msec followed by a silent interval (off-time) of 100 msec. Oscilloscope measurement showed that actual signal on-time was about 210 msec and off-time about 90 msec. Total presentation time for each rhythmic pattern was approximately 2400 msec.

<u>Frequency mode regular patterns</u>. For the regular patterns in the frequency accent mode, stronger accent (that is, the higher frequency) was always placed at serial positions 1 and 5. These locations correspond to the two strongest relative accent levels described by the relative accent level rule. Stronger accent was also

located at lower relative accent levels, but a high degree of regularity was constantly maintained. This was also true for the corresponding dummy patterns. Such accent placement evenly subdivided the entire pattern into groupings of two and four events. An example of a regular rhythmic pattern and its corresponding dummy pattern in the frequency accent mode is presented in Figure 18.

From the example, it will be noted that the dummy pattern is identical to the experimental pattern with the exception of a frequency difference at serial position 7. The accentual arrangement for all other dummy patterns in the frequency accent mode also differed from the corresponding experimental pattern with respect to a frequency change of a single event.

<u>Frequency mode irregular patterns</u>. For the irregular rhythmic patterns in the frequency accent mode, stronger accent was always placed at serial positions 1 and 6 as well as at other locations. These accentual arrangements subdivided the pattern unevenly into groupings of two and three events. Unevenness of accent placement in all irregular patterns was insured by the absence of strong accent at serial position 5 which corresponds to the second strongest relative accent level described by the relative accent level rule. An example of an irregular rhythmic pattern and its

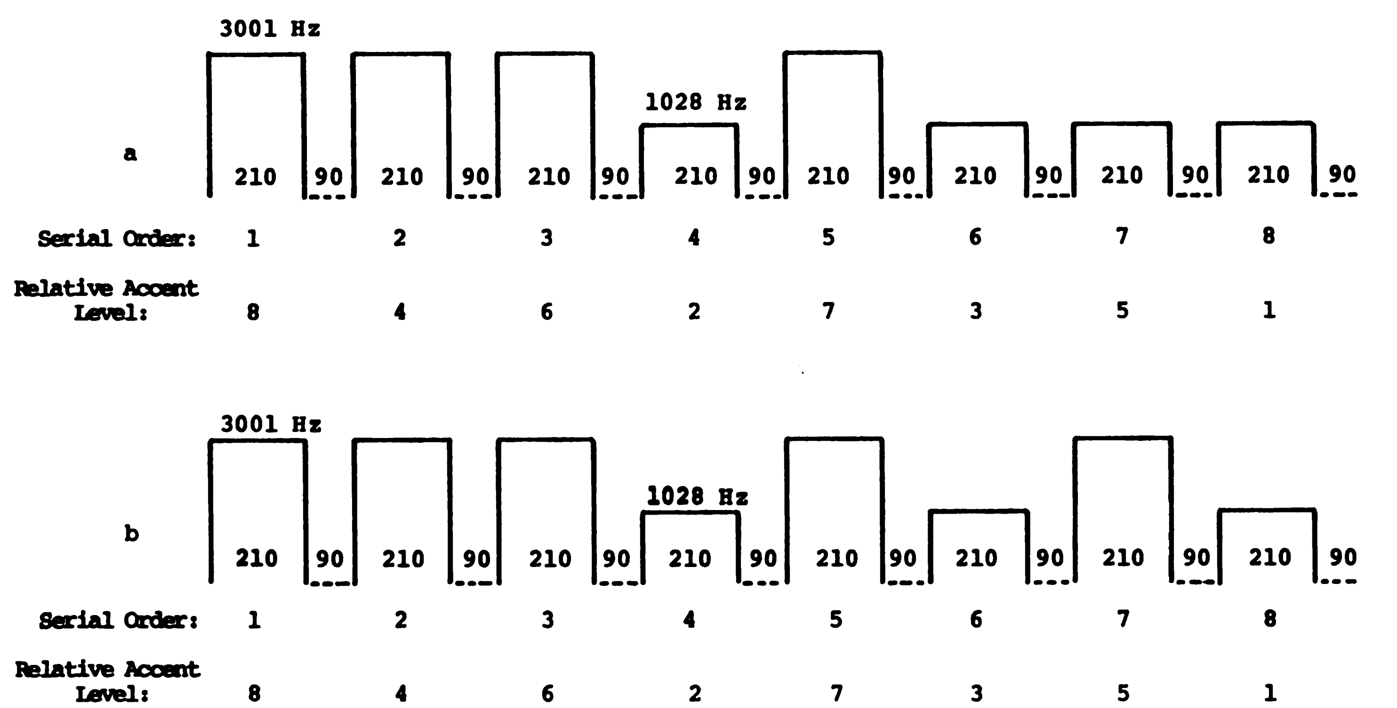


Figure 18. Example of a regular rhythmic pattern in the frequency accent mode (a) and corresponding dummy pattern (b). Variation in height of the columns indicates changes between the two test frequencies. Broken lines denote the silent portion of each event. Signal on-time was 210 msec, and signal off-time was 90 msec.

corresponding dummy pattern in the frequency accent mode are presented in Figure 19. All frequency accent mode experimental and dummy patterns are presented in Appendix B.

Duration Accent Mode

For the four regular and irregular duration accent mode patterns (and the corresponding dummy patterns), accent was produced through a bi-level change in duration among pattern events. The two durational values used were in a 2:1 ratio; that is, accented events were twice as long as unaccented events. These durational proportions are analogous to those usually associated with immediately successive beat subdivisions, such as quarter note (♩) and eighth note (♪), where the latter is half the durational value of the former (♪ + ♪ = ♩).

All duration accent mode patterns were designed according to an eight-beat arrangement of events. Unlike the frequency accent mode patterns, duration mode patterns ranged from 11 to 14 events in length. This was necessary because of the use of two different durations. A single frequency of 1040 Hz (± 1 Hz), was used as the sound portion of all pattern events.

Signal duration, onset, offset, and rise/fall time were controlled in the manner indicated previously. The frequency signal on-time for both long and short durational

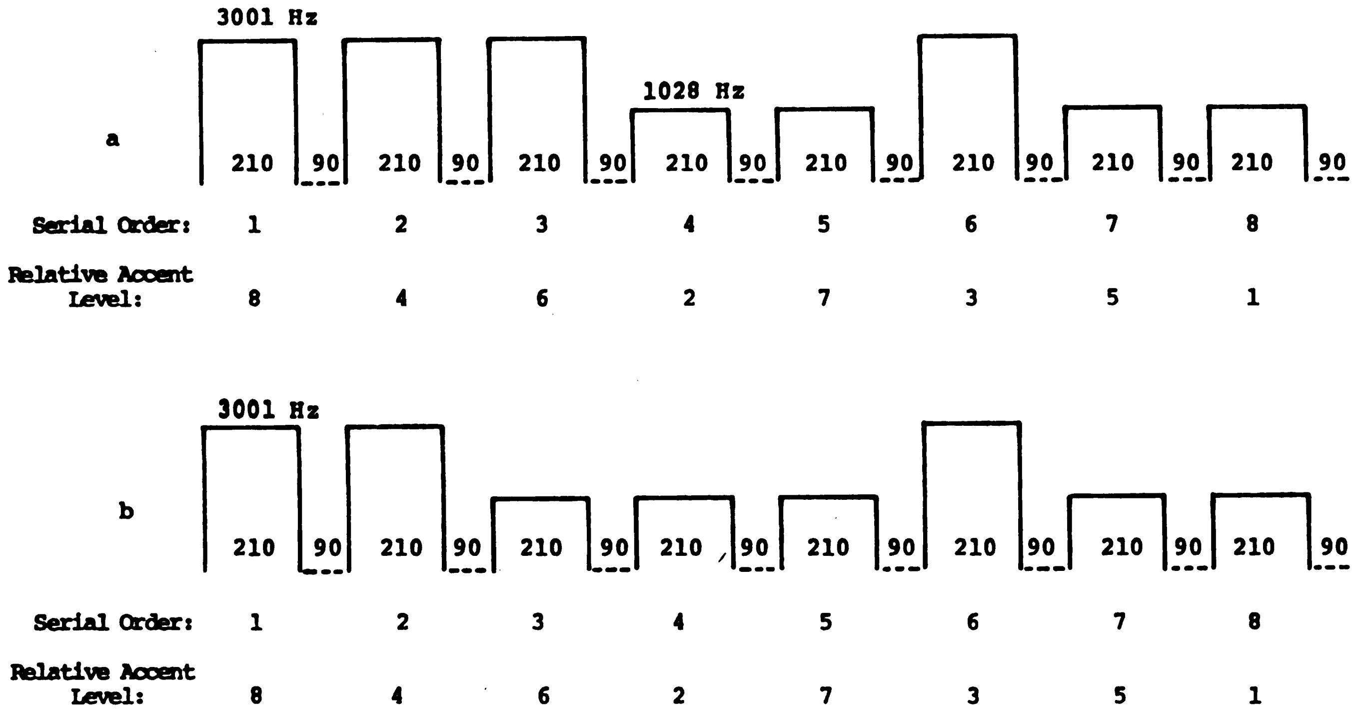


Figure 19. Example of an irregular rhythmic pattern in the frequency accent mode (a) and corresponding dummy pattern (b). Variation in height of the columns indicates changes between the two test frequencies. Broken lines denote the silent portion of each event. Signal on-time was 210 msec, and signal off-time was 90 msec.

events was held constant at a nominal value of 100 msec. Oscilloscopic measurement showed that actual signal on-time was 80 msec with a rise/fall time of 12 msec. Change in durational values among pattern events was produced by either lengthening or shortening the silent interval (off-time) which followed each signal on-time. Thus, the longer of the two types of event consisted of a signal on-time of about 80 msec followed by a long silent interval (major off-time) of about 160 msec. For the shorter event, frequency signal on-time (80 msec) was followed by a short (minor off-time) silent interval measured at about 40 msec. Examples of a short and long durational event are presented in Figure 20. Note that the shorter event is about half the durational value of the longer event.

The increased number of pattern events necessitated the initial use of a four-node level hierarchical tree in order to ascertain relative accent level positions and to categorize the rhythmic patterns. In terms of the hierarchical tree, longer events were produced by including null right branches at the lowest node level (I). Rhythmic pattern durational changes among experimental pattern events can also be shown in relation to an eight-beat structure by using a three-node level tree as illustrated in Figure 21.

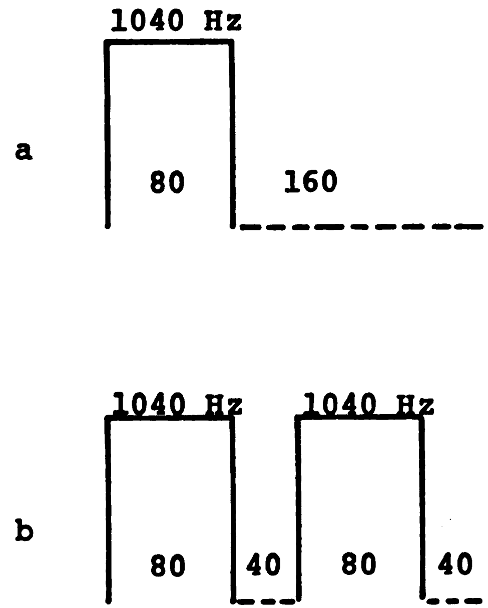


Figure 20. Examples of long (a) and short (b) events used in the duration accent mode. Columns indicate signal on-time (80 msec); broken lines denote signal off-time (160 msec or 40 msec). Test frequency for all events was 1040 Hz.

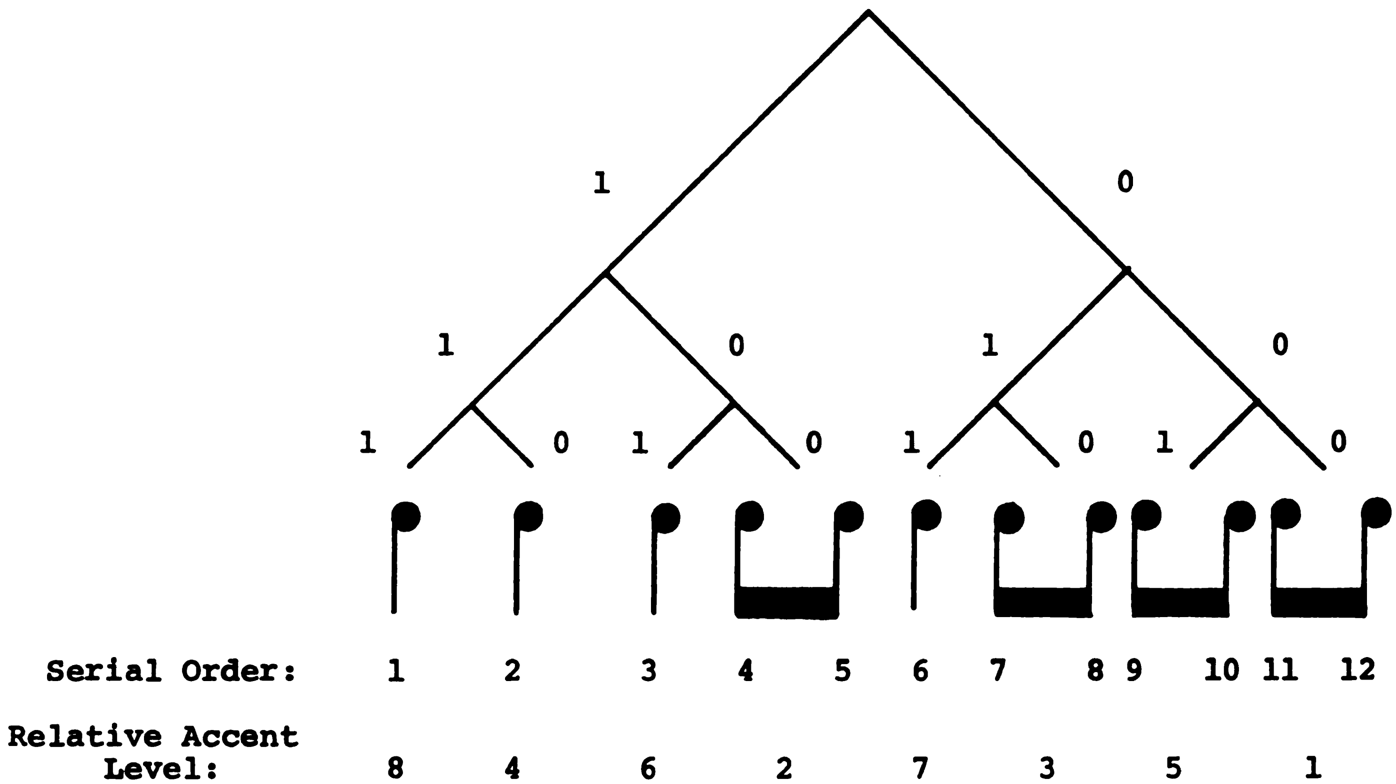


Figure 21. Representation of rhythmic pattern durational changes among pattern events (duration accent mode) in relation to relative accent levels described by a three-node level hierarchical tree.

<u>Duration mode regular patterns</u>. For regular patterns in the duration accent mode, longer durational values (accent) were located at relative accent level positions 8 and 7 and at other regular locations as described by the three-node level hierarchical tree (Figure 21). As with the regular patterns in the frequency accent mode, such accentual distribution subdivided the eight beats in to groups of two's and four's. An example of a regular pattern in the duration accent mode and its corresponding dummy pattern is presented in Figure 22. The dummy pattern differs from the experimental pattern only in terms of the durational arrangement of the second beat. The accentual arrangement for all other dummy patterns in the duration mode also differed from the corresponding experimental pattern with respect to durational alteration of one beat.

<u>Duration mode irregular patterns</u>. For the irregular patterns in the duration accent mode, longer durational values were always placed at relative accent levels 8 and 3 of the three-node level tree resulting in an uneven beat grouping (two's and three's). Longer events were also used at other relative accent level locations, but a low degree of regularity was maintained. An example of an irregular pattern and corresponding dummy pattern are

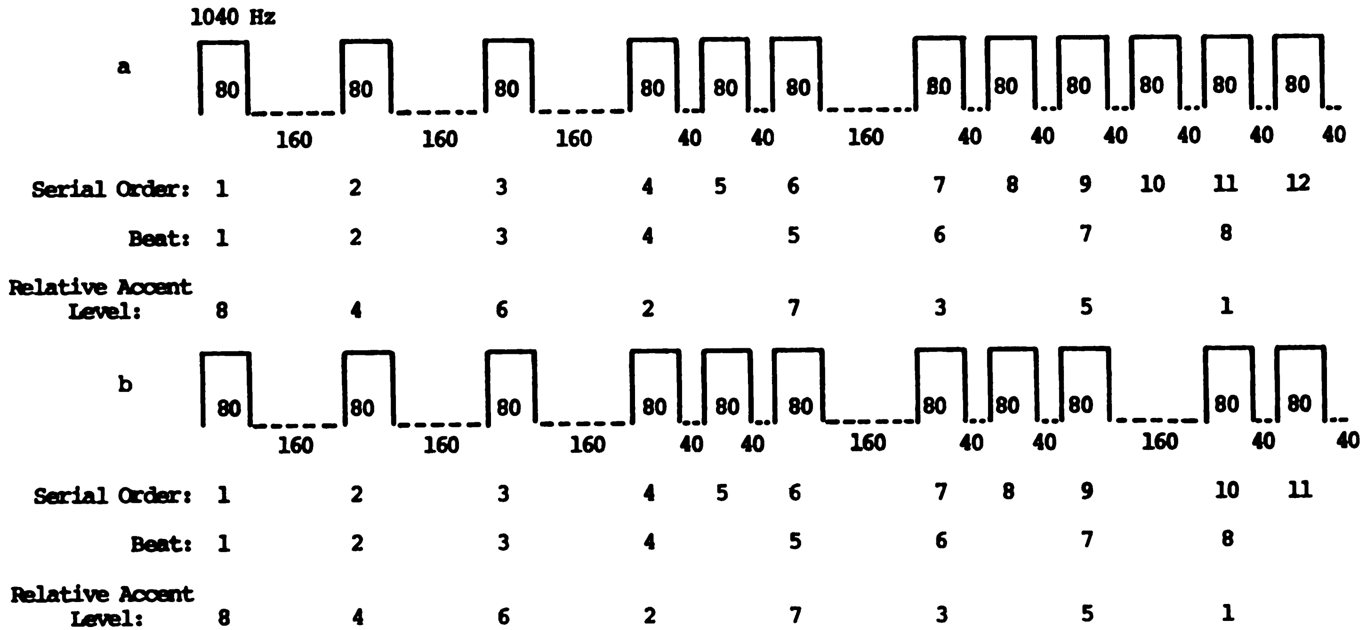


Figure 22. Example of a regular rhythmic pattern (a) and corresponding dummy pattern (b) in the duration accent mode. Columns represent signal on-time for each event (80 msec). Changes in durational values of events was produced through variation of signal off-times (160 msec or 40 msec). Broken lines denote the silent portion of each event. Test frequency for all events was 1040 Hz. The relative accent levels used are described by a three-node level hierarchical tree.

presented in Figure 23. All duration accent mode experimental and dummy patterns are included in Appendix C.

Recording Procedures

Submaster Recording of Accent Mode Test Stimuli

Submaster recordings were prepared separately for each accent mode. Each pair of experimental and dummy patterns were generated and recorded in the four combinations illustrated in Figure 24 so as to accommodate the ABX paradigm comparison format. A pause of approximately 500 msec was inserted between each of the three patterns in each stimulus event. The order of the 32 stimulus events for each accent mode (8 patterns x 4 combinations = 32 stimulus events) was randomized with the following constraints:

1. Regular rhythmic pattern stimulus events were always preceded and followed by irregular pattern stimulus events and vice versa.

2. The four combinations for each experimental-dummy pattern pairing were counterbalanced within each of the two blocks of 32 stimulus events.

Appendix D presents the order for the frequency and duration accent mode stimulus events.

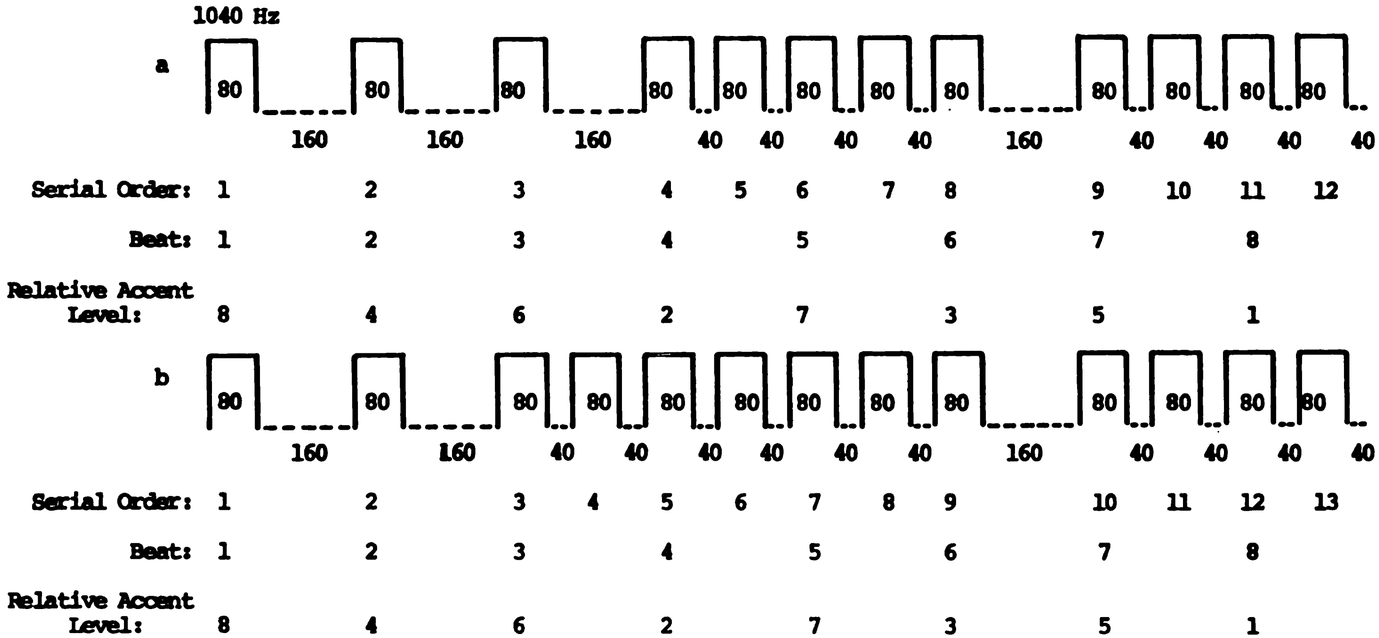


Figure 23. Example of an irregular rhythmic pattern (a) and corresponding dummy pattern (b) in the duration accent mode. Columns represent signal on-time for each event (80 msec). Changes in durational values of events was produced through variation of signal off-times (160 msec or 40 msec). Broken lines denote the silent portion of each event. Test frequency for all events was 1040 Hz. The relative accent levels used are described by a three-node level hierarchical tree.

Experimental Pattern	(500 msec)	Dummy Pattern	(500 msec)	Experimental Pattern
Experimental Pattern	(500 msec)	Dummy Pattern	(500 msec)	Dummy Pattern
Dummy Pattern	(500 msec)	Experimental Pattern	(500 msec)	Dummy Pattern
Dummy Pattern	(500 msec)	Experimental Pattern	(500 msec)	Experimental Pattern

Figure 24. Four combinations of experimental-dummy pattern pairings used to accommodate the ABX paradigm comparison format. Each of the eight pairs of patterns in both accent modes were generated and recorded in the four orders. A pause of approximately 500 msec separated the three patterns in each combination.

Master Recordings of Stimulus Events

Master tapes were produced separately for frequency and duration accent mode stimulus events by splicing taped instructions, practice items, stimulus labels ("Number 1," "Number 2," etc.), and two-second response delays into the submaster recordings for each stimulus event.

Final Run Tapes

Test run tapes were generated by re-recording each of the two master tapes using an Otari (MX-5050B) reel-to-reel recorder. Thus, potentially distracting transient signals produced by the tape splicing operation could be eliminated. It is noted that these clicks did not occur in close proximity to the test stimuli.

Apparatus

Stimuli were reproduced from run tapes on a reel-to-reel recorder (Akai 1722II), the output level of which was adjusted to produce a level of 0 VU for the level calibration signal. The output of the tape recorder was connected to a multiple headphone driver (Avid), which in turn drove eight sets of eight-ohm earphones (Avid H-88). The earphones were wired to present stimuli diotically.

The Avid multiple headphone driver was equipped with eight separate level controls, one for each earphone set.

It was desired to adjust each of these controls to the same relative position. To accomplish this, the electrical resistance of a mid-scale setting of one level control was measured with an ohmeter. The remaining controls were adjusted to produce the same resistance, and the dial positions were marked. Similarly, the earphones used in the study were equipped with individual level controls. Each of these was adjusted to what was judged as a comfortable loudness level by the experimenter (about three-fourths of full-scale). The resulting dial positions were marked. Subjects were instructed not to adjust earphone settings during the experiment.

It is normally desirable to specify signal presentation level through objective measurement of the sound pressure level (SPL) generated by an earphone. Such measurement employs a standard acoustic coupler, the volume of which simulates the volume observed between the earphone diaphragm and the tympanic membrane of an "average" listener. The coupler is attached to a calibrated microphone-sound level meter system and SPL is measured in decibels (re: 20 μ Pa). This approach was not possible with the earphones available for the experiment because the cushion of these earphones was too large for the coupler that was available for calibration. For this reason, it was necessary to indirectly measure signal presentation level through the use of a loudness balancing procedure and a standard laboratory earphone, the cushion of which permitted coupler calibration. These measurements were performed after experimental data were gathered, and are detailed in Appendix E. The standard earphone coupler SPL measured in this manner was 60 dB.

Assuming that experimental subjects had normal auditory sensitivity, the indirectly measured presentation level would be easily audible and comfortable. Again, assuming normal sensitivity, a SPL of 60 dB would be expected to be approximately 50 dB above threshold. This is an estimate because the auditory thresholds of listeners were not measured. Nonetheless, it is reasoned that experimental signals were presented at levels great enough to minimize effects due to variations in the absolute sensitivity of listeners.

An additional, informal, auditory comparison between standard and experimental earphones suggested that the experimental earphones produced signals of comparable loudness in the frequency range, 300-4000 Hz.

Test Environment

Testing was carried out in an academic seminar room (10' x 12') with no exterior walls. Acoustic tile covered the ceiling and part of the wall space. The floor was tiled. The room was not rigorously sound-treated but was moderately quiet. Subjects were seated in desk chairs which encircled the test apparatus. The seating arrangement was such that subjects faced away from the center of the circle, thus minimizing distraction by equipment and other subjects. Subjects were assigned to the same set of earphones in both trials. Supervision was maintained through all test proceedings by the experimenter.

Experimental Procedures

Experimental procedures are summarized in Figure 25. Subjects were assigned to experimental groups (Group 1, Group 2) on the basis of their scores on the musical ability test. Each of the two groups was further divided into four subgroups. All members of a subgroup were tested at one time.

Subjects were tested in each of two trials (Trial 1, Trial 2) separated by a four-week interval. During each trial, subjects were presented with all frequency and duration accent mode test items.

Immediately preceding each trial, subjects were asked about history of hearing problems. The following taped instructions were then presented:

> For each question in this test, you will hear a series of three rhythmic patterns. There will be a short interval between each of the three patterns.

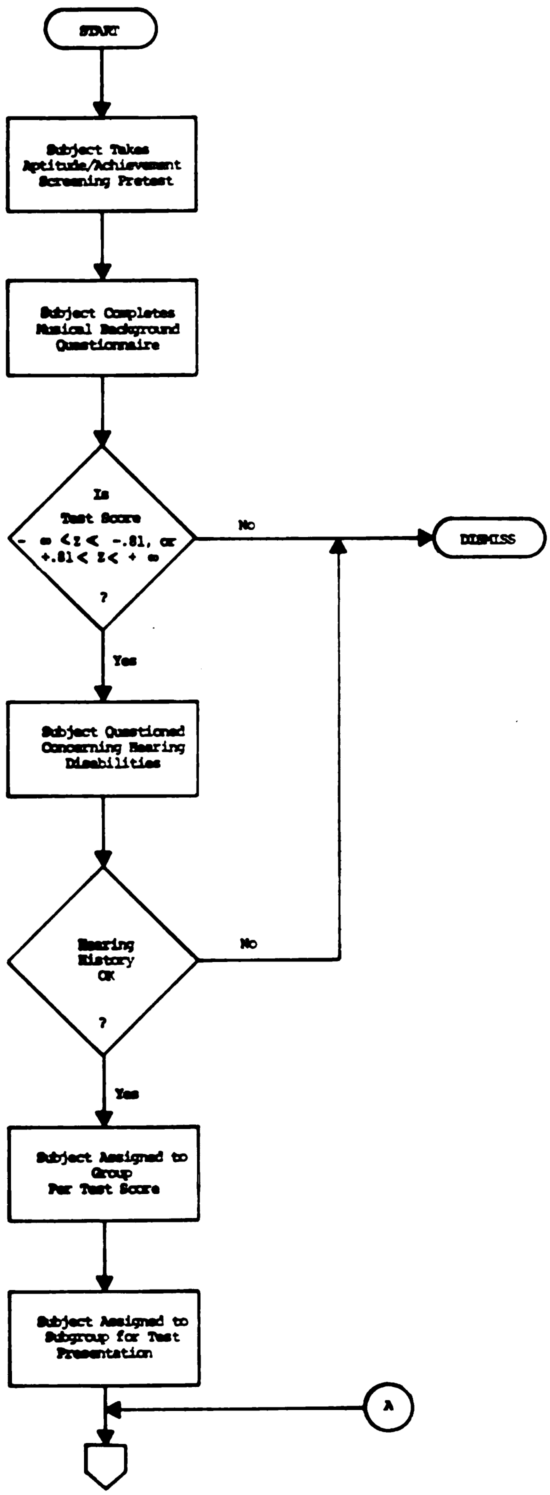


Figure 25. Procedural flowchart.

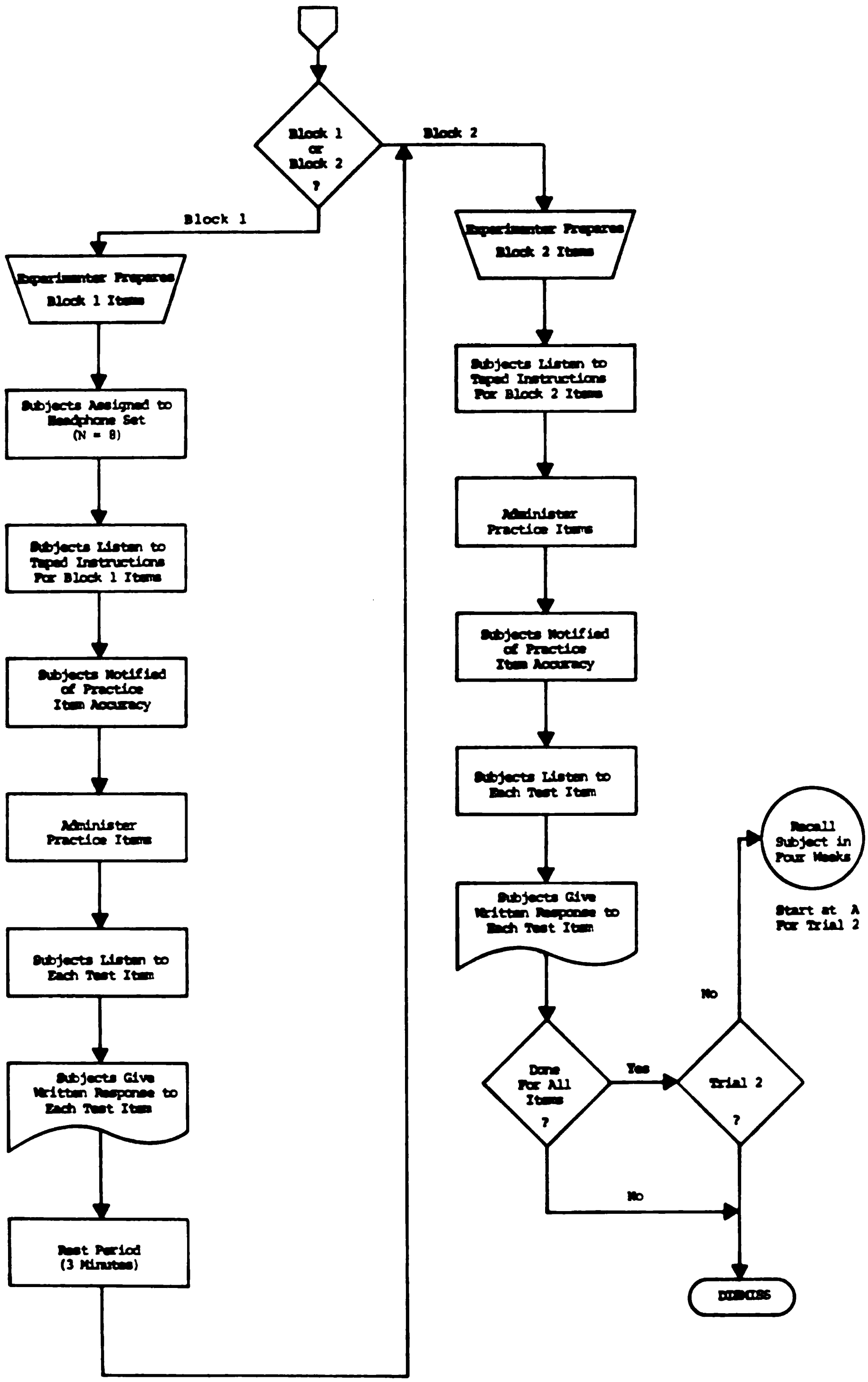


Figure 25 continued.

> The first and second patterns of each series will always be different. The third pattern of each series will be the same as either Number 1 or Number 2.
>
> After listening to all three patterns, decide whether the third pattern is the same as Number 1 or Number 2. If you think that the third pattern is the same as Number 1, then circle the "1" on your response sheet for that question. If you think that the third pattern is the same as Number 2, then circle the "2" on your response sheet for that question. If you are not sure, then make a guess.

Subjects then listened and responded to three practice items consisting of rhythmic patterns similar to those used in the test items. After each practice item, subjects were informed as to whether they had responded correctly or incorrectly. After completion of the practice items, subjects were reinstructed and earphone level control settings were checked visually. A one-minute pause on the tape separated preparatory material from the block of test items. Each item was preceded by a recorded verbal "label" which specified test item number.

Subjects were required to respond to each test item within two seconds by circling either a number "1" or "2" on a response sheet (a sample response sheet is included in Appendix F). This procedure was repeated until the block of 32 items was completed. Subjects were then given a rest period of approximately three minutes, after which the second block of test items was presented.

Procedure for the second-block presentation was identical to the first. Approximately 28 minutes were required to complete each trial.

Presentation Orders

Order of presentation is presented in Figure 26. In order to counterbalance the effects of presentation order, two of the four subgroups in each of the two experimental groups were presented with the 32 frequency accent mode test items first followed by the duration accent mode test items in Trial 1. The other two subgroups in each group heard the duration accent mode test items first followed by the frequency accent mode items in the first trial. Order of presentation of the two accent modes was reversed for all subjects in Trial 2. All other experimental procedures were identical for both trials.

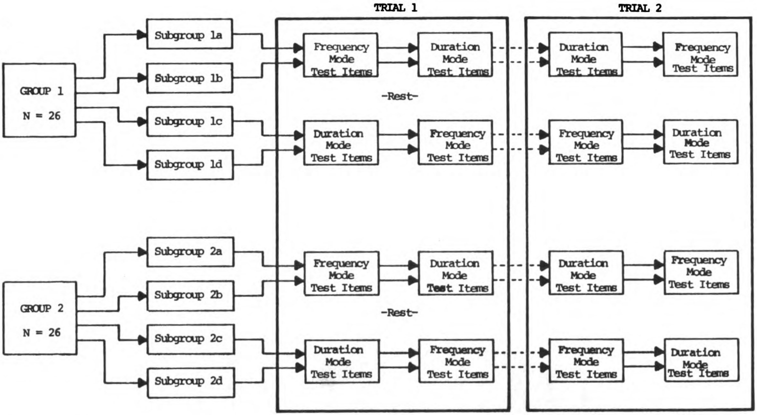


Figure 26. Representation of presentation orders in two experimental trials. Selection of subjects for subgroups was random. Rest periods lasted about three minutes. The two trials were separated by a four-week interval.

CHAPTER V

RESULTS

Introduction

This study examined the effect of relative accent level and relative timing arrangements on rhythmic auditory pattern discrimination. Fifty-two subjects were evenly divided into two groups on the basis of performance on a test of musical training and experience. Subjects whose pre-test standardized scores exceeded +.81 were assigned to the high musical experience group (Group 1), while subjects whose pre-test standardized scores were less than -.81 were assigned to the low musical experience group (Group 2).

Subjects were tested twice (Trial 1 and Trial 2) under each of two conditions of accent mode (frequency and duration) and each of two conditions of rhythmic auditory pattern type (regular and irregular). Within each trial, ABX paradigm discrimination judgments were obtained in two counterbalanced blocks which differed in terms of accent mode. Each block consisted of four replications of eight different pairings of experimental and dummy stimuli.

The dependent variable was percent-correct pattern discrimination averaged across replications. The resulting data formed a four-dimensional matrix consisting of groups (trained vs. untrained), pattern types (regular vs. irregular), accent modes (frequency vs. duration), and trials (first vs. second). The factors of pattern type, accent mode, and trial were repeated observations nested within the category of groups.

Experimental Questions

The data were examined to answer the following experimental questions:

1. With what consistency do normal hearing persons with and without musical training discriminate rhythmic auditory patterns which differ in regularity (that is, regular vs. irregular)?

2. Does pattern regularity significantly influence discrimination of rhythmic auditory patterns?

3. Does musical training significantly influence discrimination of rhythmic auditory patterns?

4. Does accent mode significantly influence discrimination of rhythmic auditory patterns?

5. Do the factors of group, pattern type, and accent mode interact to significantly influence the discrimination of rhythmic auditory patterns?

Analysis Procedures

Means, standard deviations, and ranges of discrimination scores were computed for all combinations of independent variables. Inter-trial consistency was assessed by computing Pearson product-moment correlation coefficients (Bruning and Kintz, 1977, pp. 171-174) and coefficients of determination. These measures were computed separately for each group and for each cell of the pattern type-by-accent mode submatrix (N = 26).

Correlation coefficients were also computed for accent mode and pattern type collapsed across both groups (N = 52). Within each accent mode, correlation coefficients for pattern type (regular, irregular) were transformed to Fisher Z scores (Hays, 1973, pp. 662-663), summed and divided by two to obtain a mean Z score. The mean Z score was then transformed to a correlation coefficient resulting in an "average" coefficient for each accent mode. Similarly, an "average" correlation coefficient computed separately for regular and irregular pattern type, collapsed across groups, using the same Fisher Z score transformation procedure.

The significance of correlation coefficients was determined through comparison of the obtained coefficient values with the t- and Z- distributions. A test for significant differences between independent correlations

(Bruning and Kintz, 1977, pp. 214-215) was used to compare the coefficients of Groups 1 and 2.

Pearson product-moment correlation coefficients and coefficients of determination were also computed for subjects according to presentation order. A test for significant differences between independent correlations was used to compare the coefficients of the two presentation orders (Presentation Order 1, Presentation Order 2). A significance criterion of $p\alpha < .20$ was used in all correlational analyses.

Intra-trial reliability was assessed by computing a split-half reliability measure (Bruning and Kintz, 1977, pp. 209-210) for discrimination scores as a function of groups collapsed across accent mode and pattern type in Trial 1 and Trial 2. A Kuder-Richardson Formula No. 20 (KR20) reliability coefficient (Kuder and Richardson, 1937) was also computed in order to assess the homogeneity of test items in terms of discrimination scores. The KR20 reliability coefficients were computed as a function of accent mode collapsed across groups in Trial 1 and Trial 2.

Answers to research questions were sought through the use of a three-way, mixed effects analysis of variance (ANOVA) with repeated measures on the factors of pattern type (regular vs. irregular) and accent mode (frequency vs. duration). The remaining factor--groups--was a nested (non-repeated) factor. This analysis was repeated separately for each of the two experimental trials. The ANOVA permitted evaluation of the main effects of (1) pattern type change, (2) accent mode change, and (3) group differences. The analysis also allowed for evaluation of group-by-accent mode, group-by-pattern type, and accent mode-by-pattern type two-way interactions, as well as a group-by-accent mode-by-pattern type three-way interaction. The criterion for statistical significance for F ratios was $p\alpha < .05$.

In addition to the usual ANOVA summary data, two other computations were completed. The exact probabilities of Type I error were estimated for each F ratio (Veldman, 1967, pp. 129-131). A strength of association statistic (eta^2) was computed for significant F ratios (Linton and Gallo, 1975, pp. 335-337). This statistic estimates the proportion of sample variance in the dependent variable (percent-correct discrimination) which can be "explained" by the independent variable.

Experimental Outcomes

Description

Figure 27 shows the mean percent-correct pattern discrimination scores as a function of regular and irregular pattern types in both accent modes for Groups 1 and 2 in both experimental trials. Table 2 summarizes the

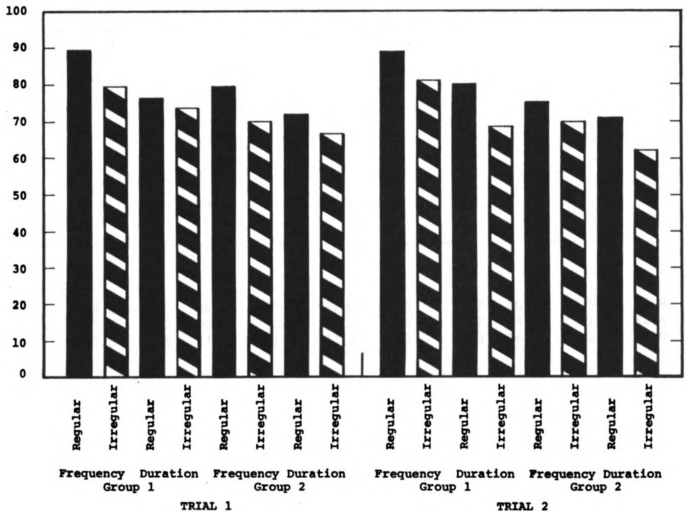


Figure 27. Mean percent-correct pattern discrimination scores for regular and irregular pattern types in both the frequency and duration accent modes for Groups 1 and 2 in both experimental trials.

TABLE 2. Percent-correct discrimination scores for Trial 1 and Trial 2 (separately and in combination) and each of two groups (separately and in combination). Subjects in Group 1 were 26 non-music majors with high levels of musical training. Subjects in Group 2 were 26 non-music majors with little or no musical training. Standard deviations were computed as sample statistics.

	Frequency Accent Mode						Duration Accent Mode					
	Regular Pattern			Irregular Pattern			Regular Pattern			Irregular Pattern		
	Trial 1	Trial 2	Both	Trial 1	Trial 2	Both	Trial 1	Trial 2	Both	Trial 1	Trial 2	Both
Group 1												
$\bar{X}$	89.2	88.3	88.7	79.6	81.0	80.3	76.7	80.3	78.5	73.8	68.1	70.0
SD	11.6	10.2	10.9	12.0	11.2	11.6	15.7	14.2	15.1	12.4	14.5	13.8
Range	37.5	37.5	37.5	50.0	43.7	50.0	62.5	56.2	56.2	50.0	56.3	62.5
Group 2												
$\bar{X}$	79.4	74.6	77.0	70.0	70.0	70.0	73.1	70.5	71.8	67.3	63.7	65.5
SD	15.2	15.5	15.5	14.6	14.7	14.7	15.8	16.9	16.4	14.0	14.7	14.5
Range	62.5	50.0	62.5	50.0	56.3	62.5	56.2	68.7	68.7	50.0	56.2	56.2
Both												
$\bar{X}$	84.3	81.4	82.8	74.8	75.5	75.2	74.9	75.4	75.2	70.6	65.9	68.2
SD	14.4	14.8	14.7	14.2	14.2	14.2	15.9	16.4	16.1	13.6	14.8	14.4
Range	62.5	50.0	62.5	50.0	62.5	62.5	62.5	68.7	68.7	62.5	62.5	68.7

mean percent-correct pattern discriminations, standard deviations, and ranges for both groups (separately and in combination) in Trials 1 and 2 (separately and in combination). Individual subject scores are presented in Appendix G.

Several trends are evident in the mean discrimination score data. First, mean scores were generally high. In Trial 1, the highest mean score was 89.2% (Group 1, regular pattern, frequency accent mode) and the lowest mean score was 67.3% (Group 2, irregular pattern type, duration accent mode). Trial 2 produced high and low means which conformed to the same group-pattern type-accent mode categories, but the values differed slightly: the high score was 88.3% and the low score was 63.7%. The grand mean score for the entire experiment was 75.3%, collapsed across groups, pattern types, accent modes, and trials.

Second the mean scores for Group 1, the members of which shared greater musical experience, always exceeded the mean score for Group 2. This was the case in each trial for all inter-group contrasts across experimental conditions. The magnitude of the group difference in mean scores ranged from 11.0% (Trial 2, irregular pattern type, frequency accent mode) to 3.6% (Trial 1, regular pattern type, duration accent mode).

Third, where other experimental factors were consistent, the frequency accent mode always yielded minimally higher mean discrimination scores than the duration accent mode. The magnitude of the accent mode difference varied from 12.9% (Trial 2, Group 1, irregular pattern type) to 2.7% (Trial 1, Group 2, irregular pattern type).

Fourth, for both groups, both trials, and both accent modes, the regular pattern types produced larger mean discrimination scores than the irregular pattern types. The pattern type effect ranged in magnitude from 12.2% (Trial 2, Group 1, duration accent mode) to 2.9% (Trial 2, Group 1, duration accent mode).

Dispersion estimates included standard deviations and ranges. Standard deviations were reasonably similar across experimental conditions, ranging from a maximum of 16.9% (Trial 2, Group 1, duration accent mode, regular pattern type) to a minimum of 10.2% (Trial 2, Group 1, frequency accent mode, regular pattern type). Standard deviations exhibited a slight but consistent tendency to vary inversely with mean score: as average discrimination score increased, the associated standard deviation decreased. Predictably, a similar trend is evident in the ranges of percent-correct scores.

Intra-Trial Reliability

Split-half reliability coefficients were computed separately for Trial 1 and Trial 2 discrimination scores as a function of groups collapsed across all other experimental conditions. Comparisons were made between the first and last halves of subjects' total scores. This assessment was possible because of the counterbalancing used to distribute (1) pattern type and (2) experimental-dummy pattern combinations evenly within the frequency and duration accent mode presentation orders.

In Trial 1, the split-half reliability coefficient computed for Group 1 was .86; for Group 2, it was .81. In Trial 2, this computation showed coefficients were .72 and .79 for the two groups respectively. The high reliability estimates suggest that in Trial 1 and Trial 2 the test items consistently measured those effects they were designed to measure.

Intra-trial reliability was also assessed using KR20 coefficients. These reliability estimates were computed as a function of trial and accent mode collapsed across groups.

The KR20 reliability coefficients in Trial 1 were .76 for the frequency accent mode and .64 for the duration accent mode. In Trial 2, the same coefficient of .73 was observed for both accent modes. These estimates suggest that the test items provided a consistent measurement of experimental effects. Further, these results suggest that the individual test items produced similar patterns of response in subject performance. Based on these findings, it is assumed that the test items were homogenous and, therefore, valid.

Inter-Trial Reliability

Figure 28 shows the Pearson product-moment correlation coefficients (r) between subjects' Trial 1 and Trial 2 discrimination scores for Group 1 and for Group 2. Table 3 displays the correlation coefficients and coefficients of determination between Trial 1 and Trial 2 scores for both groups. All of the coefficients computed differed significantly from $r = 0$ at or beyond the .20 level ($df = 24$; $r_{critical} = .26$).

Because the two subject groups differed in musical training and experience, it was possible that they might also differ in their inter-trial consistency. To test this hypothesis, tests for significant differences between Group 1 and Group 2 correlation coefficients were computed. This was accomplished by converting each of the compared coefficients to Fisher Z scores and testing for significant difference ($df = 23$; $z_{critical} = 1.96$). Results of this computation revealed no statistically significant difference ($p\alpha < .05$) between the correlation values of the two groups.

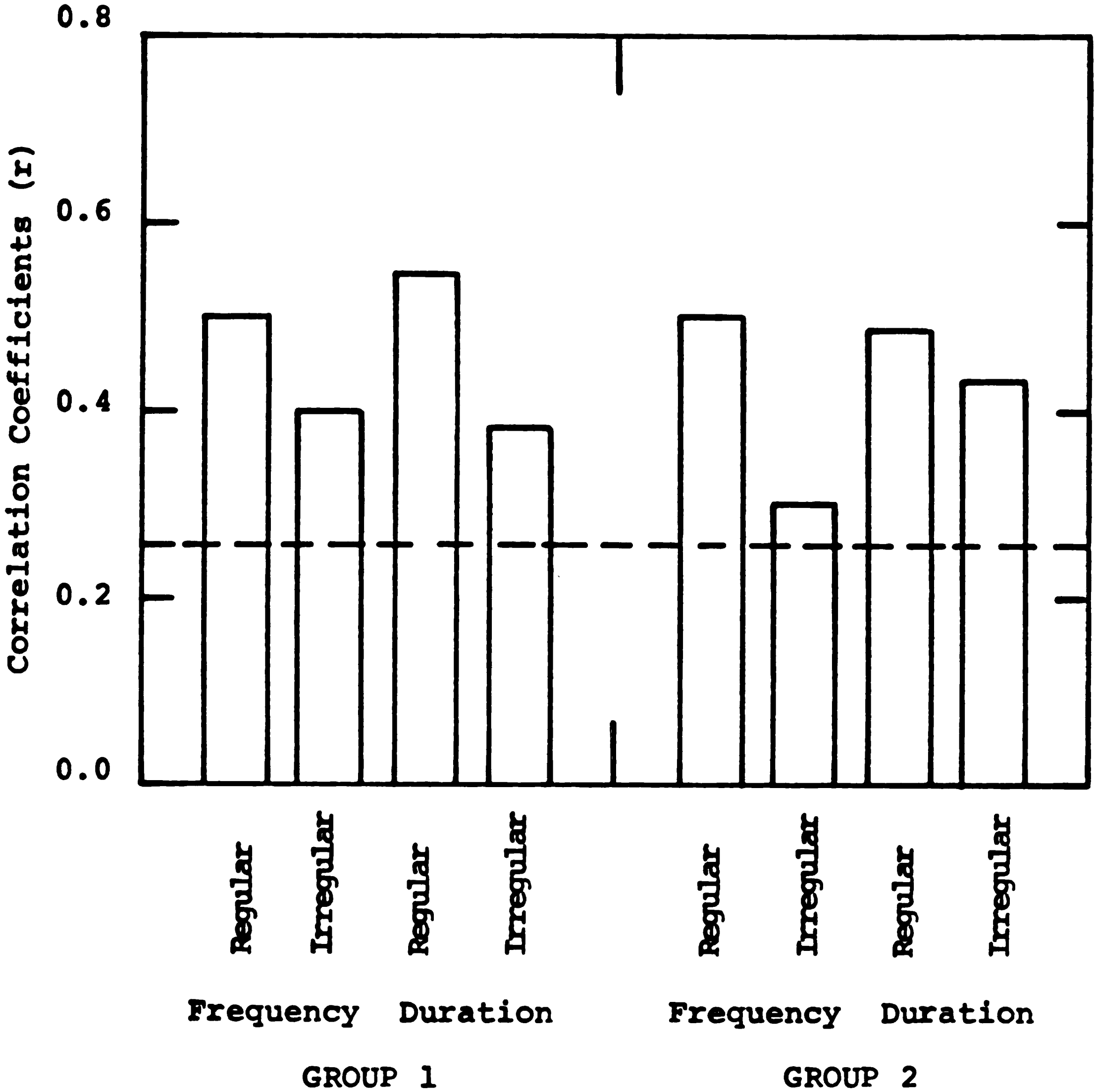


Figure 28. Inter-trial correlation coefficients (r) for two groups of 26 subjects under two accent modes and two pattern types. The dashed horizontal line denotes the significance criterion (r = .26).

TABLE 3. Inter-trial correlation coefficients (r) and coefficients of determination (r^2) for musically experienced (Group 1) and inexperienced (Group 2) subjects tested under each of two conditions of pattern type in each of two conditions of accent mode. Each correlation is based on data from 26 subjects. All correlations are positive; each was significant at or beyond the .20 level.

	GROUP			
	Group 1		Group 2	
Source	r	r^2	r	r^2
Accent Mode				
Frequency				
Pattern Type				
Regular	.50	.25	.50	.25
Irregular	.40	.16	.30	.09
Duration				
Pattern Type				
Regular	.54	.30	.48	.23
Irregular	.38	.14	.43	.18

Coefficients ranged from .54 to .38 for Group 1 and from .50 to .30 for Group 2. Thus, a statistically significant, moderate positive relationship existed between subjects' Trial 1 and Trial 2 responses as a function of groups.

Figure 29 displays the Pearson product-moment correlation coefficients between subjects' Trial 1 and Trial 2 discrimination scores collapsed across groups. Table 4 summarizes coefficients and coefficients of determination between subjects' Trial 1 and Trial 2 scores collapsed across groups. All of the coefficients computed differed significantly from r = 0 at or beyond the .20 level (df = 50; $r_{critical} = .18$).

The "average" coefficients for accent modes, collapsed across groups, were .49 for the frequency mode and .48 for the duration mode, indicating a statistically significant, moderate positive inter-trial response relationship as a function of accent mode. The "average" coefficients for pattern types, collapsed across groups, were .54 for regular patterns and .43 for irregular patterns. This also indicates a moderate, but substantial relationship between subjects' Trial 1 and Trial 2 discrimination scores as a function of pattern type.

Order of presentation of the frequency and duration accent mode test items was counterbalanced in both experimental trials such that half of Groups 1 and 2

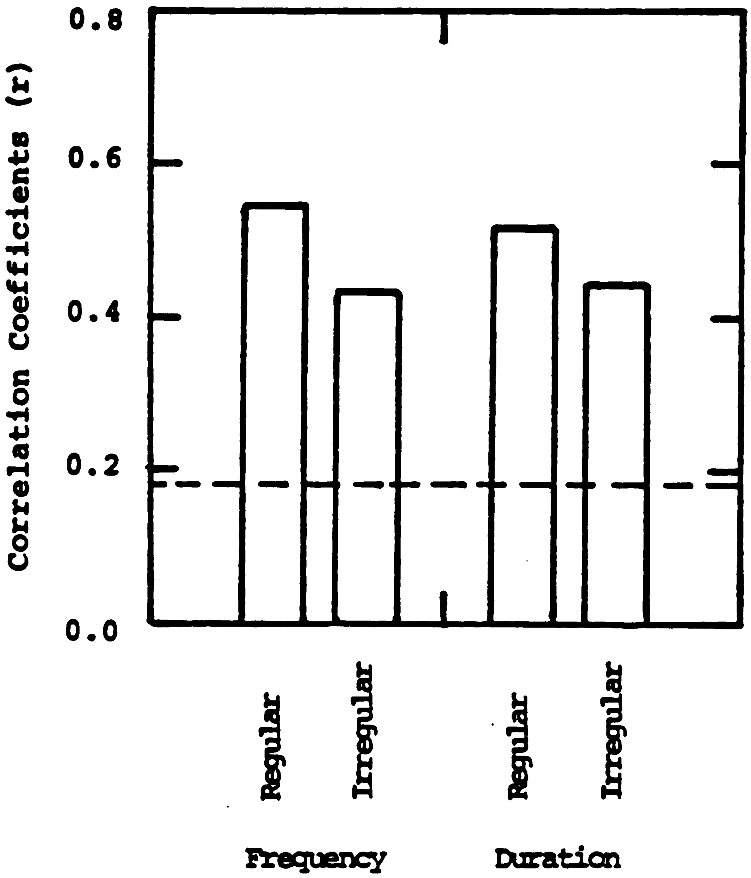


Figure 29. Inter-trial correlation coefficients (r) for two accent modes and two pattern types collapsed across groups. The dashed horizontal line denotes the significance criterion (r = .18).

TABLE 4. Inter-trial correlation coefficients (r) and coefficients of determination (r^2) for two accent modes and two pattern types. Each coefficient is based upon data from 52 subjects. All correlations are positive; each was significant at or beyond the .20 level. Mean coefficients and coefficients of determination for the two accent modes were computed using the Fisher Z transformation procedure.*

Source	r	r^2
Accent Mode		
Frequency		
Pattern Type		
Regular	.55	.30
Irregular	.42	.18
(Mean)	(.49)	(.24)
Duration		
Pattern Type		
Regular	.52	.27
Irregular	.43	.18
(Mean)	(.48)	(.23)

*$Z = 1/2 \, [\log_e (1 + r) - \log_e (1 - r)]$

heard the frequency accent mode items first followed by the duration accent mode items in Trial 1 (Presentation Order 1). The other half of both groups listened to the duration mode items first followed by the frequency mode items in the first trial (Presentation Order 2). Presentation order of the two accent mode test items was reversed in Trial 2 for all subjects.

Figure 30 displays the Pearson product-moment correlation coefficients between subjects' Trial 1 and Trial 2 discrimination scores for Presentation Order 1 and Presentation Order 2. Table 5 presents the correlation coefficients and coefficients of determination between Trial 1 and Trial 2 scores for the two presentation orders. All of the coefficients computed differed significantly from $r = 0$ at or beyond the .20 level ($df = 24$; $r_{critical} = .26$).

Although two presentation orders were used to distribute any experimental order effects, it was possible that they might result in differences in inter-trial consistency. To test this hypothesis, tests for significant differences between Presentation Order 1 and Presentation Order 2 correlation coefficients were computed. Results of this computation revealed no statistically significant differences ($p\alpha < .05$) between the correlation values of the two presentation orders.

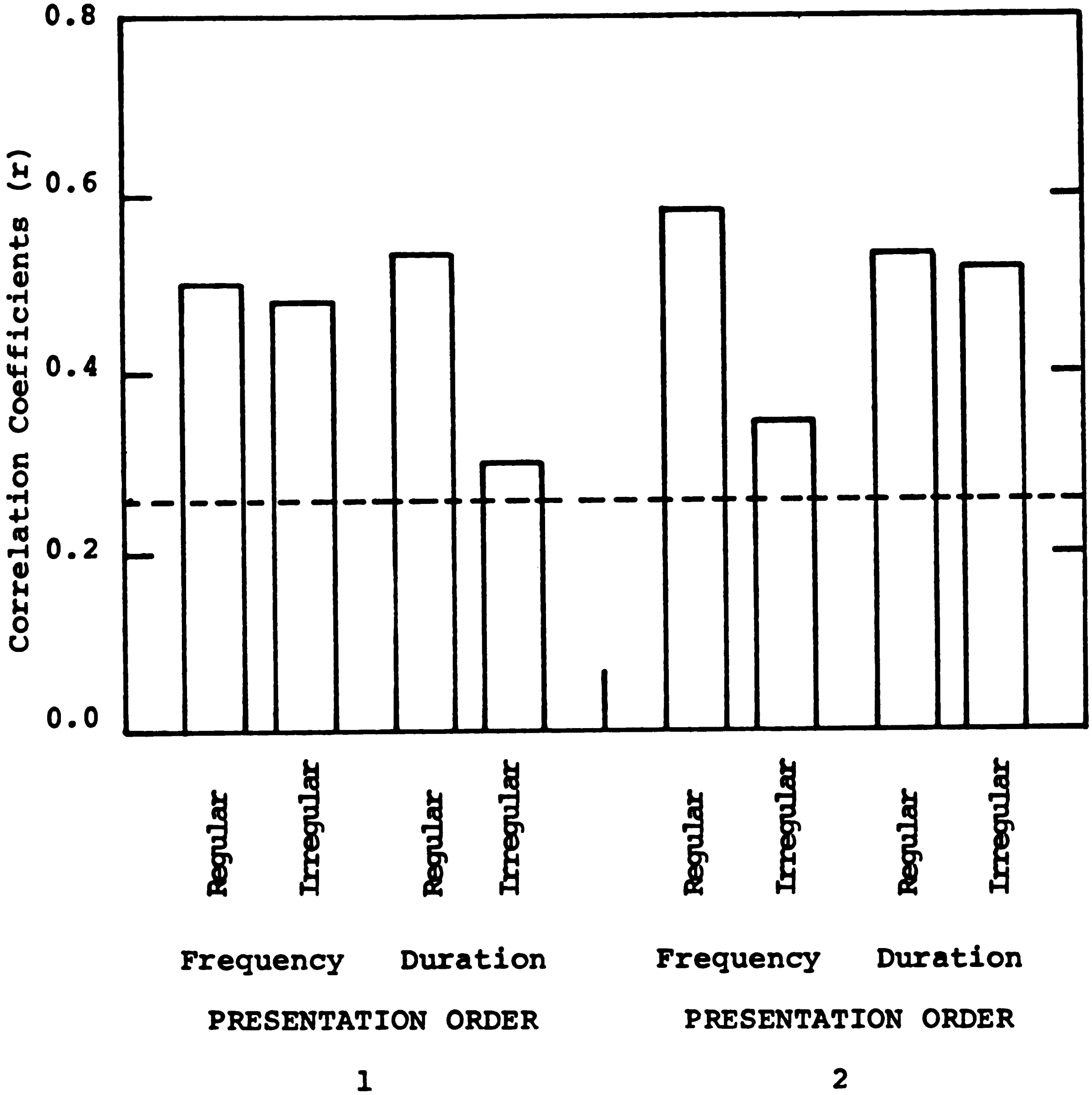


Figure 30. Inter-trial correlation coefficients (r) as a function of two presentation orders. Each correlation is based upon data from 26 subjects. The dashed horizontal line denotes the significance criterion (r = .26).

TABLE 5. Inter-trial correlation coefficients (r) and coefficients of determination (r^2) for two test item presentation orders. Each correlation is based upon data from 26 subjects. All correlations are positive; each was significant at or beyond the .20 level.

	PRESENTATION ORDER			
	Presentation Order 1		Presentation Order 2	
Source	r	r^2	r	r^2
Accent Mode				
Frequency				
Pattern Type				
Regular	.50	.25	.58	.34
Irregular	.47	.22	.34	.12
Duration				
Pattern Type				
Regular	.53	.28	.53	.28
Irregular	.30	.09	.52	.27

Analysis of Experimental Effects

Trial 1

Table 6 summarizes the results of a three-way, mixed effects analysis of variance in pattern discrimination as a function of two listener groups (Group 1, Group 2), two pattern types (regular, irregular), and two accent modes (frequency, duration) for Trial 1.

The main effects of group, pattern type, and accent mode were all significant. This suggests that the factors of group, pattern type, and accent mode caused statistically significant differences in mean pattern discrimination. There were no significant interactions. These outcomes confirm the comparisons of mean discrimination scores offered above.

Eta^2 was computed to estimate the proportion of variance in percent-correct scores that could be accounted for by each significant outcome noted in Table 6. Approximately 5% of the variance in percent-correct discrimination scores could be attributed to pattern type and to accent mode separately. The group effect contributed about 6% of the total variation in scores. Thus, none of the significant experimental effects was very strong.

Trial 2

Table 7 shows the results of a three-way, mixed effects analysis of variance in pattern discrimination

TABLE 6. Three-way, mixed effects analysis of variance (ANOVA) of percent-correct pattern discrimination scores with repeated measures on two factors (pattern type and accent mode) for Trial 1. There were 52 subjects with 26 in each group.

Source	SS	df	ms	F	α for $F_{obs.}$	eta^2
Total	49145.20	207	--	--	--	--
Between Subjects	27279.10	51	--	--	--	--
Groups	2840.81	1	2840.81	5.81*	1.9×10^{2}	0.06
$Error_b$	24438.29	50	488.77	--	--	--
within Subjects	21866.10	156	--	--	--	--
Accent Mode	2397.00	1	2397.00	19.47*	1.7×10^{-4}	0.05
Pattern Type	2481.90	1	2481.90	24.76*	5.6×10^{-5}	0.05
G X AM	285.50	1	285.50	2.32	1.3×10^{-1}	--
G X PT	22.47	1	22.47	0.22	6.4×10^{-1}	--
AM X PT	346.10	1	346.10	3.37	6.9×10^{-2}	--
G X AM X PT	31.62	1	31.62	0.31	5.9×10^{-1}	--
Error 1	6155.20	50	123.10	--	--	--
Error 2	5011.50	50	100.23	--	--	--
Error 3	5134.81	50	102.70	--	--	--

*denotes significance at or beyond the .05 level.

TABLE 7. Three-way, mixed effects analysis of variance (ANOVA) of percent-correct pattern discrimination scores with repeated measures on two factors (pattern type and accent mode) for Trial 2. There were 52 subjects with 26 in each group.

Source	SS	df	ms	F	α for $F_{obs.}$	eta^2
Total	53539.60	207	--	--	--	--
Between Subjects	30574.45	51	--	--	--	--
Groups	4925.72	1	4925.72	9.60*	3.5×10^{-3}	0.09
$Error_b$	25648.73	50	512.97	--	--	--
Within Subjects	22965.15	156	--	--	--	--
Accent Mode	3174.62	1	3174.62	21.24*	1.2×10^{-4}	0.06
Pattern Type	3081.54	1	3081.54	34.73*	1.1×10^{-5}	0.06
G X AM	363.05	1	363.05	2.43	1.2×10^{-1}	--
G X PT	216.08	1	216.08	2.44	1.2×10^{-1}	--
AM X PT	169.20	1	169.20	2.10	1.5×10^{-1}	--
G X AM X PT	26.75	1	26.75	0.33	5.7×10^{-1}	--
Error 1	7474.88	50	149.50	--	--	--
Error 2	4436.23	50	88.72	--	--	--
Error 3	4022.83	50	80.46	--	--	--

*denotes significance at or beyond the .05 level.

for Trial 2. The main effects of groups, pattern types, and accent modes were all significant, again suggesting that differences in mean pattern discrimination were caused by each of the three main effects. None of the interactions were significant.

The outcome of this analysis confirms what was observed for Trial 1. The main effects of pattern type and accent mode each accounted for about 6% of the variance in scores. The group effect contributed 9% of the total variation in scores.

The ANOVA results can be summarized as follows. In both trials, musically more experienced listeners produced higher mean pattern discrimination scores. Similarly, the regular pattern type yielded higher mean scores than did the irregular pattern type, and the frequency accent mode caused higher scores than the duration accent mode.

Supplemental Analysis

The experimental stimuli used in this study were designed using Martin's (1972) relative accent level and relative timing rules to generate patterns which differed grossly in regularity (that is, regular vs. irregular). No attempt was made initially to select patterns in terms of relative redundancy level or the index of relative redundancy described in Chapter III. Subsequent to stimulus design and data acquisition, it was decided to compare the relative redundancy level of rhythmic patterns and mean discrimination score. The purpose of this comparison was to assess the utility of the relative redundancy quantification procedure presented above.

Organization of Test Items

An index of relative redundancy (IRR) was computed for each experimental and dummy rhythmic pattern used in the study following the procedures described in Chapter III. Computed IRRs are presented in Tables 8 and 9. In the frequency accent mode, the IRR for all regular rhythmic patterns ranged from 0.92 to 0.74, and IRRs for all irregular patterns in the frequency accent mode ranged from 0.68 to 0.52. In the duration mode, IRR ranged from 0.95 to 0.72 for regular patterns and from 0.68 to 0.50 for irregular patterns. These IRRs indicate that there were no extreme differences in levels of regularity between regular and irregular patterns in either accent mode.

Each test item consisted of three rhythmic patterns. The three patterns, in turn, were made up of one of four combinations of an experimental-dummy pattern pairing. An IRR for each test item was computed by averaging the IRRs for the three rhythmic patterns. In the frequency accent mode, for example, the third test item consisted

TABLE 8. Computed indices of relative redundancy (IRRs) for eight pairs of experimental and dummy patterns in the frequency accent mode.

Pattern Number	Pattern Type: Regular, Experimental	Pattern Type: Regular, Dummy	Pattern Type: Irregular, Experimental	Pattern Type: Irregular, Dummy
1	.82	.92	.56	.61
2	.74	.74	.64	.65
3	.87	.79	.62	.68
4	.86	.79	.52	.55

TABLE 9. Computed indices of relative redundancy (IRRs) for eight pairs of experimental and dummy patterns in the duration accent mode.

Pattern Number	Pattern Type: Regular		Pattern Type: Irregular	
	Experimental	Dummy	Experimental	Dummy
1	.80	.95	.55	.58
2	.75	.72	.62	.63
3	.91	.82	.61	.68
4	.79	.82	.50	.52

of the third regular pattern (FMRP 3; IRR = 0.87), followed by its corresponding dummy pattern (FMDRP 3; IRR = 0.79), followed by the FMRP 3 pattern (IRR = 0.87). Thus, the average IRR for the third test item in the frequency accent mode was,

$$\frac{0.87 + 0.79 + 0.87}{3}$$

$$= 0.84.$$

The average IRRs for both the frequency and duration accent mode test items are presented in Tables 10 and 11 respectively.

In the frequency accent mode, averaged test item IRRs for regular patterns ranged from 0.89 to 0.74. Test item averaged IRRs for irregular patterns in the frequency mode ranged from 0.66 to 0.53. In the duration accent mode, averaged test item IRRs for regular patterns ranged from 0.90 to 0.73 and from 0.66 to 0.50 for averaged test item IRRs for irregular patterns. The averaged test item IRRs suggest that there were no extreme differences in the overall levels of regularity between regular and irregular pattern test items in either accent mode.

Organization of Percent-Correct Discrimination Scores

Percent-correct discrimination scores were computed separately for each accent mode test item for both experimental trials collapsed across groups. Trial 1 and Trial 2

TABLE 10. Averaged indices of relative redundancy (IRRs) for test items in the frequency accent mode. The four combinations of experimental-dummy pattern pairings are represented as follows: "A," experimental-dummy-experimental; "B," experimental-dummy-dummy; "C," dummy-experimental-dummy; and "D," dummy-experimental-experimental.

Item Number	Pattern Type	Pattern Number	Combination	Averaged Test Item IRR
1	Regular	1	C	.89
2	Irregular	2	D	.64
3	Regular	3	A	.84
4	Irregular	4	B	.54
5	Regular	2	D	.74
6	Irregular	3	A	.64
7	Regular	4	B	.81
8	Irregular	1	C	.59
9	Regular	3	D	.84
10	Irregular	4	C	.54
11	Regular	1	B	.89
12	Irregular	2	A	.64
13	Regular	4	C	.81
14	Irregular	1	B	.59
15	Regular	2	A	.74
16	Irregular	3	D	.64
17	Regular	1	A	.85
18	Irregular	2	D	.65
19	Regular	3	B	.82
20	Irregular	4	D	.54
21	Regular	2	B	.74
22	Irregular	3	C	.66
23	Regular	4	D	.84
24	Irregular	1	A	.58
25	Regular	3	C	.82
26	Irregular	4	A	.53
27	Regular	1	D	.85
28	Irregular	2	B	.65
29	Regular	4	A	.84
30	Irregular	1	D	.54
31	Regular	2	C	.74
32	Irregular	3	B	.66

TABLE 11. Averaged indices of relative redundancy (IRRs) for test items in the duration accent mode. The four combinations of experimental-dummy pattern pairings are represented as follows: "A," experimental-dummy-experimental; "B," experimental-dummy-dummy; "C," dummy-experimental-dummy; and "D," dummy-experimental-experimental.

Item Number	Pattern Type	Pattern Number	Combination	Averaged Test Item IRR
1	Irregular	1	C	.57
2	Regular	2	B	.73
3	Irregular	3	D	.63
4	Regular	4	A	.80
5	Irregular	2	B	.65
6	Regular	3	D	.88
7	Irregular	4	A	.50
8	Regular	1	C	.90
9	Irregular	3	A	.63
10	Regular	4	B	.81
11	Irregular	1	D	.56
12	Regular	2	C	.73
13	Irregular	4	D	.50
14	Regular	1	A	.85
15	Irregular	2	C	.63
16	Regular	3	B	.85
17	Irregular	1	A	.56
18	Regular	2	D	.74
19	Irregular	3	B	.66
20	Regular	4	C	.81
21	Irregular	2	A	.62
22	Regular	3	C	.85
23	Irregular	4	B	.51
24	Regular	1	D	.85
25	Irregular	3	C	.66
26	Regular	4	D	.80
27	Irregular	1	B	.57
28	Regular	2	A	.74
29	Irregular	4	C	.51
30	Regular	1	B	.90
31	Irregular	2	D	.62
32	Regular	3	A	.88

percent-correct discrimination scores for each test item were then averaged, and the resulting grand mean discrimination scores were grouped according to accent mode. Table 12 summarizes the outcome of these computations.

Comparison Procedure

There were 13 unique levels of item-averaged IRRs in the frequency accent mode, and 14 unique levels of item-averaged IRRs in the duration accent mode. Two procedures were undertaken in order to simplify comparisons between averaged test item IRRs and percent-correct discrimination scores. First, the percent-correct discrimination scores averaged across the two trials for each test item were grouped according to unique levels of averaged test item IRR. This was done separately for each accent mode. A grand mean of the grouped average percent-correct discrimination scores was then computed. This allowed a comparison of the unique levels of averaged test item IRR with the corresponding averages of the grouped average discrimination scores. Tables 13 and 14 present the corresponding averaged test item IRRs and averages of grouped average discrimination scores for the frequency and duration accent modes respectively.

Second, the unique levels of averaged test item IRR and the averages of grouped average discrimination scores were subjected to an arcsin transformation (Edwards, 1972,

TABLE 12. Percent-correct discrimination scores computed separately for each accent mode test item for both experimental trials collapsed across groups. Grand mean discrimination scores were averaged across trials for each test item.

	Accent Mode					
	Frequency			Duration		
Item Number	Trial 1	Trial 2	Grand $\overline{X}$	Trial 1	Trial 2	Grand $\overline{X}$
1	92.0	88.0	90.0	81.0	79.0	80.0
2	87.0	85.0	86.0	79.0	79.0	79.0
3	92.0	90.0	91.0	60.0	63.0	61.5
4	87.0	88.0	87.5	87.0	85.0	86.0
5	90.0	85.0	87.5	92.0	88.0	90.0
6	54.0	71.0	62.5	88.0	85.0	86.5
7	73.0	85.0	79.0	69.0	73.0	71.0
8	62.0	73.0	67.5	88.0	87.0	87.5
9	87.0	87.0	87.0	69.0	63.0	66.0
10	83.0	85.0	84.0	58.0	81.0	69.5
11	94.0	88.0	91.0	65.0	50.0	57.5
12	73.0	56.0	64.5	63.0	69.0	66.0
13	73.0	87.0	80.0	79.0	71.0	75.0
14	75.0	75.0	75.0	85.0	83.0	84.0
15	75.0	73.0	74.0	73.0	67.0	70.0
16	67.0	63.0	65.0	62.0	83.0	72.5
17	94.0	87.0	90.5	58.0	56.0	57.0
18	81.0	83.0	82.0	77.0	58.0	67.5
19	90.0	75.0	82.5	73.0	67.0	70.0
20	79.0	85.0	82.0	81.0	83.0	82.0
21	83.0	79.0	81.0	38.0	46.0	42.0
22	65.0	73.0	6910	54.0	50.0	52.0
23	85.0	87.0	86.0	73.0	60.0	66.5
24	73.0	75.0	74.0	77.0	79.0	78.0
25	81.0	71.0	76.0	81.0	71.0	76.0
26	85.0	77.0	81.0	85.0	81.0	83.0
27	88.0	83.0	85.5	83.0	87.0	85.0
28	92.0	94.0	93.0	58.0	60.0	59.0
29	81.0	81.0	81.0	73.0	60.0	66.5
30	73.0	56.0	64.5	75.0	73.0	74.0
31	65.0	58.0	66.5	63.0	52.0	57.5
32	65.0	69.0	67.0	81.0	73.0	77.0

TABLE 13. Average test item indices of relative redundancy (IRRs) for the frequency accent mode and corresponding average discrimination scores obtained by 52 subjects in two trials.

Averaged Test Item IRR	Average of Grouped Average Discrimination Score
.89	90.5
.85	88.0
.84	86.3
.82	79.3
.81	79.5
.74	77.3
.66	68.0
.65	87.5
.64	69.5
.59	71.3
.58	69.3
.54	85.8
.53	81.5

TABLE 14. Average test item indices of relative redundancy (IRRs) for the duration accent mode and corresponding average discrimination scores obtained by 52 subjects in two trials.

Unique Level of Averaged Test Item IRR	Average of Grouped Average Discrimination Score
.90	80.8
.88	81.8
.85	71.6
.81	75.8
.80	83.0
.74	63.3
.73	72.5
.66	73.0
.63	71.9
.62	49.8
.57	82.5
.56	57.3
.51	66.5
.50	73.0

pp. 106-107); Snedecor and Cochran, 1967, pp. 327-329). This transformation was accomplished in order to (1) increase the effective spread of percent-correct discrimination scores and (2) to counteract the positive skewness in the unique levels of averaged test item IRRs. The mean for 27 unique levels of test item IRR was .70, whereas the median was .66, indicating an asymmetrical distribution. Table 15 presents the transformed values.

Analysis

Pearson product-moment correlation coefficients (r) were computed to assess the relations between arcsin transforms of averaged test item IRRs and the corresponding averages of grouped average discrimination scores. Correlation coefficients were computed separately for each accent mode.

The frequency accent mode produced a moderate positive relationship between averaged test item IRR levels and averages of grouped average discrimination scores: $r = .50$. In the duration mode, the comparable correlation was found to be $r = .47$, also a moderate positive relationship.

Figure 31 presents the correlation coefficients, computed lines of regression, and regression equations for the two accent modes. Both lines of regression suggest a moderate positive relationship between the

TABLE 15. Arcsin transformations* of unique levels of averaged test item indices of relative redundancy (IRRs) and corresponding averages of grouped average discrimination scores in the frequency and duration accent modes.

ACCENT MODE			
Frequency		Duration	
$\sin^{-1}\sqrt{IRR}$	$\sin^{-1}\sqrt{\%\text{-correct}}$	$\sin^{-1}\sqrt{IRR}$	$\sin^{-1}\sqrt{\%\text{-correct}}$
70.63	72.05	71.56	64.01
67.21	69.73	69.73	64.75
66.42	68.28	67.21	57.80
64.90	62.94	64.16	60.53
64.16	63.08	63.44	65.65
59.34	61.55	59.34	52.71
54.33	55.55	58.69	58.37
53.73	69.30	54.33	58.69
53.13	56.48	52.53	57.99
50.18	57.61	51.94	44.89
49.60	56.35	49.02	65.27
47.29	67.86	48.45	49.20
46.72	64.52	45.57	54.63
		45.00	58.69

*Angle = $\arcsin\sqrt{\text{percentage}}$.

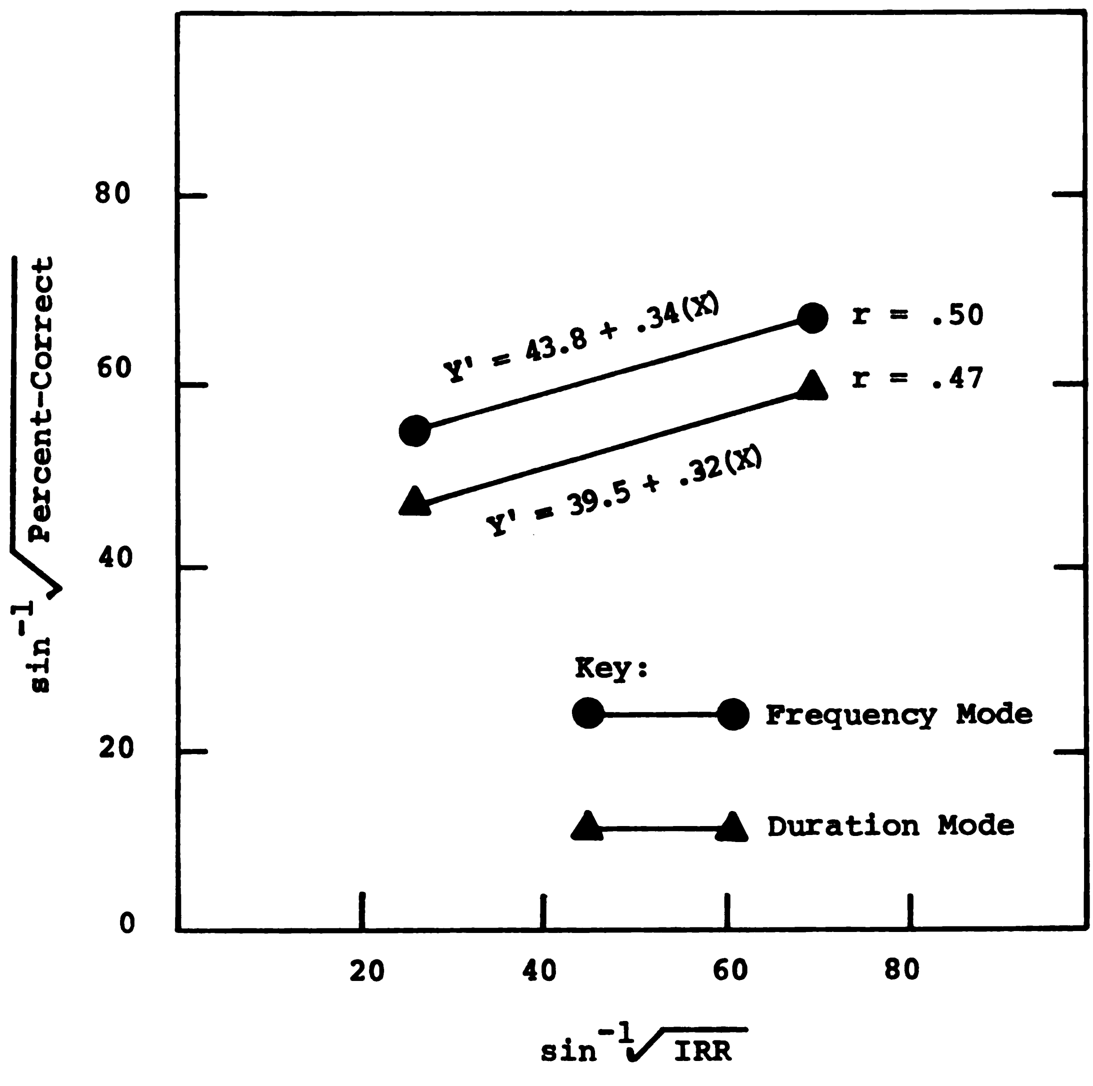


Figure 31. Correlation coefficients (r), lines of regression, and regression equations computed for arcsin transforms of averaged test item indices of relative redundancy (IRRs) and averages of grouped average discrimination scores. Comparisons were computed separately for the frequency and for the duration accent modes.

transformed unique levels of averaged test item IRR and the corresponding averages of grouped average discrimination scores. It would appear that discrimination scores increase monotonically with IRR level. This result suggests that the IRR quantification method may provide a useful measure of redundancy levels in rhythmic auditory patterns.

Summary

The dependent variable considered here was percent-correct pattern discriminations. Intra-trial reliability of subjects' responses showed a high level of internal consistency. Reliability coefficients suggest that the test items produced an accurate and homogenous measurement of the experimental effects as well as similar patterns of response in subject performance.

Analysis of inter-trial reliability showed a moderate but substantial strength of relationship. The two subject groups did not differ significantly in their inter-trial consistency; nor did the two orders of presentation of accent modes produce statistically significant differences in inter-trial consistency.

The results of a three-way, mixed effects analysis of variance of percent-correct discrimination scores showed statistically significant differences for each of the three main effects of group, pattern type, and accent mode. This occurred in both experimental trials. There were no significant interactions.

In all instances, the mean percent-correct discrimination scores were higher for Group 1 than for Group 2, suggesting that musical training significantly influenced pattern discrimination. Similarly, the mean percent-correct discrimination scores for the frequency accent mode were, in all instances, higher than the mean percent-correct discrimination scores for the duration accent mode. This result suggests that the type of accent generation used in the study (that is, binary frequency change vs. bi-level changes in event duration) significantly influenced pattern discrimination.

The mean percent-correct discrimination scores for regular rhythmic patterns were, in all instances, higher than the mean percent-correct discrimination scores for irregular patterns. This suggests that the degree of pattern regularity, as defined by the rules of relative accent level and relative timing, significantly influenced rhythmic pattern discrimination.

CHAPTER VI

DISCUSSION

Introduction

Chapter V described the results produced by 26 non-music majors with high levels of musical training (Group 1) and 26 non-music majors with little or no musical training (Group 2) on a pattern discrimination task. Pattern discrimination responses were obtained for the two groups as a function of pattern types (regular vs. irregular) and accent modes (frequency vs. duration) in each of two experimental trials (Trial 1, Trial 2).

The dependent variable under investigation was percent-correct pattern discrimination. Subjects' discrimination scores were analyzed to determine the strength of relationship between Trial 1 and Trial 2 responses. Intra-trial reliability was also assessed. Subjects' scores were examined for the significance of differences as a function of (1) pattern regularity, (2) accent mode, and (3) musical training, as well as three possible two-way interactions and one three-way interaction. The analysis was repeated separately for each of the two experimental trials.

Comparisons between percent-correct discrimination scores and pattern regularity was also analyzed using the relative redundancy quantification procedure described in Chapter III. The purpose of this analysis was to assess the strength of relationship between IRR and discrimination scores.

Discussion of the findings is divided into three parts. First, intra-trial and inter-trial reliability of responses are outlined and examined. Second, analysis of discrimination scores as a function of the three main effects is presented and discussed in terms of the experimental questions in Chapter V. Finally, implications of the findings are discussed in relation to the perceptual model and the relative redundancy quantification procedure. Implications for future research are outlined in terms of the model's descriptive potential and the adequacy of the IRR scale of measurement.

Reliability

Intra-Trial Reliability

Split-half and KR20 reliability coefficients were computed in order to assess intra-trial reliability. The KR20 coefficient was based on subjects' scores in each of the two experimental trials as a function of accent mode collapsed across the group and pattern type factors. Split-half reliability coefficients were computed for subjects' total discrimination scores (that is, scores collapsed across accent modes and pattern types).

The coefficients ranged from .76 to .64. The high reliability coefficients suggest that test items in both accent modes produced similar patterns of response and that test item difficulty was fairly homogenous. Split-half reliability coefficients computed as a function of group ranged from .86 to .72, suggesting that test items provided an accurate measure of the experimental effects in each trial.

Inter-Trial Reliability

Pearson product-moment correlation coefficients (r), based on subjects' percent-correct discrimination scores across experimental trials, were used to assess the inter-trial reliability of the data. Correlation coefficients were computed for discrimination scores across experimental trials as a function of (1) experimental group and (2) presentation order.

Coefficients computed as a function of group showed a moderate positive inter-trial strength of relationship in discrimination score variance. Coefficients ranged from .54 to .38 for Group 1 and from .50 to .30 for Group 2. Coefficients computed for accent mode and pattern type collapsed across groups also showed a moderate but substantial strength of relationship. The "average" coefficients for pattern type were .54 for regular patterns and .43 for irregular patterns. The "average" coefficients for accent mode were .49 for the frequency mode and .48 for the duration mode. All correlation coefficients computed were significant at or beyond the established .20 level. There were no statistically significant differences ($p\alpha < .05$) between correlation coefficients for Group 1 and Group 2.

Correlation coefficients computed for the two presentation orders also showed a moderate positive inter-trial strength of relationship of percent-correct discrimination scores. Coefficients for Presentation Order 1 ranged from .53 to .30, while coefficients ranged from .58 to .34 for Presentation Order 2. All coefficients computed were significant at or beyond the established .20 level, and there were no statistically significant differences ($p\alpha < .05$) between coefficients computed for Presentation Order 1 and Presentation Order 2.

Although selected pairwise comparisons of correlation coefficients failed to differentiate them, higher mean scores were generally associated with larger between-trial correlations. Subjects' scores indicate greater accuracy (and greater trial-to-trial consistency) in discrimination of regular rhythmic patterns than in discrimination of irregular rhythmic patterns. This was true in both accent modes. It is reasonable to speculate that the relative difficulty in pattern discrimination influenced inter-trial strength of relationships: regular rhythmic patterns produced more consistent judgments because they were more easily discriminated. Similarly, the frequency accent mode resulted in more consistent judgments than the duration accent mode because the former provided for easier discrimination.

Mean percent-correct discrimination scores for Group 1 were higher than those observed for Group 2, a generalization which holds across pattern types, accent modes, and trials. Correlation coefficients for the two groups indicate slightly greater inter-trial consistency for Group 1 than for Group 2, even though this difference was not statistically significant. It appears that greater musical training results in better discrimination and, hence, greater consistency in judgment across trials.

All subjects were tested under similar conditions and received identical practice item training. Stimulus presentation order was counterbalanced to reduce order effects, and there was no statistically significant difference between the correlations for the two presentation orders. Why, then, did the inter-trial correlation coefficients display only a moderate agreement?

Subjects were drawn from a student population and were tested in a small group situation. Inter-trial consistency might be improved with greater experimental control of the subjects (e.g., individual testing or criterion-referenced training). The test-retest correlation coefficients observed in the study are consistent with those obtained in other studies where relatively untrained listeners are used.

Another possible source of variation between Trial 1 and Trial 2 scores is the nature of the discrimination task itself. Perhaps the criteria used by subjects to compare rhythmic patterns are variable. If so, then discrimination scores would be expected to fluctuate as a function of changes in criterion. Random measurement error, attributable to the listening test (that is, the specific experimental and dummy patterns used) is another potential source of inter-trial variation, although high intra-trial reliability coefficients suggest that this is not the case.

Several factors may have affected subjects' attention to the perceptual task and, hence, their inter-trial response consistency. First, the nature or level of noise in the experimental environment, though assumed to be unimportant, may have disrupted subject focus on the judgment task. Second, changes in the nature or level of noise between the first and second trials may have influenced response consistency. Third, subject attention may have been influenced by motivation and attitude. It was not feasible to offer monetary or academic incentives for test participation. The nature of the test item presentation demanded subject attention over a period of about 28 minutes. In Trial 2, subjects quickly became aware of the fact that the perceptual task experienced in Trial 1 was about to be repeated. In some instances, this resulted in an observable decrease in attention to the task (e.g., erratic marking of answers, superfluous configurations on response sheets). Of course, another explanation is that the criteria required of subjects were based upon pairs of signals which did not differ greatly enough to be consistently perceived.

Subsequent research employing the present (or a similar) paradigm would probably benefit from efforts to improve response consistency through more rigorous control of the acoustical environment and attitudinal sets of listeners, the audiometric status of listeners, and the perceptual skills of listeners.

Pattern Discrimination Analysis

The second experimental question asked whether pattern regularity significantly influenced pattern discrimination. The results indicate that the difference between regular and irregular rhythmic patterns causes related differences in pattern discrimination. In all instances, the mean percent-correct discrimination score was higher for the regular pattern type than for the irregular pattern type. This difference between correct discriminations was statistically significant in both experimental trials.

Patterns were categorized as regular or irregular on the basis of whether they adhered to or violated the rules of relative accent level and relative timing. In all of the irregular patterns, experimental and dummy, the second strongest accent position, as described by the two rules, was left unaccented. In no instance were the rules of accentual and durational value violated for the strongest relative accent level position. Thus, although the irregular patterns were properly labelled as such, they did not differ greatly from the regular patterns in terms of <u>degree</u> of regularity. It is likely that the magnitude of the observed perceptual differences between regular and irregular patterns would be larger if the locus of rule violation were to coincide with the strongest relative accent position. The significant outcome in the present study suggests that relatively minor departures from regularity have a potent effect upon perception.

Sturges and Martin (1974) used rhythmic patterns similar to the frequency accent mode patterns in the present study. Although their presentation rate and test frequencies differed from those reported above, the listener tasks were similar. Sturges and Martin reported a mean proportion of correct judgments of 80% for the "good" (that is, regular) rhythmic patterns and 74% for the "poor" (that is, irregular) patterns in the two experiments which did not involve a response delay. The present outcomes were quite similar to the results of the Sturges and Martin study in terms of absolute discrimination performance and in terms of the direction and magnitude of differences in mean performance caused by pattern regularity.

The third experimental question addressed the impact of musical training on pattern discrimination. It was found that, on the average, subjects with high levels of musical training (Group 1) always produced higher discrimination scores than subjects with little or no musical training (Group 2). Although none of the subjects were music majors, pre-experimental questions revealed a wide range of musical background and experience. Most of the subjects in Group 1, for example, had received several years of private instruction on a musical instrument and had participated in performing ensembles. Few subjects in Group 2 had received any musical training either privately or in a formal education setting.

The experimental outcomes in both trials suggest that subject selection criteria resulted in significant differences in group discrimination scores. Subjects with higher levels of musical experience displayed greater pattern discrimination skill than did those subjects with minimal music background. Group characteristics did not, however, result in significant differences in consistency of discrimination response across the two trials, although, in most instances, the musically experienced listeners were slightly more consistent in discriminatory response.

The fourth experimental question pertained to the effect of accent mode on pattern discrimination. In each experimental trial, for each pattern type, and for both groups, discrimination scores were higher for the frequency accent mode than for the duration mode. This difference may have resulted from the increased number of pattern events used in the duration mode (duration mode patterns ranged in length from 11 to 14 elements, whereas all frequency mode patterns were eight elements in length). This hypothesized effect of pattern length on level of difficulty could be partially evaluated if the two accent mode test items were intermixed in test presentation order. It is also possible that frequency change provided for a more acute perceptual demarcation of accent location than did event duration change, thus resulting in a more accurate perceptual discrimination of pattern regularity.

Implications for the Perceptual Model

The present findings seem to support several features of the perceptual model described in Chapter III. The model suggests that an increase in prior knowledge (that is, long-term memory) allows for greater precision in rhythmic pattern temporal relation expectancy, thus increasing the level of redundancy reduction possible. This results in greater facility of perceptual processing of temporal order. The fact that subjects with higher levels of prior musical knowledge (Group 1) displayed greater discrimination accuracy supports the contention of a long-term memory effect, but not necessarily in the context of a modified expectancy set.

Higher levels of accuracy in pattern discrimination were displayed by both groups for those patterns in which accent was generated by means of a binary frequency change. This was true for regular and irregular pattern types. In terms of model operation, this would suggest that greater amounts of temporal information reaching the pitch differentiator could be channeled to the relative redundancy computer and ultimately summated in advance of transmission to the recoder. Poorer discrimination of duration accent mode patterns suggests that less inhibition was possible for information directed primarily at the protensity differentiator resulting in less redundancy reduction. Alternately (and more likely), the pitch and protensity differentiator <u>outputs</u> are weighted differently causing differences in levels of redundancy reduction.

The monotonic correspondence between the IRR levels and pattern discrimination scores suggests that higher levels of pattern regularity did allow for an increase in redundancy reduction. For regular patterns, greater amounts of temporal information were channeled to the relative redundancy computer and scaler operations. This increase in the proportion of summated information, in turn, allowed for greater accuracy with regard to expectancies established for succeeding pattern temporal relations.

Schema for Future Research

The index of relative redundancy (IRR) is an objective measure of a physical signal. At issue is the goodness of fit between IRR and discrimination data, which are subjective measures of a psychological response to the physical signal. Issues of fit can be addressed from the perspective of the formal philosophical theory of measurement suggested by Bergmann and Spence (1953). From this perspective, measurement is the act of assigning numbers to the events of a dimension or to an attribute. Dimensions differ from attributes in that dimensions (which are properties of physical objects) are amenable to objective differentiation, while attributes depend upon a discriminatory response for definition. Therefore, relative redundancy (as a characteristic of a physical signal) is probably best labelled an "attribute."

Percent-correct pattern discrimination was used in the present study as a measure of perceived rhythm; that is, the product of redundancy reduction. Whereas relative redundancy is defined as a characteristic of the physical domain (that is, pertaining to the acoustical signal), perceived rhythm, as measured by percent-correct pattern discrimination, is a characteristic of the response domain.

Within the signal attribute of relative redundancy, there are assumed to exist certain relations, some of which pertain to aspects of the attribute itself (internal relations), and others which connect relative redundancy to other characteristics of the physical domain. Measurement scales are intended to reflect these relations. The proposed IRR scale, therefore, is intended to reflect the relations of the relative redundancy attribute.

Similarly, there are assumed to exist within the perceptual domain certain relations which pertain to (1) aspects of perceived rhythm independent of other response domain characteristics and (2) perceived rhythm in terms of other features of the response domain. The percent-correct discrimination scale is intended to reflect these relations.

Manipulation of the relative redundancy attribute was intended to produce change in subject response (that is, variation in perceived rhythm as indicated by variation in percent-correct discrimination). Thus, it must also be assumed that interconnective relations exist between relative redundancy and perceived rhythm. In the present study, it was hypothesized that redundancy reduction would increase monotonically with relative redundancy level. It is possible, however, that this positive correspondence is untrue--that the measures of relative redundancy (IRR) and perceived rhythm (percent-correct discrimination) (1) do not adequately reflect interconnective relations, or (2) do not adequately reflect internal relations of the relative redundancy attribute or perceived rhythm.

The hypothesized internal and interconnective relations of relative redundancy and perceived rhythm can be tested through comparison with certain axioms (empirical laws). This type of functional analysis indicates the degree to which the tested relations may be subsumed under more general principles (Hempel, 1959) of both the physical and response domain. Because relative redundancy and the process of redundancy reduction underpin the perceptual model, the analysis also effectively identifies the boundaries beyond which the predictions of the model fail.

The empirical laws generally used for evaluation of relations are the axioms of order and additivity. Ordinality effectively identifies an attribute as being

<u>intensive</u>, and implicitly includes axioms of transitivity and equivalency (identity). Additivity defines <u>extensive</u> attributes or characteristics. It is noted that intensive and extensive characteristics are properties of attributes and not of scales of measurement (Bergmann and Spence, 1953, p. 106). The intensive-extensive classification scheme outlined by Bergmann and Spence (1953) is used below to identify directions for further investigation of relative redundancy, the IRR scale, and the perceptual model. Axioms of order, transitivity, equivalency, and additivity constitute the major classificatory conditions to be described.

An attribute is considered intensive if three conditions are fulfilled. First, that there exist within the attribute two relations which can be designated by, $\underline{>}$ and $\underline{=}$; that is, X $\underline{>}$ Y, and X $\underline{=}$ Y, are true and meaningful statements about attribute relations (Bergmann and Spence, 1953, p. 107). The symbols, $\underline{>}$ and $\underline{=}$ are not the usual arithmetic signs, but refer to relations of attributes. If, for example, $RR_x \underline{>} RR_y$, and $RR_x \underline{=} RR_y$ were shown to be true statements about relations within the relative redundancy attribute, then it could be said that a favorable comparison exists between the relative redundancy attribute and the initial intensive condition. The two types of relations just described are prerequisite for axioms of order and, subsequently, additivity.

The second intensive condition requires that statements of $\underline{>}$ and $\underline{=}$ must be testable within the attribute without reference to other laws or rules which pertain to that attribute in relation to other attributes or dimensions in the domain. For example, the accent levels described by the relative accent level rule must be independent of absolute values of frequency and duration in order for relative redundancy to compare favorably with this second condition. The testing of relations would be in the form of manipulation of attribute characteristics. This second intensive condition makes clear the distinction between an attribute and a dimension, for while dimensional manipulation (e.g., changes in length) results in observation of invariant relations within the dimension itself, attribute manipulation, because of a dependence upon discriminatory response for definition, results in an observation of <u>limits</u> within which invariant relations hold.

The third intensive condition is the axiom of order. Thus, the relative redundancy attribute would be considered intensive if the relations defined by the first condition compare favorably with the ordinal axiom, such that either $RR_x \underline{>} RR_y$, or $RR_x \underline{=} RR_y$, or $RR_y \underline{>} RR_x$ is a true statement. Axioms of transitivity and equivalency are also implicit in this third condition, such that,

if $RR_x \ \underline{>}\ RR_y$, and $RR_y \ \underline{>}\ RR_z$, then $RR_x \ \underline{>}\ RR_z$; and

if $RR_x \ \underline{=}\ RR_y$, and $RR_y \ \underline{=}\ RR_z$, then $RR_x \ \underline{=}\ RR_z$

are true and meaningful statements about relations within the relative redundancy attribute. If further study reveals that relations within the relative redundancy attribute and the perceived rhythm characteristic compare favorably with the axiomatic conditions, then interconnective relations assumed to exist between relative redundancy and perceived rhythm could be subjected to the same comparisons.

Adequacy of the IRR and percent-correct pattern discrimination scales of measurement can be determined by the degree to which they reflect attribute and characteristic relations (both internal and interconnective) identified by axiomatic comparison. For example, if $RR_x \ \underline{>}\ RR_y$ were shown to compare favorably with the ordinal axiom, then the IRR scale should reflect this relation, such that, $IRR_{RR_x} > IRR_{RR_y}$.

The present study indicates that the internal and interconnective relations within and between relative redundancy and perceived rhythm may fulfill intensive and ordinal conditions. In the frequency and duration accent mode patterns, different levels of relative redundancy were produced by the same two test frequencies and event durations. The monotonic correspondence between averaged test item IRR and percent-correct discrimination scores, observed for two different types of accent generation suggests a favorable comparison of the interconnective relations with the second intensive condition. This conclusion remains tentative because there was no systematic variation of test frequency and event times. Further, experimental design did not accommodate systematic inspection of internal relations of the relative redundancy attribute.

An attribute or characteristic is considered to be extensive if, in addition to the three intensive conditions, the following two conditions are fulfilled. First, that there is an internal relation designated by, $\underline{+}$ which, if performed upon any two events of the attribute, results in another event of the attribute (Bergmann and Spence, 1953, p. 107). The second extensive condition is the axiom of additivity, such that, $X \underline{+} Y \underline{=} Y \underline{+} X$ is shown to be a true and meaningful statement about the internal relations. For the relative redundancy attribute, a favorable comparison of attribute relations with the additive axiom would mean that, $RR_x \underline{+} RR_y \underline{=} RR_y \underline{+} RR_x$ is a true relational statement. Adequacy of IRR and percent-correct discrimination scales would be determined by the degree to which they reflected identified additive relations.

One of the means by which intensive and extensive conditions may be compared with attribute relations involves manipulation of rhythmic pattern physical dimensions. The extent to which relative redundancy and perceived rhythm, independently and interconnectively, compare favorably (or unfavorably) with the axiomatic conditions delineates the boundaries of the perceptual model.

One manipulation which could be used to test relative redundancy relations is variation in presentation rate. This type of variation would be accomplished by systematically increasing and decreasing the number of pattern elements per unit of time. Such variation should allow observation of internal relations of the perceived rhythm characteristic, as well as interconnective relations. The efficiency with which the two scales of measurement reflected either discriminatory confusion or relative redundancy level inconsistency could also be analyzed. Of course, the "breakdown" could also be phenomenological; that is, a "real" perceptual event.

Another manipulation which could be used to discover parameters of relative redundancy and perceived rhythm is signal duration. Recall that the stimulus durations used in this study differed from those used by Sturges and Martin (1974) in their investigation of rhythm marked by a binary change in frequency. Yet, the outcomes of the two studies were essentially similar. Systematic variation of stimulus and interstimulus interval should more completely identify the types of internal and interconnective relations present, as well as expand the range of comparisons possible between relations and axiomatic conditions. Such duration manipulation also should include the use of more than two types of event durations (e.g., quarter notes, eighth notes, and sixteenth notes).

Use of different test frequencies offers another pattern manipulation which could support axiomatic comparison. The two test frequencies used in the present study to mark accent were selected in order to minimize the impact of potentially confounding incidental effects. Although the primary objective of frequency change was accent production, it is possible that the quality of certain frequencies not used in the present study would interact with pattern temporal order in such a way as to confound the limits of invariant relations tentatively identified by the experimental outcomes. Such an observation would indicate an unfavorable comparison of relative redundancy with the second intensive condition.

Spectral variation of pattern events is another method whereby axiomatic comparisons can be investigated. The spectrum of a wave consists of three dimensions (frequency, amplitude, and phase) which describe the wave completely and uniquely. In the present study, a single type of signal (sinusoidal) was used exclusively for stimulus production. Spectral variation would involve the use of different simple wave-forms (e.g., square wave, triangular wave) to produce rhythmic pattern events.

A positive comparison of relative redundancy attribute relations with ordinal and additive axioms under the conditions of spectral variation would indicate increased descriptive power of the perceptual model. Such an observation would indicate that internal attribute relations were independent of laws or rules which govern other rhythmic pattern properties, thus partially fulfilling the second intensive condition.

Summary

The present study provides initial evidence that (1) interconnective relations of the relative redundancy attribute and perceived rhythm compare favorably with, at least, the ordinal axioms and (2) the IRR and percent-correct pattern discrimination scales of measurement adequately reflect these relations. The findings, however, are limited because not all possible axiomatic comparisons were implemented in the experimental design. As a result, the descriptive and explanatory power of the perceptual model is restricted to those specific signal properties used in the study. Future research which develops the comparison strategies outlined above should allow (1) clarification of attribute and characteristic parameters, (2) further analysis of the adequacy of the IRR and percent-correct pattern discrimination scales of measurement, and (3) increased generalizability of the perceptual model.

Other Research Issues

The findings of the present study suggest that the following additional research questions warrant investigation if a more complete understanding of the perceptual processing of rhythmic auditory patterns is to be achieved.

1. What is it about musical training that produces differences in perceptual skill with regard to the discrimination of auditory patterns?

2. How stable are listener criteria for differences in auditory patterns? Can listener criteria be influenced by (a) manipulation of the motivational matrix, (b) manipulation of the opinion probability that two patterns will differ, or (c) feedback concerning discrimination accuracy?

3. If short term memory is a factor, can manipulation of short term memory produce differences in pattern discrimination (e.g., variation of inter-pattern interval, variation of stimulus response interval)?

4. If attention is a factor, can manipulation of attention produce discrimination differences (e.g.,

presence vs. absence of a distracting task such as counting events)?

CHAPTER VII

SUMMARY AND CONCLUSIONS

Introduction

Background

Traditional theories pertaining to the perceptual processing of auditory pattern temporal order have generally followed one of two strategies. One approach has been to portray the auditory sequence as an associative chain of elements which are successively perceived. The second approach has focused upon overall pattern context with individual elements being perceived in relation to the total pattern.

An alternative approach is possible through an explanation of the structure of whole patterns in terms of special combinations of the individual elements (Lashley, 1951). Based on this concept, Martin (1972) has developed rules of relative accent level and relative timing which describe maximum regularity with regard to accent placement and durational change in auditory patterns.

In the present study, a method was developed whereby levels of relative redundancy in rhythmic patterns can be quantified. This procedure results in an index of relative redundancy which compares the regularity of a given pattern to the maximum regularity possible for a pattern of the same length (number of elements). Regularity is defined in the manner proposed by Martin.

An original perceptual model was proposed to illustrate how the perceptual system may make use of temporal structure in the encoding, decoding, and recoding of auditory events. The model accommodates Martin's concepts of relative accent level and relative timing, and deals explicitly with the effect of redundancy reduction (Barlow, 1969) on the perceptual processing of serially ordered patterns.

Purpose

This study was designed to investigate the effect of certain temporal structures present in rhythmic auditory stimuli on the discrimination of temporal order. Martin's two rules were used as a structural framework to categorize patterns as either regular or irregular and to generate experimental sound sequences. Pitch variation and durational change among pattern events were used to produce accent. Listener responses were obtained as a function of musical training, pattern type (regular vs. irregular), accent mode (frequency vs. duration), and experimental trials (Trial 1, Trial 2). The percent-correct pattern discrimination scores were analyzed in order to answer the following questions:

1. With what consistency do normal hearing persons with and without musical training discriminate rhythmic auditory patterns which differ in regularity (that is, regular vs. irregular)?

2. Does pattern regularity significantly influence discrimination of rhythmic auditory patterns?

3. Does musical training significantly influence discrimination of rhythmic auditory patterns?

4. Does accent mode (that is, pitch variation vs. duration variation) significantly influence discrimination of rhythmic auditory patterns?

5. Do the factors of pattern regularity and musical training interact to significantly influence discrimination of rhythmic auditory patterns?

6. Do the factors of accent mode and musical training interact to significantly influence discrimination of rhythmic auditory patterns?

7. Do the factors of accent mode and pattern regularity interact to significantly influence discrimination of rhythmic auditory patterns?

8. Do the factors of musical training, accent mode, and pattern regularity interact to significantly influence discrimination of rhythmic auditory patterns?

A supplemental analysis was accomplished to compare the relative redundancy level quantification procedure with listener discriminations of pattern regularity.

Experimental Design

Subjects

Two groups of normal hearing subjects were used. Group 1 consisted of 26 non-music majors with high levels of musical training. Group 2 consisted of 26 non-music majors with little or no musical training. Differentiation of subjects was based on the results of a musical ability test and two questionnaires.

Stimuli

Sixteen pairs of experimental and dummy rhythmic patterns with different levels of inter-event temporal regularity (8 regular, 8 irregular) were developed for the experiment. For four of the regular and irregular pairs of patterns, accent was marked through a binary frequency change (frequency accent mode). Each pattern consisted of eight elements. For the other regular and irregular pairs of patterns, accent was marked by a bi-level durational change among pattern events (duration accent mode). These patterns contained from 11 to 14 elements.

An ABX paradigm was used for each experimental-dummy pattern pairing. All four possible combinations of each pair of patterns were used. Thus, there were 32 test items for the frequency accent mode and 32 test items for the duration accent mode. Test items were randomized within each of the two blocks.

Procedures

Subjects were assigned to one of four subgroups within each of the two experimental groups. Subgroups were tested individually. Experimentation consisted of two separate trials for all subjects. The two trials were separated by a four-week interval. Subjects responded to all 64 test items in both trials.

Test materials were presented through individual headphone sets. Both the frequency and duration accent mode blocks of test items were preceded by taped instructions and three practice items. Subjects then listened to and gave a written response to each test item.

Presentation Orders

Presentation order of the test items for the two accent modes was counterbalanced such that in Trial 1, half of the subjects in both groups listened to the frequency accent mode items first followed by the duration accent mode items; the other half of both groups listened to the duration accent mode test items first followed by the frequency mode items. Order of presentation of the two accent modes was reversed for all subjects in Trial 2. All other experimental procedures were identical for both trials.

The dependent variable under investigation was percent-correct pattern discrimination. The resulting data formed a four-dimensional matrix consisting of groups (trained vs. untrained), pattern type (regular vs. irregular), accent modes (frequency vs. duration), and trials (first vs. second).

Findings

Findings of the study include the following.

1. High intra-trial reliability coefficients (KR20, split-half) suggest that test items in both accent modes produced similar patterns of response and provided an accurate measure of the experimental effects under investigation.

2. Analysis of inter-trial reliability showed a moderate but substantial strength of relationship. The two experimental groups did not differ significantly in their inter-trial consistency; nor did the two orders of presentation of accent modes produce statistically significant differences in inter-trial consistency.

3. The mean discrimination scores for Group 1 were higher than mean discriminations for Group 2. This was so within accent modes and within regularity conditions.

4. The mean percent-correct discrimination scores obtained with regular rhythmic patterns were consistently higher than those obtained with irregular patterns.

5. The mean percent-correct discrimination scores obtained in the frequency accent mode were higher than those obtained in the duration accent mode.

6. There were no significant interactions among the factors of group, pattern type, or accent mode in either experimental trial.

7. The proposed quantification of regularity (index of relative redundancy--IRR) produced values monotonically related to percent-correct discrimination scores.

Conclusions

The results of this study provide the basis for the following conclusions.

1. Differences in levels of pattern regularity (as described by the rules of relative timing and relative accent level) significantly influences pattern discrimination. Rhythmic patterns which adhere to the maximum regularity described by the two rules are more accurately discriminated than patterns which violate the rules.

2. The effect of pattern regularity upon discrimination is not limited to one mode of accent generation. Greater discriminatory accuracy for regular patterns appears to be true at least for patterns in which accent is marked through bi-level pitch variation and bi-level durational change.

3. Musical training and experience significantly influence pattern discrimination. Listeners with higher levels of musical experience display greater skill in judging rhythmic patterns than listeners with little or no musical training.

4. Frequency change, used as a means to produce accent, appears to allow for greater accuracy in pattern discrimination than does durational change.

5. The proposed perceptual model appears to provide an adequate description for certain aspects of the perceptual processing of rhythmic auditory patterns. Specifically, the model accommodates (1) the effect of differences in levels of musical training on pattern perception, (2) the effect of levels of relative redundancy in rhythmic patterns on discrimination accuracy, and (3) the effect of different types of accent generation on pattern discrimination.

6. The index of relative redundancy (IRR) appears to be a useful measurement of relative redundancy levels present in rhythmic patterns.

7. Experimentation of the type described in the present study would benefit from more rigorous control of the audiometric status of subjects and the levels at which signals are presented.

8. The findings of this study are sufficiently encouraging to warrant additional research concerning (1) the effect of levels of rhythmic pattern regularity on pattern discrimination, (2) the nature of the relative redundancy attribute, (3) the sufficiency of the IRR scale as a measure of relative redundancy, and (4) the accuracy of the perceptual model.

APPENDICES

APPENDIX A

MUSICAL ABILITY TEST AND BACKGROUND QUESTIONNAIRES

APPENDIX A

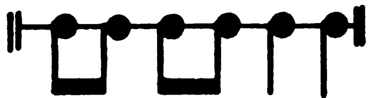
MUSICAL ABILITY TEST AND BACKGROUND QUESTIONNAIRES

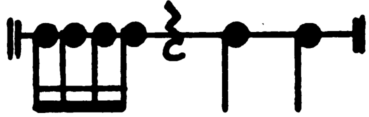
The following musical ability test and background questionnaires were used to differentiate subjects on the basis of musical experience and training. The ability test allowed for observation of subjects' aural and cognitive musical skills. The questionnaires were used to discover (1) the nature of subjects' previous formal musical instruction, (2) duration of involvement in formal instruction, (3) performing ensemble participation, and (4) musical style preferences.

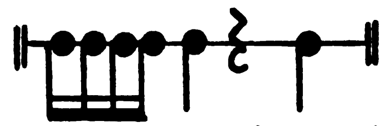
Subjects whose Z scores were greater than .81 above the mean on the musical ability test were classified as "high" in ability (N = 26); those whose Z scores were less than -.81 below the mean were classified as "low" in musical ability (N = 26). The questionnaires were used to confirm what was observed on the musical ability test.

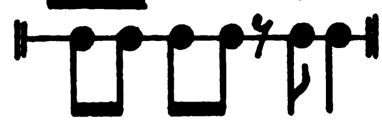
MUSICAL ABILITY TEST

1. A rhythm pattern will be played twice. Select the correct notation for the excerpt performed.

1. 

2. 

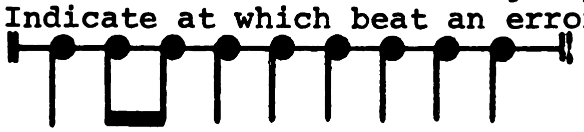
3. 

4. 

2. You will hear a series of beats grouped through the use of accents. Select the answer which best describes what you have heard.

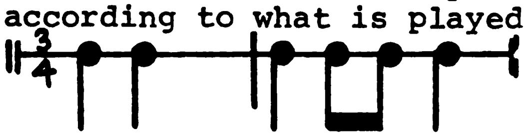
   1. two beats per group
   2. three beats per group
   3. four beats per group
   4. five beats per group

3. You will hear the following rhythm pattern twice. Indicate at which beat an error is performed.



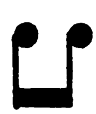
   1. beat number three
   2. beat number four
   3. beat number five
   4. beat number seven

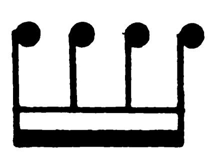
4. A rhythmic example is provided below. Select the correct notation to complete the first measure according to what is played.



1. 

2. 

3. 

4. 

5. You will hear four, five-tone patterns starting on the pitch, F. Only one will be the correct pattern for singing a major triad from the root (1,3,5,3,1). The correct pattern is:

   1. example 1
   2. example 2
   3. example 3
   4. example 4

6. You will hear one of four triad types played. The triad type is:

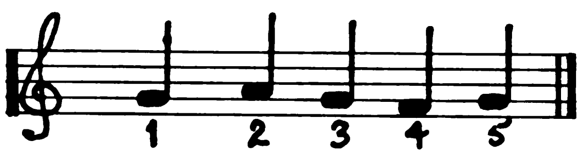
   1. a minor triad
   2. a major triad
   3. a diminished triad
   4. an augmented triad

7. You will hear a melodic interval played either ascending or descending. What is the interval ?

   1. a perfect fourth
   2. a perfect fifth
   3. a perfect octave
   4. a major third

8. You will hear a sequence of five pitches. By following the written example below, indicate on which beat an error occurred.

   1. on beat 2
   2. on beat 3
   3. on beat 4
   4. on beat 5



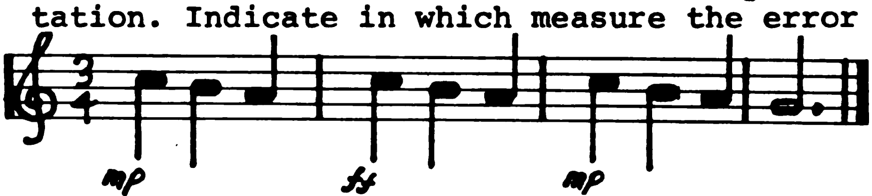
9. You will hear one of the scales listed below. Which scale do you hear ?

   1. an Aeolian mode
   2. a major scale
   3. a chromatic scale
   4. a harmonic minor scale

10. You will hear a short melodic-rhythmic example. Determine how you might characterize it in relation to the unity-variety continuum.

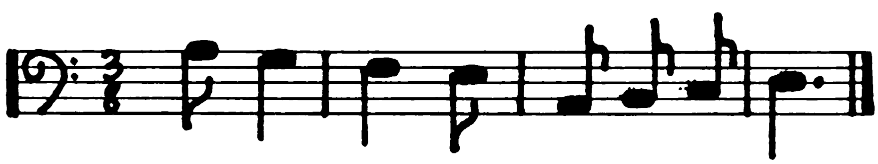
    1. more unity than variety
    2. more variety than unity
    3. balance between unity and variety

11. You will hear a short excerpt for which you have the notation. There will be an error in dynamic interpretation. Indicate in which measure the error occurs.



    1. in measure 1
    2. in measure 2
    3. in measure 3
    4. in measure 4

12. You will hear a short excerpt that features an error in tempo modification. The notation for this excerpt is shown below. Indicate which variation in tempo term is performed.



    1. tempo giusto
    2. tempo rubato
    3. meno mosso
    4. accelerando

Part II: Cognitive

---

13. The basic durational unit in music is known as:

    1. scale
    2. rhythm pattern
    3. accent
    4. beat

14. The pace at which music moves is called:

    1. timbre
    2. accent
    3. tempo
    4. rhythm

15. Periods of silence in music are indicated by:

    1. rests
    2. notes with dots
    3. ties
    4. dots

16. If ♩ has a value of 1 beat, then 𝅗𝅥 has a value of:

    1. 4/3 beats
    2. 1/2 beats
    3. 2 beats
    4. 3 beats

17. If ♩ has a value of 1/2 beat, then 𝅝 has a value of:

    1. 2 beats
    2. 3 1/2 beats
    3. 4 beats
    4. 2 1/2 beats

18. To yield a single sound of greater duration, two notes representing the same pitch may be joined by:

    1. a plus sign
    2. a barline
    3. a slur
    4. a tie

19. A dot placed immediately after a note means that the total durational value equals that of the original note plus:

1. 2/3 the note's value
2. 1/2 the note's value
3. 1/4 the note's value
4. twice the note's value

20. Eight  are equal to two:

1.  2.  3.  4. 

21. Two  are equal to four:

1.  2.  3.  4. 

22. The distances between barlines are known as:

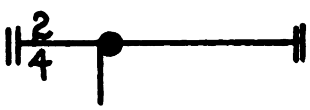
1. clefs
2. measures
3. double bars
4. meters

23. The grouping of beats is called:

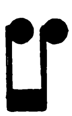
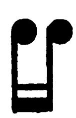
1. unit-patterns
2. beat
3. meter
4. barlines

24. Measure signatures indicate:

1. beats per measure
2. unit-patterns per measure
3. amount of notation per measure
4. rhythm-patterns per measure

25. 

would be complete if

1.  was added
2.  was added
3.  was added
4.  was added

26. In the basic scales, the half steps occur between:

1. C-D and F-G
2. F-G and E-F
3. B-C and E-F
4. G-A and A-B

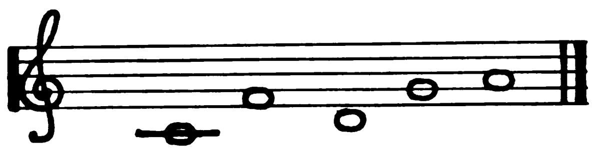
27. The sharp is a symbol that:

1. raises a natural tone a half step
2. lowers a natural tone a half step
3. raises a natural tone a whole step
4. lowers a natural tone a whole step

28. The flat is a symbol that:

1. raises a natural tone a half step
2. lowers a natural tone a half step
3. raises a natural tone a whole step
4. lowers a natural tone a whole step

29. The names of the following notes are:



1. C,F,E,G,A
2. C,E,F,A,B
3. C,F,D,G,A
4. C,F,D,G,B

30. When a major third is made smaller by a half step, it becomes:

1. a diminished third
2. an augmented third
3. a tritone
4. a minor third

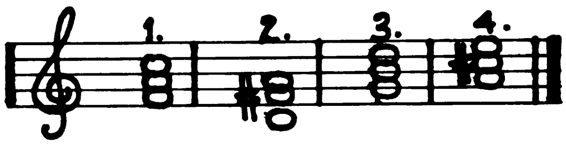
31. A triad is a chord of:

1. three different pitches
2. two different pitches
3. four different pitches
4. two tritones

32. The three triad members are identified as the:

    1. second, fourth, and sixth
    2. root, fourth, and sixth
    3. root, third, and fifth
    4. third, fifth, and octave

33. Of the four examples below, the one that is correctly spelled as an A-major triad is:



1. Example 1	3. Example 3
2. Example 2	4. Example 4

34. An orderly, horizontal succession of tones heard as the dominating line in music is called:

1. a scale	3. an Aeolian mode
2. a melody	4. the dominant

35. In the major scale, half steps occur between scale members:

1. 4-5 and 6-7	3. 1-2 and 5-6
2. 3-4 and 7-8	4. 2-3 and 6-7

36. The G major scale includes the following pitches as scale members:

1. F# and G#	3. F#, A#, and C#
2. Bb	4. F#

37. In the major scale, the tonic (keynote) is always:

    1. a half step below the first alteration sign in the key signature
    2. a half step above the last sharp or the next to last flat
    3. a half step below the last alteration sign in the key signature
    4. a half step above the last flat in the key signature

38. In a composition, variety is achieved through:

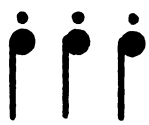
1. contrast
2. unity
3. restatement
4. balance

39. Which symbol represents the same meaning as the term, crescendo ?

1. >
2. *mp*
3. 
4. 

40. A fermata (𝄐) indicates a tone is to be:

1. shortened
2. slurred
3. tongued
4. held longer

41. Tones marked  are played:

1. slurred
2. staccato
3. held
4. normal duration

42. Which of the following indicates the slowest tempo ?

1. largo
2. allegro
3. presto
4. adagio

43. If sound quality is varied, it is variation in:

1. tempo
2. timbre (tone color)
3. articulation
4. beat

MUSICAL BACKGROUND QUESTIONNAIRE I

NAME: ________________________________ Student No.________
(last) (first) (middle)

Instruments you play or have played: _____________yrs.___

_____________yrs.___

Musical organizations you have performed in at junior and senior high schools:

Band_____ yrs._____ Glee Club_____ yrs._____

Orch.____ yrs._____ Other________________yrs.___

Choir____ yrs._____

Recreational Instruments you play: Guitar_____(and type

_____________________)
(pop, rock, folk)

Recorder_____

Other_________________

List family members who play a musical instrument

____

Record collection: small moderate extensive

Types of records collected: folk, popular, classic or

describe____

<u>Other music courses</u> taken in high school or college:

____________________________________ describe:

____________________________________ describe:

<u>Musical participation</u>: little average a great deal
(circle answer)

<u>Participation preference</u>: listening singing

playing an instrument

How? solo or in a group ?

MUSICAL BACKGROUND

QUESTIONNAIRE II

Name: ______________________

Student Number: ____________

Major: _____________________

Other: _____________________

MUSICAL BACKGROUND

1. Have you ever taken a music course at the college or university level?

   Yes_____ No_____

   If yes, please give the name of the course(s), a brief description of the material covered, and at what institution you participated in the course.

   ____

   ____

2. Please indicate the performing ensembles in which you have taken part during public school. Include the type of ensemble (band, orchestra, choir, etc.) as well as the number of years of participation.

   ____

   ____

   ____

3. Have you studied music privately? Yes_____ No_____ If yes, please indicate the number of years of study, the instrument studied, and when the instruction took place.

Instrument	No. of Years	When

4. If you are presently studying or working with a musical instrument, please indicate.

Instrument	No. of Years	Private Instruction?

5. Please indicate those performing ensembles in which you have taken part outside of the formal education system (church, community, etc.)

____

____

6. If you have studied music theory either privately or in public schools, please describe below.

____

____

7. Please indicate any professional performing groups in which you have taken part.

____

____

8. Please give an indication as to your personal preference in regard to musical styles.

____

____

APPENDIX B

FREQUENCY ACCENT MODE EXPERIMENTAL AND DUMMY PATTERNS

APPENDIX B

FREQUENCY ACCENT MODE EXPERIMENTAL AND DUMMY PATTERNS

The table which follows illustrates the frequency accent mode experimental and dummy pattern pairings used in the study. Two test frequencies of 3001 Hz (± 1 Hz) and 1028 Hz (± 1 Hz) were used in pattern generation. The higher frequency was positioned at those temporal points designated for stronger accent placement. Each pattern event consisted of a signal on-time of 210 msec followed by a silent interval (off-time) of 90 msec. Rise/fall time for each event was 12 msec.

TABLE B-1. Frequency accent mode experimental and dummy patterns. The number "1" denotes the location of the higher test frequency (3001 Hz) in the pattern, while the "0" indicates lower frequency (1028 Hz) position.

Pattern No.	Pattern Type: Regular — Experimental	Regular — Dummy	Irregular — Experimental	Irregular — Dummy
1	11101000	11101010	11100100	11000100
2	11001110	10001110	11000110	10000110
3	10101000	10101100	10110110	10110010
4	10101110	10101100	11010100	11010110

APPENDIX C

DURATION ACCENT MODE EXPERIMENTAL AND DUMMY PATTERNS

APPENDIX C

DURATION ACCENT MODE EXPERIMENTAL AND DUMMY PATTERNS

The table which follows illustrates the duration accent mode experimental and dummy pattern pairings used in the study. A single test frequency of 1040 Hz (± 1 Hz) was used as the sound portion of all pattern events. Accent was produced through a bi-level change in duration among pattern events. The two durational values used were in a 2:1 ratio; that is accented events were twice as long as unaccented events.

Duration mode patterns were arranged according to an eight-beat arrangement of events. Because of the use of two different durations, patterns ranged from 11 to 14 elements in length.

The frequency signal on-time for both long and short durational events was about 80 msec with a rise/fall time of 12 msec. Signal on-time for the longer duration was followed by a silent interval (off-time) of about 160 msec. For the shorter duration, signal on-time was followed by a silent interval of about 40 msec. Thus, total duration for longer durational events was about 240 msec, while total duration for shorter events was about 120 msec.

TABLE C-1. Duration accent mode experimental and dummy patterns. The number "1" denotes the location of the longer durational value, while the "0" indicates the positions for shorter durations.

Pattern No.	Pattern Type: Regular		Pattern Type: Irregular	
	Experimental	Dummy	Experimental	Dummy
1	111001000000	11100100100	111000010000	1100000010000
2	11000011100	100000011100	110000001100	1000000001100
3	1001001000000	100100110000	10011001100	100110000100
4	10010011100	100100110000	110010010000	11001001100

APPENDIX D

ORDER OF FREQUENCY AND DURATION

ACCENT MODE STIMULUS EVENTS

APPENDIX D

ORDER OF FREQUENCY AND DURATION ACCENT MODE STIMULUS EVENTS

The two tables which follow present the order for the 32 frequency accent mode (Table D-1) and 32 duration accent mode (Table D-2) stimulus events. Each pair of experimental and dummy patterns in both modes were generated and recorded in four different combinations so as to accommodate the ABX paradigm comparison format. A pause of approximately 500 msec was inserted between each of the three patterns in each stimulus event. The order of the 32 stimulus events for each accent mode was randomized with the following constraints:

1. Regular rhythmic pattern stimulus events were always preceded and followed by irregular rhythmic pattern stimulus events and vice versa.

2. The four combinations for each experimental-dummy pattern pairing were counterbalanced within each of the two blocks of 32 stimulus events.

TABLE D-1. Order of frequency accent mode stimulus events. The four combinations of experimental-dummy pattern pairings are represented as follows: "A," experimental-dummy-experimental; "B," experimental-dummy-dummy; "C," dummy-experimental-dummy; "D," dummy-experimental-experimental. A pause of about 500 msec was inserted between each of the three patterns in a stimulus event.

Item Number	Pattern Type	Pattern Number	Combination
1	Regular	1	C
2	Irregular	2	D
3	Regular	3	A
4	Irregular	4	B
5	Regular	2	D
6	Irregular	3	A
7	Regular	4	B
8	Irregular	1	C
9	Regular	3	D
10	Irregular	4	C
11	Regular	1	B
12	Irregular	2	A
13	Regular	4	C
14	Irregular	1	B
15	Regular	2	A
16	Irregular	3	D
17	Regular	1	A
18	Irregular	2	C
19	Regular	3	B
20	Irregular	4	D
21	Regular	2	B
22	Irregular	3	C
23	Regular	4	D
24	Irregular	1	A
25	Regular	3	C
26	Irregular	4	A
27	Regular	1	D
28	Irregular	2	B
29	Regular	4	A
30	Irregular	1	D
31	Regular	2	C
32	Irregular	3	B

TABLE D-2. Order of duration accent mode stimulus events. The four combinations of experimental-dummy pattern pairings are represented as follows: "A," experimental-dummy-experimental; "B," experimental-dummy-dummy; "C," dummy-experimental-dummy; "D," dummy-experimental-experimental. A pause of about 500 msec was inserted between each of the three patterns in a stimulus event.

Item Number	Pattern Type	Pattern Number	Combination
1	Irregular	1	C
2	Regular	2	B
3	Irregular	3	D
4	Regular	4	A
5	Irregular	2	B
6	Regular	3	D
7	Irregular	4	A
8	Regular	1	C
9	Irregular	3	A
10	Regular	4	B
11	Irregular	1	D
12	Regular	2	C
13	Irregular	4	D
14	Regular	1	A
15	Irregular	2	C
16	Regular	3	B
17	Irregular	1	A
18	Regular	2	D
19	Irregular	3	B
20	Regular	4	C
21	Irregular	2	A
22	Regular	3	C
23	Irregular	4	B
24	Regular	1	D
25	Irregular	3	C
26	Regular	4	D
27	Irregular	1	B
28	Regular	2	A
29	Irregular	4	C
30	Regular	1	B
31	Irregular	2	D
32	Regular	3	A

APPENDIX E

SIGNAL PRESENTATION LEVEL MEASUREMENTS

OF EXPERIMENTAL EARPHONES

APPENDIX E

SIGNAL PRESENTATION LEVEL MEASUREMENTS OF EXPERIMENTAL EARPHONES

It is normally desirable to specify signal presentation level through objective measurement of the sound pressure level (SPL) generated by an earphone. Such measurement employs a standard acoustic coupler, the volume of which simulates the volume observed between the earphone diaphragm and the eardrum of an "average" listener. The coupler is attached to a calibrated microphone-sound level meter system, and SPL is measured in decibels (re: 20 μ Pa). This approach was not possible with the earphones available for the experiment because the cushions of these earphones are too large for the coupler that was available for calibration. For this reason, it was necessary to indirectly measure signal presentation level through the use of a loudness balancing procedure and a "standard" laboratory earphone, the cushion of which permitted coupler calibration. These measurements were performed after experimental data were gathered.

The standard earphone was a Telephonic TDH-39 audiometric driver mounted in a MX-41/AR supra-aural cushion. Loudness matching was performed in a sound-treated test chamber by an experienced listener (M. R. Chial) using an alternate binaural loudness balance (ABLB) paradigm and a psychophysical method of adjustment. A 1.0-kHz sinusoid was employed in the balancing procedure.

The indirect level calibration began with a measurement of the voltage at the terminals of the experimental earphones under conditions as identical as possible to those used in the testing of subjects. A steady-state reference tone (1.0 kHz) was recorded and reproduced by the Ampex AG-500 tape recorder. The tape recorder input level control was set to produce a 0 VU for the reference tone. The multiple headphone driver was equipped with eight separate level controls, one for each earphone set. The electrical resistance of a mid-scale setting of one level control was measured with an ohmeter. The remaining controls were adjusted to produce the same resistance. Each of the earphones was also adjusted to the same loudness level (about three-fourths of full-scale). A single experimental earphone was selected, and the input voltage was measured with an RMS voltmeter (Heath Sclumberger, Model SM-4100). This voltage was found to be 250 mv.

The equipment configuration depicted in Figure E-1 was produced. This instrumentation allowed alternating

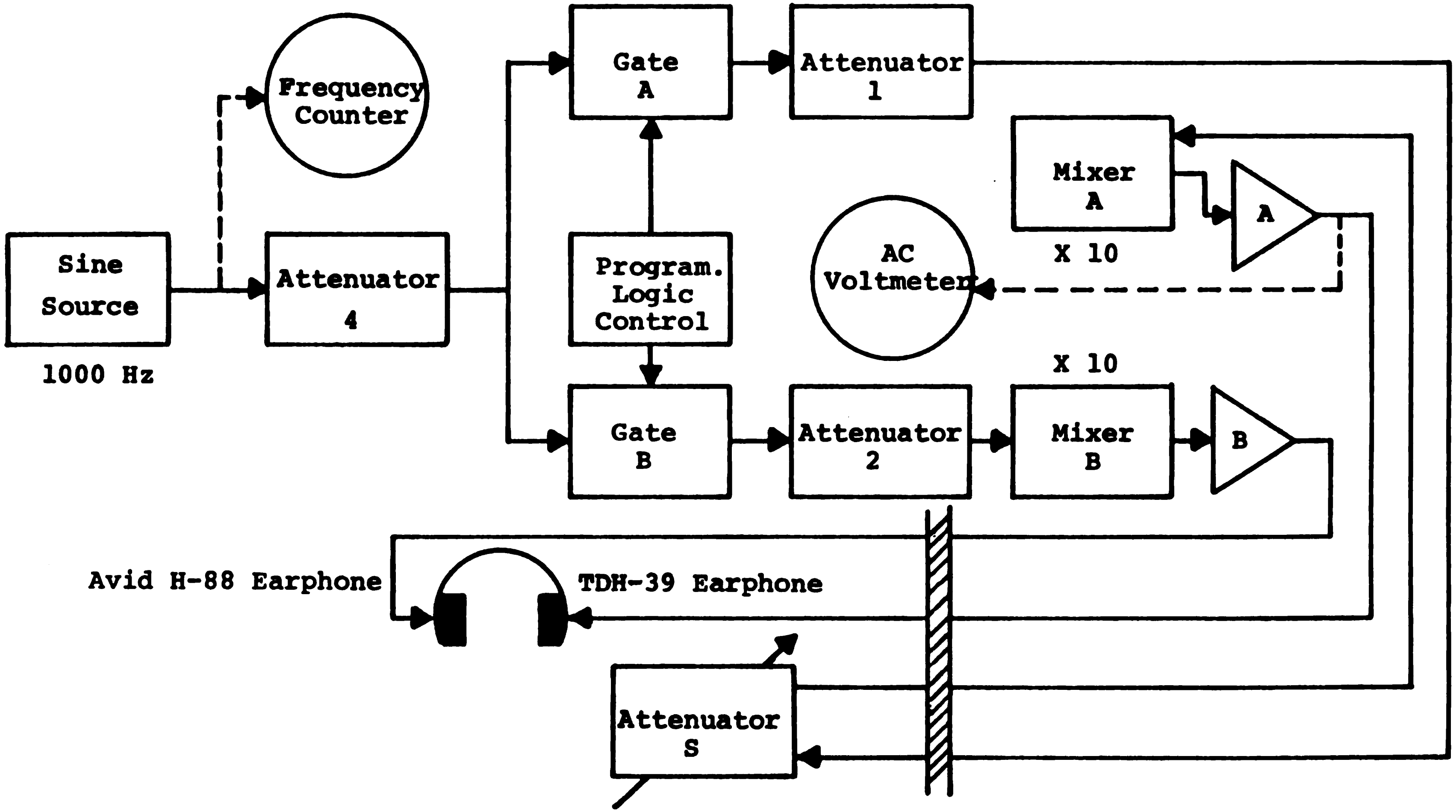


Figure E-1. Apparatus used for the loudness matching operation.

presentation of a test signal (1.0 kHz) to the experimental and standard earphones. The input voltage presented to the experimental earphone was adjusted to 250 mv. The unused driver of the experimental headphone set was taped to reduce the signal produced by that driver to an inaudible level. The single standard earphone was placed under the unused experimental driver so that the headband of the experimental earphone held both active earphones in place. The experimenter entered a randomly chosen attenuation value at the "control" attenuator (to reduce expectancy bias) and the listener adjusted his attenuator until the signals produced by the two earphones were judged equally loud. This process was repeated for several trials and for both pairings of ears and earphones. The result was a mean total attenuation (in decibels) in the signal line to the standard earphone. Consistency of measurement was ± 3 dB.

With this mean attenuation, the coupler SPL of the standard earphone was measured following the procedure specified in ANSI S3.7 (1973). The earphone was joined to an NBS-9A acoustic coupler with a 400-gram mass. The coupler was attached to a precision condenser microphone (Bruel and Kjaer 4144) and precision sound level meter (Bruel and Kjaer, Type 2204) which previously had been calibrated with a sound level calibration set (General

Radio, 1986). The standard earphone coupler SPL measured in this manner was 60 dB.

Assuming that experimental subjects had normal auditory sensitivity, the indirectly measured presentation level would be easily audible and comfortable. Again, assuming normal sensitivity, a SPL of 60 dB would be expected to be approximately 50 dB above threshold. This is an estimate because the auditory thresholds of listeners were not measured. Nonetheless, it is reasoned that experimental signals were presented at levels great enough to minimize effects due to variations in the absolute sensitivity of listeners.

An additional auditory comparison (this one informal) between standard and experimental earphones suggested that the experimental earphones produced signals of comparable loudness in the frequency range, 300-4000 Hz.

APPENDIX F

RESPONSE SHEET FOR THE LISTENING TASK

APPENDIX F

RESPONSE SHEET FOR THE LISTENING TASK

RESPONSE SHEET

NAME:____________________________ SUB. NO.______________

STUDENT NUMBER:________________ GRP. NO.______________

PHONES________________

MODE ORDER________________

EXAMPLE I	1	2
EXAMPLE II	1	2
EXAMPLE III	1	2

RESPONSE SHEET

NAME:______________________________ SUB. NO.______________

STUDENT NUMBER:__________________ GRP. NO.______________

PHONES______________

MODE ORDER________________

1.	1	2	17.	1	2
2.	1	2	18.	1	2
3.	1	2	19.	1	2
4.	1	2	20.	1	2
5.	1	2	21.	1	2
6.	1	2	22.	1	2
7.	1	2	23.	1	2
8.	1	2	24.	1	2
9.	1	2	25.	1	2
10.	1	2	26.	1	2
11.	1	2	27.	1	2
12.	1	2	28.	1	2
13.	1	2	29.	1	2
14.	1	2	30.	1	2
15.	1	2	31.	1	2
16.	1	2	32.	1	2

TOTAL________ RRP________ IRP________

APPENDIX G

TABULAR SUMMARY OF PERCENT-CORRECT

DISCRIMINATION SCORES FOR INDIVIDUAL SUBJECTS

APPENDIX G

TABULAR SUMMARY OF PERCENT-CORRECT DISCRIMINATION SCORES FOR INDIVIDUAL SUBJECTS

The four tables which follow summarize the percent-correct discrimination scores for individual subjects. Table G-1 summarizes discrimination scores for Group 1 in Trial 1. Table G-2 lists the same information for Group 2. Table G-3 summarizes the discrimination scores for Group 1 in Trial 2. Table G-4 lists the same information for Group 2.

TABLE G-1. Summary of percent-correct discrimination scores for individual subjects of Group 1 in Trial 1.

	Frequency Mode		Duration Mode	
	Pattern Type		Pattern Type	
Subject	Regular	Irregular	Regular	Irregular
1	100.0	87.5	81.3	75.0
2	93.8	81.3	56.3	62.5
3	93.8	81.3	81.3	62.5
4	100.0	87.5	87.5	68.8
5	93.8	87.5	75.0	68.8
6	100.0	68.8	56.3	50.0
7	93.8	93.8	87.5	56.3
8	62.5	68.8	68.8	68.8
9	81.3	75.0	75.0	81.3
10	87.5	68.8	93.8	68.8
11	81.3	75.0	87.5	62.5
12	100.0	81.3	93.8	87.5
13	68.8	68.8	68.8	62.5
14	100.0	93.8	81.3	75.0
15	62.5	62.5	37.5	56.3
16	87.5	50.0	43.8	81.3
17	81.3	68.8	56.3	87.5
18	75.0	75.0	68.8	81.3
19	100.0	93.8	75.0	87.5
20	93.8	75.0	87.5	62.5
21	100.0	100.0	100.0	75.0
22	87.5	81.3	81.3	87.5
23	100.0	93.8	100.0	100.0
24	100.0	100.0	87.5	93.8
25	81.3	75.0	81.3	75.0
26	93.8	75.0	81.3	81.3

TABLE G-2. Summary of percent-correct discrimination scores for individual subjects of Group 2 in Trial 1.

	Frequency Mode		Duration Mode	
	Pattern Type		Pattern Type	
Subject	Regular	Irregular	Regular	Irregular
27	81.3	68.8	68.8	50.0
28	81.3	62.5	68.8	37.5
29	56.3	56.3	62.5	62.5
30	81.3	50.0	81.3	68.8
31	62.5	62.5	93.8	81.3
32	100.0	81.3	100.0	87.5
33	75.0	56.3	56.3	50.0
34	87.5	87.5	87.5	81.3
35	62.5	56.3	56.3	68.8
36	93.8	87.5	93.8	62.5
37	93.8	75.0	81.3	81.3
38	68.8	56.3	81.3	75.0
39	93.8	93.8	93.8	87.5
40	100.0	81.3	75.0	81.3
41	75.0	68.8	87.5	68.8
42	75.0	75.0	50.0	56.3
43	68.8	81.3	62.5	56.3
44	100.0	100.0	87.5	75.0
45	75.0	87.5	75.0	81.3
46	87.5	62.5	68.8	62.5
47	100.0	75.0	43.8	81.3
48	87.5	81.3	62.5	81.3
49	62.5	56.3	50.0	56.3
50	37.5	43.8	50.0	50.0
51	81.3	56.3	75.0	62.5
52	75.0	56.3	87.5	43.8

TABLE G-3. Summary of percent-correct discrimination scores for individual subjects of Group 1 in Trial 2.

	Frequency Mode		Duration Mode	
	Pattern Type		Pattern Type	
Subject	Regular	Irregular	Regular	Irregular
1	100.0	93.8	100.0	81.3
2	81.3	87.5	43.8	37.5
3	81.3	87.5	87.5	62.5
4	93.8	75.0	87.5	81.3
5	81.3	56.3	93.8	75.0
6	81.3	93.8	81.3	75.0
7	100.0	75.0	68.8	68.8
8	62.5	87.5	50.0	50.0
9	68.8	75.0	87.5	81.3
10	100.0	75.0	93.8	68.8
11	100.0	93.8	75.0	43.8
12	93.8	81.3	81.3	87.5
13	93.8	68.8	81.3	75.0
14	87.5	75.0	75.0	50.0
15	81.3	75.0	68.8	56.3
16	87.5	62.5	75.0	75.0
17	75.0	81.3	62.5	50.0
18	81.3	62.5	81.3	62.5
19	93.8	81.3	87.5	56.3
20	87.5	75.0	68.8	75.0
21	100.0	93.8	100.0	68.8
22	93.8	87.5	81.3	75.0
23	100.0	100.0	100.0	93.8
24	100.0	100.0	100.0	93.8
25	87.5	81.3	75.0	56.3
26	81.3	81.3	81.3	68.8

TABLE G-4. Summary of percent-correct discrimination scores for individual subjects of Group 2 in Trial 2.

	Frequency Mode		Duration Mode	
	Pattern Type		Pattern Type	
Subject	Regular	Irregular	Regular	Irregular
27	56.3	62.5	68.8	62.5
28	68.8	68.8	56.3	62.5
29	56.3	62.5	56.3	68.8
30	93.8	62.5	68.8	68.8
31	81.3	62.5	81.3	56.3
32	93.8	81.3	93.8	75.0
33	50.0	56.3	62.5	56.3
34	75.0	81.3	93.8	87.5
35	81.3	62.5	68.8	62.5
36	50.0	37.5	56.3	50.0
37	100.0	93.8	87.5	50.0
38	81.3	50.0	75.0	75.0
39	93.8	81.3	87.5	75.0
40	93.8	93.8	100.0	87.5
41	56.3	87.5	68.8	50.0
42	75.0	68.8	62.5	75.0
43	68.8	68.8	87.5	50.0
44	87.5	87.5	81.3	93.8
45	87.5	81.3	87.5	75.0
46	81.3	68.8	68.8	62.5
47	87.5	81.3	81.3	75.0
48	50.0	37.5	43.8	43.8
49	62.5	75.0	43.8	31.3
50	56.3	75.0	31.3	43.8
51	81.3	75.0	56.3	62.5
52	68.8	56.3	62.5	56.3

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