THE AURAL PERCEPTION OF PITCH-CLASS SET RELATIONS:
A COMPUTER-ASSISTED INVESTIGATION

DISSERTATION

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By

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Allen Forte's theory of pitch-class set structure has provided useful tools for discovering structural relationships in atonal music. As valuable as set-theoretic procedures are for composers and analysts, the extent to which set relationships are perceptible by the listener largely remains to be investigated. This study addresses the need for aural-perceptual considerations in analysis, reviews related research in music perception, and poses questions concerning the aural perceptibility of set relationships. Specifically, it describes and presents the results of a computer-assisted experiment in testing the perceptibility of set-equivalency relationships.

The experiment consisted of three phases for participation by subjects: a perception ability test in which subjects were screened for absolute-pitch and interval recognition, an interactive tutorial on the fundamentals of set theory to provide subjects with some criteria for making judgments about set equivalency, and a perception test on recognizing equivalency relationships. All training and testing was administered using Apple microcomputers.

The perception test was designed to measure how recognition of set equivalency may be affected by the perceptual
ability of the listener, the set types used and the particular set manipulation involved in the equivalency relationship. The test paradigm consisted of the presentation of an original set followed by three comparison sets, one of which was transpositionally or inversionally equivalent to the original, the other two being non-equivalent lures in an Rp, R1 or R2 similarity relation with the original. Five set equivalency relationships were used: ordered transposition, ordered inversion, ordered transposition with octave displacement, reordered transposition and reordered inversion.

Statistical tests of subject-response data showed that: subjects with absolute-pitch recognition performed with more accuracy; ordered transformations were more recognizable than reordered transformations; transpositional equivalencies were more discernable than inversional equivalencies; octave displacement disguised set equivalency; and non-equivalent sets with similarity through contour or successive interval invariance were easily confused with equivalent sets.
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CHAPTER I

EXPLORATION OF THE PROBLEM

In recent years, Allen Forte's theory of set structure has gained great popularity and respect. Forte's method provides the analyst with a means of uncovering structural relationships in compositions for which traditional techniques of harmonic and formal analysis are inapplicable.

Some writings about the atonal, non-dodecaphonic works of Schoenberg, Berg and Webern have assumed them to have been composed only according to negative criteria—to avoid tonal associations and functional relationships. However, set-theoretic analyses have revealed important structural relationships in atonal music, suggesting that compositions are not random successions of unrelated pitches, but are organized successions, chosen from a limited vocabulary of set types and set relationships.

Perceptual Problems in Set-Theoretic Analysis

Forte does not pretend to have defined a theory of how structure in atonal music is aurally perceived. Nevertheless, among the many assessments of Forte's ideas, the problem of aural perceptibility of set relationships has been raised a number of times.
Questions Concerning the Perceptibility of Forte's Theory

The question, "How is musical structure actually perceived?" is not a new one. It has been as popular an objection to theoretical explanations of musical structure as that which insists that any valid analysis must be proven to have been a part of the composer's intent. Jim Samson, in his book on the music of the years 1900-1920, *Music in Transition*, raised both criticisms of Forte's theory. He doubted that set-theoretic procedures were a part of composers' conscious processes. He continued, "If, on the other hand, Forte's relationships are not a part of the conscious process of composition, they may equally be justified if they form, or could form, a part of our aural experience of the music."\(^1\)

As valuable as set-theoretic procedures are for composers and analysts, who have visual and stop-time aural access to the material, the listener must approach the work aurally in real time. According to Richmond Browne in his review of Forte's *The Structure of Atonal Music*, "when we listen to it [atonal music] we are left with our own competence, whatever it is, as our real-time listening resource as we try to find coherence."\(^2\)

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In a set-theoretic explication of a composition, the analyst seeks to uncover relationships among sonorities and among groups of sonorities in either their literal forms as stated pitches in the score or in their abstractions as prime-form pitch-class sets. But are these relationships, often only discovered after tedious manipulations of pitch-class set members, in any way apparent through aural analysis? "Are equivalent sets heard as equivalent?"  

Alfred Pike, in his discussion of the difficulties in the perception of serial music, stated that perceptibility is enhanced through analysis of the score, but he said this visual analysis "provides an aural deception, however, because what appears to be identical to the eye is quite different to the ear when the score is played or heard." Could this be also true of set-theoretic analyses?  

Browne admitted to his own difficulty in hearing what he was able to see in the written score. Forte, in his early exposition (1964) of set theory, stated that "...given two sets, one can immediately say whether or not they are in

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3 If the reader is not familiar with set theory as applied to the analysis of music, he may find Appendix C to be helpful. (See p. 161.)


the defined [inclusion] relation.""\(^6\) Responding to this claim, Browne stated, "The word 'immediately' applies only to computers; ...running even the set identification algorithms with a pencil, let alone the ear, is not an immediate process even with experience.""\(^7\) He continued,

One cannot attend to every sound and relation calculable in a presentation. Thus, although it is certainly valuable for Forte to have provided us with a stated relation linking any event to large numbers of possible events, it remains unlikely that anyone can actually discriminate between the various relatively large complexes which differ so little from one another.

Browne also admitted that,

half of the time, I am afraid that, though I may see that there is a definable pc/ic set comparison present, I cannot perform the act of perceiving the sounds presented on the two sides of the equivalence as members of a conceptual entity called an unordered pc/ic [pitch-class/interval-class] set.

An opposing viewpoint is that of Hans Keller who in speaking of the perception of twelve-tone relations said, "Everything that is recognizable on paper is recognizable 'by the ear alone.'"\(^8\) Is this also true of set-theoretic relationships? How perceptible are the relations defined in set theory?


\(^7\) Browne, op. cit., 402.

\(^8\) Ibid., 397.

\(^9\) Ibid., 400.

In Forte's theory of set structure, sets may be related through equivalence, through similarity relations and through inclusion relations. The closest relationship between two sets is the equivalence relation in which the sets "are reducible to the same prime form by transposition or by inversion followed by transposition."\(^\text{11}\) Although sets related to one another through transposition or inversion are by definition equivalent, it seems likely that all equivalent sets are not "equally equivalent" to the ear. Since recognition requires remembering, it seems certain that, for one, proximity in time would influence the perceptibility of any relationship between two sets. The excerpt shown in Figure 1 is an excerpt from Webern's "Five Movements for String Quartet, op. 5/5," given by Forte as an example of equivalence through transposition.\(^\text{12}\) This relationship is concealed not only through a separation in time by a distance of thirteen measures, but also by a difference in presentation: one set is stated melodically, the other harmonically. Another disguising factor is the ordering of set members; the second set (whether read from top to bottom or from bottom to top) is a reordering of the first set. The transposition relationship between the two sonorities is not visible (and presumably not audible) until


\(^{12}\) Ibid.
both are conceived in their normal orders, through which the second is seen to be a transposition of the first by ten half-steps.

Forte also gave an example from Webern's "Cello Sonata, 1914" (shown in Figure 2) in which two melodic sets are reordered transpositions of one another.\textsuperscript{13}

Examination of the rearrangement of the two sets in normal order reveals that the second is a transposition of the first by nine half-steps.

\textsuperscript{13}Ibid., p. 61.
Forte also provided an example of equivalence through transposition with an excerpt from Schoenberg's "Five Pieces for Orchestra, op. 16/2" in which none of the disguising factors of the previous examples exist.\(^4\) (See Figure 3.) In this example, both sets are presented melodically, in successive measures and with set-member order preserved.

Surely such an ordered transposition is more easily recognizable than one in which a reordering has taken place.

Forte gave further examples of equivalence using excerpts from Schoenberg's "George Lieder, op. 15/2" and "Five Pieces for Orchestra, op. 16/1."\(^5\) The difference in perceptibility between ordered- and reordered-equivalence relationships can be seen through a comparison of these examples (shown in Figure 4). The equivalency of the two sets in Figure 4a is visually and aurally more obvious; the sets' interval successions are identical, only reversed in direction. In

\(^4\)Ibid., p. 63.

\(^5\)Ibid., p. 63 and p. 11.
Figure 4b, interval successions, though similar, are not the same. Similarity between the two sets may be attributed not to their inversional relationship but to their pitch content; four of the sets' five pitches are identical.

Fig. 4—Ordered—versus reordered—set equivalencies.

From these examples, it can be seen that equivalency relationships come in a variety of forms. The nature of an equivalency relationship can be transpositional, inversional, ordered or reordered, and it may be further characterized through similarities or differences in presentation (melodic or harmonic), rhythmic setting, tempo, instrumentation, register and dynamics. Certainly, such varied relationships, although all by definition are "equivalent," would have varying degrees of perceptibility.

Need for Perceptual Considerations in Analysis

Some contend that audibility is not a criterion for significance in music. Was isorhythm in the fourteenth century perceptible, or crab canons in the eighteenth
century? Are not aurally obscure, visually apparent relationships significant in music? Yes, but only the composer or analyst may appreciate visual relationships; the listener must approach the music aurally.

Schoenberg expressed his belief in the importance of perceptual considerations in his Style and Idea (1950). He stated:

Form in the arts, and especially in music, aims primarily at comprehensibility. The relaxation which a satisfied listener experiences when he can follow an idea, its development, and the reasons for such development is closely related, psychologically speaking, to a feeling of beauty. Thus, artistic value demands comprehensibility...Composition with twelve-tones has no other aim than comprehensibility."\(^{16}\)

Later in the same work, he pronounced, "Every note a master has written should be perceived."\(^ {17}\)

On the importance of perceptual considerations, Robert Erickson said, "A music theory that does not take into account our perceptual processing and perceptual strategies cannot possibly be related to any real-world musical activity no matter how ingenious its superstructure."\(^ {18}\)

A number of other writers have pointed out the need for perceptual considerations in the analysis of music.

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\(^{16}\) Arnold Schoenberg, Style and Idea (New York, 1950), p. 103.

\(^{17}\) Ibid., p. 149.

Concerning serialism, Hans Keller wrote, "the aesthetic significance of serialism stands and falls with its audibility," and Alfred Pike echoed, "the meaning of serialism depends greatly upon its degree of perceptibility or audibility."

Keith Johnston, in "Musical Essence and Perception," attempted to show that analytical systems in general fail to account for our phenomenological experience of music. He believes that perception should be a part of our analytical explanations of musical structure. "Our perceptions exist, and through them we will find greater understanding." Thomas Fay also addressed this issue in his article, "Perceived Hierarchic Structure in Language in Music:

Analytic discussions of music are often concerned with processes that are not immediately perceivable. It may be that the analyst is concerned merely with the application of a collection of rules of practice or with the description of the compositional process. But whatever his aim, he often fails—most notably in twentieth-century music—to illuminate our immediate musical experience. It may be that the results of research on perceptual processes can lead us to a new analytic framework that will more closely describe our immediate reactions and will relate them to elements of construction and form.

20 Pike, op. cit., 55.
Forte's theory of sets and the assumptions of equivalence on which it is based were questioned by Diana Deutsch in her article, "The Processing of Pitch Combinations." She described Forte's system and made reference to the work of Howe, Lewin, Perle and Teitelbaum. She pointed out the need for research on perception of set structure in saying, "The extent to which the structures defined by such theories are processed by the listener remains to be determined." 23

In speaking to this need, the present study is an investigation of the perceptibility of set relationships, specifically the perception 24 of equivalent sets. Its purpose is to contribute to our understanding of the perception of atonal music and thereby to improve our analytical procedures and pedagogical methods.

Related Studies in Music Perception

A great number of studies on aural perception have been carried out by psychologists and acousticians, as well as by music educators and theorists. Studies which are particularly pertinent to this investigation are those which have dealt with the perception of relatedness between a melodic


24 The term "perception" is used here in the sense of pattern perception as in psychological research, rather than sensory perception as in audiological research.
pattern and its variants. A set and its equivalents when presented melodically may be considered as transpositional and inversional variants of the same motive; thus, research on the perception of melodic transformations directly relates to the present investigation.

Previous research on the perceptibility of melodic transformations has indicated factors which significantly affect recognition. The results of these studies and their relevance for the present study are given here. In this discussion, studies are grouped by topic as follows:

1. recognition of transposed melodies
2. recognition of transformed (inverted, retrograde or otherwise manipulated) melodies, and
3. recognition of twelve-tone row transformations.

Recognition of Transposed Melodies

Three studies on recognition of transposed melodic sequences are of particular interest. Dowling and Fujitani (1971)\(^25\) investigated short-term memory for five-tone, atonal melodies. They found that subjects could not distinguish exact transpositions from transposed same-contour imitations, but had little difficulty distinguishing transpositions from different-contour comparisons. This finding suggests that recognition of equivalency between

\(^{25}\)See Bibliography for complete references for works referred to in this section.
sets might be affected by the presence of same-contour, non-equivalent sets.

Experiments by Bartlett and Dowling (1980) attempted to judge the effect of transposition to a closely related key (the dominant) versus to a remote key (a tritone away). Subjects were asked to distinguish between transpositions of familiar melodies and tonal imitations which retained the same contour but changed the interval succession. Results showed fewer errors of recognition when transposition was to the distant key. This finding implies that the level of transposition involved could affect recognition of set equivalencies. It also confirms Dowling and Fujitani's finding that a melody similar in contour may be easily confused with an exact transposition.

A study of recognition for transposed sequences by Cuddy and Cohen (1976) was designed according to perceptual models which assumed that "accuracy in melody recognition is dependent upon accuracy of abstraction of the component intervals." Results showed that accuracy of recognition for three-note transposed sequences depended not only on the size of the intervals contained in the sequence, but on their order or configuration. This study indicates that recognition of set equivalency may be affected by the size.

of the intervals in the set and the ordering of the set's elements in the transformation.

Recognition of Transformed Melodies

Other researchers have dealt with the perception of melodic transformations other than transposition. Two studies by Jay Dowling (1971 and 1972) investigated the effect of inversion, retrograde and retrograde-inversion of melodies. He found the ascending order of perceptual difficulty to be: inversion, retrograde, retrograde-inversion. Inversions of melodies were also found to be more difficult to recognize than transpositions. Subjects also had difficulty in distinguishing transpositions from transposed same-contour comparisons and in distinguishing exact inversions from inversion of contour only.

Ronald Larsen (1972-1973) investigated the levels of cognitive reasoning involved in the solution of tasks concerning melodic permutation by children of various ages. He hypothesized that formal operational thought was required to conceptualize inversion, retrograde and retrograde-inversion of a melody. Results showed that the older subjects completed tasks faster and with fewer repetitions and only they accepted retrograde and retrograde-inversion as valid means of melodic variation, recognizing them to be systematically (even if not aurally) related to the original contour. This study suggests that the transformations of inversion, retrograde and retrograde-inversion are not all
equally recognizable and that the recognition of these transformations may be affected also by the age of the listener. This adds credence to the present investigation's hypothesis that all equivalency relationships are not "equally equivalent" aurally. It also suggests the need for controlling the factor of listener characteristics in testing recognition of set equivalency.

Manipulations of interval size, interval order, rhythm and octave placement have also been found to affect melody recognition. An experiment carried out by Benjamin White (1960) measured the effects of the first three of these factors. Results indicated that simple transposition had little or no effect on recognition, and that recognition was impaired the least when intervals were left their original size or direction. This finding suggests that among the many ways in which a set may be manipulated, those manipulations which preserve the original interval order and size would be most easily recognizable.

The effect of octave displacement on melody recognition was examined experimentally by Deutsch (1972). Deutsch tested recognition of the tune "Yankee Doodle" under three conditions: using an untransformed version, a version with each pitch randomly placed in one of three octaves, and a version with all pitch information removed (rhythm only). Results showed that recognition of the randomized octaves version was no better than for the version with all pitch
information extracted. This finding suggests that octave displacement has a serious effect on melodic recognition and that equivalence relationships which involve interval class equivalents of the original intervals (through octave displacement of one or more pitches) would be more difficult to recognize than relationships in which the original interval sizes were preserved.

Recognition of Twelve-Tone Row Transformations

A number of researchers have addressed the issue of perceptibility of permutations of twelve-tone rows. The four basic row forms (0, I, R, RI) of the twelve-tone technique have parallels in set theory as transposed or inverted set equivalencies. Thus, findings concerning factors affecting recognition of row transformations and the relative perceptibility of the various row forms are pertinent to the present investigation.

Questions about the perceptibility of row transformations are thoroughly discussed in Bruce Thrall's "The Audibility of Twelve-Tone Serial Structures" (1962). However, Thrall's work only presents questions for consideration; no experimentation is carried out on the hypotheses presented. In the same year, the results of Alan Walker's work on the subject were published in A Study in Musical Analysis. Walker raised the old question, "Why should a composer waste his time employing mirror devices which
cannot be heard?" He then set out to prove that Schoenberg's twelve-tone system is musically valid by showing that all cases of mirror organization (I, R and RI) are in some sense perceptible. He designed audibility tests of five levels of difficulty in which subjects were presented with melodic lines followed by three mirror forms and requested to identify the derivation of each. The results of the tests proved for him that the mirror forms are intrinsically unified and that these devices are potentially comprehensible to all. Interestingly, he found that the retrograde relationships were easier to comprehend than the inversions. Larsen's study, on the other hand, suggested that inversions can be recognized more readily than retrogrades.

Walker also revived a notion presented earlier in 1953 by Anton Ehrenzweig. Ehrenzweig believed that aurally-obscure relationships such as those between a retrograde or inverted variant and the original, though not apparently related in our surface perception, may be perceived as being related in the "depth-mind." Such unconscious perception of relatedness was suggested by Walker to explain why some subjects in his investigation recognized the unity between


a row and its variant but were unable to identify which variant it was.

Walker tested his theory of unconscious perception in another experiment by requiring subjects to respond spontaneously to a single hearing of stimuli to make a judgement about which two of a group of items were related. In this experiment subjects were given no time for analytic consideration of the stimuli. Since the majority of the subjects, given no time for reflection, correctly identified the two related themes, Walker attributed the recognition of unity to unconscious perception.

A more recent investigation by Edward Largent (1972) attempted to define an order of perceptual difficulty in identifying row transformations. As might be expected, he discovered the original form to be most easily recognizable by his subjects, retrograde-inversion to be most difficult, and retrograde and inversion to be in between. Symmetrical row forms were found to be easier for recognizing row transformations.

A study by Christiaan de Lannoy in the same year tested recognition of row permutations. The test required subjects to indicate if the comparison melody was derived from or not related to the original. He found that some series were easily discriminated, others could be discriminated only by trained groups and others always confused by both trained and untrained subjects. He made no claim to having found a
"final sentence about discriminability" but concluded that
dodecaphonic music is not fundamentally more or less easily
discriminated than tonal music.

Implications of Previous Research for
Present Investigation

Previous research has indicated that there are many factors which influence the recognition of a motive or melody in its transformations. These findings are particularly pertinent to research in the perceptibility of melodic set relationships. Conclusions of previous research considered in the development of the present investigation are summarized below:

1. Recognition of melodies may be affected by the interval sizes in the melody, the ordering and reordering of pitches, transposition-distance and octave displacement.

2. Some transformations are more recognizable than others.

3. Transpositions are easily confused with same-contour imitations.

4. Accuracy in melody recognition is dependent on the subject's ability for interval abstraction.

In addition, according to Maxine Moore in "A Consideration of the Perceptual Process," tasks can be arranged in order of difficulty according to the amount of information extracted in the perceptual process. Tasks requiring extraction of more information are perceptually
more difficult. An application of this idea to set relationships suggests that transpositions are more easily recognizable than inversions and that ordered manipulations (with original interval succession preserved) are more easily recognizable than reordered transformations.

The factors of listeners' ability and experience, an all-important element in a study of perception, has been addressed in a number of studies. Among them is Robert Lawson's "Scientific Approaches to Problems in Aural Perceptibility in Music." Lawson classified a number of variables which affect perception including listener characteristics, which he defines as the composite of the subject's I. Q., length of background exposure and aptitude. Listener characteristics have been discussed perhaps most thoroughly by Warren Prince in his article, "A Paradigm for Research on Music Listening." In this article Prince defined the multiplicity of variables involved in music listening and the relationship of these variables to one another. He considered The following listener characteristics as being influential to the perceptual process: personality, maturation, musical training and experience, musical memory, musical aptitude, socially-educationally

derived attitudes toward music, state of attention and expectation.  

Philip Vernon (1930) also described the effect of experience on music perception:  

To one observer a musical phrase may be grammatical, logical, and easily intelligible, but to another observer, whose musical experience differs quantitatively and qualitatively from that of the first, will be sure to find the same phrase of a very different degree of comprehensibility.

It is clear that the greater the subject's experience, aptitude and prior exposure to the stimuli, the greater is his ability to perceive.

With such possible diversity among subjects, how can any conclusive results be obtained from a study in musical perception? Most studies on perception try to control these variables either by limiting participants to a particular age group or level of ability, or by dividing participants into ability groups. In Largent's study (described earlier) and in a study by Jack Taylor (1976) on the perception of tonality in melodies, participants were divided into groups according to their musical experience and ability. In both cases, listener characteristics were treated as a variable in the experiment; results showed that this variable did

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contribute significantly to variance in performance. This suggests that perceptual ability should be controlled in some way in testing subjects' recognition of set equivalency.

The paradigm most frequently used in studies on music recognition is as follows: presentation of a stimulus (the standard), presentation of one or more comparison stimuli and determination if a specified relationship exists between a comparison stimulus and the standard. In this study the specified relationship would be set equivalency; the subject's task would be to identify which of several comparison stimuli was equivalent to the standard.

In the discussion to follow the terms "perception" and "perceptibility" are frequently used. It is necessary at this point to clarify the meaning intended. "Perception of set relationships" can have at least two different meanings:

1. that the listener can experience the relatedness of two sets without being able to identify the exact relationship involved, or

2. that the listener can identify the particular set relationship presented.

In the former case, the listener can distinguish equivalent sets from non-equivalent sets and can recognize a transformation of a set as being of the same set type, without necessarily knowing what transformation has taken place. In the second case, true comprehension of the set
relationship occurs. The perceptual task involved in this investigation required only a general recognition of relatedness, as described in the former case given above, and it is this meaning that is intended in the use of the term "perception."

Description of the Investigation

Research Hypotheses: Questions to be Considered

The main hypothesis of this investigation was that certain set equivalency relationships are more easily recognizable than others. A matter of primary interest to the researcher was the effect of reordering on the recognition of set equivalency. Sets may be subjected to permutations of the order of their elements, without loosing their identity (at least in theory). The majority of previous studies has been limited to transformations which preserve the interval succession of the original. The aspect of equivalency under order-permutation, in which originally adjacent intervals become non-adjacent and vice versa, makes set-theoretic relationships unique and presumably causes special problems for the listener. Therefore, one of the main questions of interest in this investigation was the effect of reordering on the recognition of equivalent sets. It was hypothesized that order-preserving manipulations are more recognizable than those which involve reordering.
Additional questions concerning the relative perceptibility of set relations are given here. Are transpositionally-equivalent relationships more recognizable than inversionally-equivalent relationships? Is the recognition of set equivalency affected by the set type of the sets involved? How does the perceptual ability of subjects affect recognition of set relationships; specifically, does the facility for absolute pitch recognition aid significantly in the perception of set equivalency? Is it possible that non-equivalent sets in Rp, R1 or R2 similarity relations could be perceived as equivalent?

These questions have shaped the design of the present investigation. (See formal definition of these research hypotheses in the discussion of data analysis, p. 75.)

Limitations on Sets and Set Transformations

This investigation was limited to the examination of the perceptibility of equivalence between sets. To reduce the great number of variables in such an experiment, limitations were placed on the sets to be used and the ways in which those sets would be manipulated in creating equivalent sets. The experiment was restricted to the evaluation of three-note, atonal (avoiding connotations of tonality), asymmetrical, melodically-presented sets. This restriction is fully explained in the description of the test design (beginning on p. 51).
Limitations on the set transformations to be used were required because of the enormous number of possible ways in which a set may be manipulated. Any set may be transposed to begin on any one of the twelve pitch-classes. It may also be inverted and transposed in its inverted form to any level. The set may then be reordered into a number of equivalent permutations. Each three-note set has six orderings: three circular permutations (rotations) and their retrogrades.

In addition, any reordering may have octave transference of any of its pitches without destroying the identity of the set.

The six melodic orderings of a three-note set may be classified according to whether they preserve the original succession of intervals. Ordered transposition and ordered inversion of a set preserve the original interval succession. In recognizing these transformations as being equivalent, only the interval information between adjacent
pitches is required. The retrograde of the ordered transposition or inversion also preserves the original succession of intervals but in reversed order. The interval succession of the rotational and retrograde/rotational transpositions and inversions preserve only one of the original intervals between adjacent pitches; the other interval in the interval succession is the outside interval of the original set. In order to recognize that these transformations are equivalent to the original, the subject must have a memory representation of the intervals between both adjacent and non-adjacent pitches of the original; that is, he must be aware of the total interval content of the original.

To measure the effect of reordered versus ordered manipulations as well as transpositions versus inversions, the following set manipulations were chosen for this investigation: ordered transposition, ordered inversion, reordered transposition, and reordered inversion. The particular reorderings chosen were arrangements which used the original set's outside interval as a successive interval in the equivalent comparison set. To test the effect of octave transference, an additional set transformation was included—ordered transposition with the octave displacement of one of its pitches. The choice of specific

\[^{32}\text{This term is used by John Rahn in Basic Atonal Theory (New York, 1980), p. 135.}\]
transpositions, inversions and reorderings used in the investigation is discussed in detail in the description of the test design (see p. 51).

**Paradigm, Foils and Lures**

As mentioned earlier, the most common paradigm for recognition experiments involves the presentation of a stimulus (standard) followed by one or more comparison stimuli. In designs with two or more comparison stimuli, the comparisons usually immediately follow one another. Using atonal set structures as stimuli, there was the possibility that a subject would lose his memory representation of the standard after the first comparison and would compare the second and third comparison sets to one another instead of to the standard. For this reason, in this experiment the standard was restated between the comparison sets.

One of the comparison sets was transpositionally or inversionally equivalent to the original set; the other two comparison sets were non-equivalent sets. The subjects' task was to determine which of the comparison sets was equivalent to the standard.

In designing such a test, it was important to control the nature of the incorrect answer choices. Their contrast to the correct answer could not be so obvious as to give the subject no choice but the correct one. Foils were carefully designed to give further information about the conditions
under which the correct answer was not chosen. In this experiment, non-equivalent sets in a similarity relation to the original were used as lures. One of the lures was a set which held invariant two of the original set's pitches; in other words, it was a set in an Rp relationship with the standard. In the first run of the experiment, the other lure was a non-equivalent set which had a contour similar to that of the original set. In the second run, this lure was replaced with one which had precisely the same interval succession as the original but was different in contour. In either case, the lure was in an R1 or R2 similarity relation with the standard. The design of the lures is presented in further detail in the discussion of test design (see pp. 60-63).

Methodology

The experiment consisted of three phases for subject participation:

1. a perception ability test,
2. lessons on the fundamentals of set theory, and
3. a perception test on equivalency relationships.

The purpose of the first test was, of course, to screen subjects as to their perceptual ability. The lessons were for the purpose of teaching subjects the basic concepts of set theory, so that they would have some criteria for making judgments about set equivalency on the experimental test to follow.
To insure the required uniformity in testing, training and evaluation, these tasks were computer-assisted. The Apple II microcomputer was employed to present and evaluate all test questions as well as to provide interactive instruction using both visual and aural examples. The computer was also used to aid in the statistical analysis of the data.

The computer programs for student use were written with the aid of the "Music Sound and Graphics Package" (MSGP) developed by Dr. Paul E. Dworak at North Texas State University. MSGP is a series of subroutines which facilitate the combination of text, high-resolution music graphics and sound production.

All testing and training was carried out at the Music C.A.I. (computer-assisted instruction) Lab at N.T.S.U. Participating subjects were all members of sophomore ear-training courses at N.T.S.U. A further discussion of each phase of the investigation follows.
CHAPTER II

PREPARATORY TESTING AND TRAINING

The Perception Ability Test

Previous research in music perception (Largent, Larsen, Lawson, Prince, and Taylor) suggests the importance of considering subjects' background experience in evaluating aural tests. A subject's previous experience and perceptual ability can greatly affect his performance on aural-recognition tasks. In order to provide control over this influential variable, a Perception Ability Test (PAT) was specially designed for the purpose of this investigation. The test evaluated the subject's performance on several aural tasks (described below) and placed them in one of three perception ability groups (PA1, PA2 or PA3).

Content

Perceptual ability was evaluated according to the subject's ability to identify correctly aural percepts particularly involved in the perception of equivalent sets. Recognition of equivalent sets is considered to involve the following tasks:

1. melodic memory for the set (both its pitch content and contour),
2. analysis of the component intervals of the set
(successive intervals as well as the non-adjacent interval between the first and last pitches),

3. analysis of the component intervals of all comparison sets, and

4. recognition of identical interval content between original and comparison set (or recognition of at least one different interval in a non-equivalent comparison set).

It is also believed that the facility for absolute pitch recognition would improve performance on the perception of equivalent sets. To provide information on the subject's ability in this area in addition to those listed above, PAT included questions on the identification of pitch names as well as on the identification of melodic intervals, identification of the non-adjacent interval of three-note melodies, and melodic memory for three-note "atonal" melodies.

The test was in four sections, corresponding to the four aural tasks mentioned above. (For the actual questions used in the test, see Appendix A, p. 148.)

Section 1: Interval Recognition I.—In this section the subject heard ten intervals and was asked to identify each by name. All intervals were simple (smaller than an octave) and were presented melodically, some ascending and

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1An attempt was made to avoid tonal implications in the construction of the three-note melodies used in the test.
some descending. The succession of intervals was planned so as to avoid any obvious tonal associations.

Section 2: Interval Recognition II.—For each question in this section the subject heard a three-note melody and was asked to identify the interval between the first and third notes. There were five questions in the section. The three-note melodies were similar to the sets to be used in the experimental test. Each of the five questions used one of the five set types to be used in the experimental test.

Section 3: Absolute Pitch Recognition.—For each of ten questions in this section the subject was presented with a pitch and was asked to identify it by name. To answer, the subject selected a pitch name from a list of the twelve pitches of the chromatic scale, including two spellings for the "black-key notes." Enharmonic spellings were given, so that, for example, whether a subject interpreted a pitch as F-sharp or G-flat he would give the same answer. The actual succession of pitches used was designed so as to avoid tonal associations. Any feelings of tonality were disrupted by the frequent use of tritones between successive pitches.

Section 4: Melodic Memory.—For each of five questions in this section, the subject heard a three-note melody (one of the five set types used in this investigation) followed by a group of three comparisons. The subject's task was to identify which of the three comparison melodies was exactly
the same as the original melody. Of course, one of the three comparison melodies was identical to the original; the other two melodies were lures. Both lures were of a set type different from the original; one was similar in contour to the original, and the other had two pitches in common with the original but was different in contour.

The following considerations were made in the ordering of the test sections.

1. Simple interval recognition (of intervals between adjacent pitches) is a task most likely very familiar to subjects. Therefore, Interval Recognition I was placed first. The more difficult task involving interval recognition of non-adjacent pitches followed.

2. The section on absolute pitch recognition was placed later in the test, so as to not discourage subjects without the facility for APR too early in the test, and to allow subjects with APR to become accustomed to the quality and tuning of the sound-producing, digital-to-analog-converter (DAC) board.

3. The section on Melodic Memory, which required different interaction and input from the subjects (see later discussion of student input), was placed last to allow those sections with similar input routines to be placed together.

The test questions for all sections were not randomly ordered but were designed to follow one another in a
specific order to avoid tonal implications and to insure that all subjects were given the same test.

Program Organization

The test was administered and scored by a BASIC computer program run on the Apple II microcomputer. The program consisted of the following sections: 1) an introductory section in which subject data was collected and general instructions were given, 2) the four test sections, 3) a scoring section and 4) a filing section. (See Appendix B for the PAT program listing, p. 150.)

The Introduction.—The introductory section first instructed the subject to type his first and last names and gave him a chance to make corrections if the name was not correct as typed. Then the subject was asked if he had Absolute Pitch Recognition. He answered with either "1 Yes," "2 No" or "3 I'm not sure." After collection of this information, the subject was given general information about the test to follow.

Test Sections.—Each section of the test provided instructions, a sample question and an option to review the instructions. The test was designed so as to make the required subject input as simple and consistent as possible. All subject input during the test was limited to the use of these keys—<H>, <->, <->, <SPACE BAR>, <1>, <2>, and <3>. In all test sections the subject pressed <H> to hear the
stimulus. Then he was shown the answer choices for the question across the screen and a pointer (↓). To answer he used the right and left arrow keys to move the pointer over the answer and pressed the <SPACE BAR> to record the answer. In the fourth section (Melodic Memory) the subject also used the <1>, <2> and <3> keys to hear the comparison melodies, but he entered his answer by moving the pointer as in the other sections.

No feedback was given to the subject during the test sections; that is, the subject was not told whether or not he had answered the questions correctly. However, the computer did compare the subject's answer with the correct answer and kept a tally of the number of questions answered correctly in each section. At the end of the test subjects were shown the percentage of questions answered correctly for each section of the test.

The subject was allowed control over the amount of time between questions. The program always waited for the subject to press <SPACE BAR> before proceeding to the next question.

**Scoring.**—As mentioned previously, the computer checked the subject's answers to questions and counted the number of questions answered correctly. Each section was worth 25 points. Questions in sections I and III (with ten questions each) were worth 2.5 points each, and questions in sections II and IV (with five questions each) were worth 5 points.
each. The total score (the sum of the scores from individual sections) was used to evaluate the subject's perceptual ability as it pertained to the aural tasks required in this investigation. The subject was placed in one of the three Perception Ability (PA) Groups, as shown in Table I.

**TABLE I**

<table>
<thead>
<tr>
<th>Score</th>
<th>Group</th>
<th>Group Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 80</td>
<td>PA1</td>
<td>Subjects with absolute pitch recognition</td>
</tr>
<tr>
<td>60-80</td>
<td>PA2</td>
<td>Subjects without APR and with good relative pitch</td>
</tr>
<tr>
<td>&lt; 60</td>
<td>PA3</td>
<td>Subjects without APR and with poor relative pitch</td>
</tr>
</tbody>
</table>

The score of 80% may seem low for being the delimiter between the top and middle groups; however, it should be realized that a subject without the facility for Absolute Pitch Recognition could hope to attain only a score of 75% if he performed perfectly on all sections except section III (on APR) and failed to answer any questions correctly in section III. A score somewhat higher than 75% was chosen because a subject with good relative pitch could use voice placement or some other method to successfully "guess" the answers to a few questions in section III. It was assumed that a subject who scored greater than 80 points had some facility for absolute pitch recognition. The score of 60 was somewhat arbitrarily chosen as the delimiter between
groups two and three. There was no clear point of division among scores of subjects without APR. The score of 60 was chosen merely because it resulted in a relatively equal grouping of subjects. Thirty-six music students enrolled in sophomore ear-training courses at N.T.S.U. were available for the first run of the experiment. The division of subjects according to the criteria described above resulted in groups of size three, fifteen and eighteen for PA1, PA2 and PA3, respectively. (See evaluation of PAT scores for second run, p. 111.)

**Filing.**--Certain information about the subject and his performance on the test was saved by the computer during the course of the program. After the subject's scores were summed and evaluated, this information was stored in a subject data file on the diskette. Each subject record in the file contained the following information:

1. first and last names
2. answer to the question about APR (1, 2 or 3)
3. scores on each section
4. total score
5. PA group (1, 2 or 3)
6. answers to every test question

The subject's actual answers to each question of each section were saved in case this information could be of some value in later analyses of this test.
The Tutorial:  "Introduction to Set Theory"

The second of the three computer-assisted activities for subject participation was a computerized lesson on the subject of set theory. The purpose of the tutorial\(^2\) was to insure that subjects understood the basic concepts behind the aural tasks of the Perception of Equivalence Test to follow. "Perception... depends on knowledge of principles involved."\(^3\) On the test, subjects would be asked to judge whether or not sets were equivalent. It was desired that subjects at least know what is meant by "equivalent" so that they would use appropriate criteria for evaluating set relationships on the Perception of Equivalence Test. (An alternative method would be to avoid any training of subjects and simply ask them to choose whether two sets were "similar" or "related." It was felt that responses on such a test would be too subjective to contribute information of significant value.)

The tutorial consisted of two major sections—a lesson module for the presentation of the basic concepts of set theory, and a practice module for the drill and practice of

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\(^2\)The term "tutorial" refers to a specific type of computer-assisted instruction in which the computer assumes the role of the teacher, presenting concepts (rather than depending on prior presentation of concepts as in drill and practice programs) through text and illustrations and providing interactive questions on those concepts.

\(^3\)Pike, op. cit., 58
set analysis. The computer program that controlled the presentation of the tutorial consisted of a main program, "Tutorial," and three subordinate programs, "Menu," "Lesson" and "Practice." (For program listings, see Appendix E, p. 179.)

The Lesson Module

The lesson was designed specifically for the purposes of the investigation. Certain limitations were placed on the scope of the lesson's content. Only those concepts felt to be essential to understanding the tasks required in the Perception of Equivalence Test were presented in the lesson.

The following concepts are involved in understanding set equivalency: the definition of set, pitch class equivalency and pc set, interval class and interval vectors, transpositional equivalence and inversional equivalence. Though the concept of prime form is basic to Forte's theory of set equivalence, the understanding of this concept is not essential to the perception of set equivalency. Finding the prime form of two given sets to determine whether they are equivalent seems an unnecessarily involved procedure for making the determination. Finding the prime form involves arranging the set in normal order, inverting the set and checking which normal order (that of the set or of its inversion) is the best normal order and transposing the best normal order to C. Performing such mental gymnastics without the aid of pencil and paper for more than one set
and remembering the results long enough to compare them for equivalency seems to be an unreasonably difficult task.

It is believed that the interval content of a set is more appreciable, and for this reason equivalency was presented in the lesson as a function of interval content. The concept of Z-related sets, those which are equivalent in interval content but which are not reducible to the same prime form and are thus not equivalent, was not presented in the tutorial. The subjects were not asked to make judgments involving Z-related sets. Explanation of prime-form relatedness and the Z-set exception to interval content equivalency would only complicate the discussion and possibly confuse the subjects. Therefore, in this tutorial interval content was presented as the criterion for judging equivalency between sets.

No explanation was given as to how to hear these relationships. To do so would involve explaining different strategies for hearing transpositions versus inversions, and order-preserved versions versus reordered versions. The explanation would necessarily imply the increased difficulty of hearing reordered transformations. Since the purpose of the study was to determine the relative perceptual difficulty of types of set transformations, giving subjects any bias towards certain relationships was strictly avoided.

Although transposition of inverted forms was discussed, no method for determining the tranposition level of an
inversion was given. Subjects were not required to label any transformations, therefore for the purpose of this study it was not necessary that they determine the interval of transposition.

An explanation of each section of the tutorial's lesson follows.

**Introduction.**—After a title display appeared, the subject was asked to type his first and last names. The computer then checked for his name in the disk file of subjects who had previously taken the lesson. The subject was then given an option for instructions. The instructions included information on the organization of the lesson, on what keys to use in proceeding through the lesson and how to quit the lesson early if desired.

If the subject had used the program before (if his name was in the subject file) and had completed all lesson sections, he was presented with a menu. The menu gave him the option to retake the entire lesson, review a particular lesson section, or to proceed to the practice module. If the subject had never used the program (if his name was not in the subject file), the lesson began immediately. The first-time user was not shown the menu of options, because it was desired that he take the whole lesson before being allowed to skip between sections or to take practice questions.
Lesson sections.—The lesson consisted of five sections plus a summary. The lesson sections were:

1. Definition of Set
2. Pitch Class and pc Set
3. Interval Content and Interval Vector
4. Transpositional Equivalence
5. Inversional Equivalence

In each lesson section the subject was given a brief explanation of the concept with visual and aural examples. At the end of each section, the subject was given the opportunity to review the section. Also, when he completed all sections of the lesson, he was given an option to review any of the lesson's sections before proceeding to the practice questions. (For the actual lesson text, see Appendix C, p. 161.)

The Practice Module

In the practice section of the tutorial the subject was given drill and practice on recognizing equivalent sets with the notation of the sets displayed. The purpose of the practice module was 1) to reinforce the concept of interval content as an indicator of set equivalency and 2) to serve as a bridge from the conception of set equivalency to the perception of set equivalency.

Question presentation.—The basic task of the practice questions was to determine whether a pair of sets was
equivalent. There were three modes of question presentation:

Level 1—notation only
Level 2—sound and notation
Level 3—sound and disappearing notation

The three levels of difficulty were not intended to provide a measure of the effect of notation on recognition of set equivalency. Although that is an interesting question, it is a subject requiring a different experimental design, not in the scope of the present study. Rather, the purpose of these levels was to provide subjects with an incentive to progress through the questions and to encourage the subjects to be less dependent on notation and more so on hearing. It is, of course, questionable whether "notation and sound" is a level more difficult than "notation only;" it is likely that the presence of an additional representation (sound) would make the task easier. Nevertheless, the above order of levels was used because it provided a transition from reading about and seeing set equivalency to hearing and perceiving set equivalency.

On all levels subjects were presented with two sets and were asked to determine whether they were equivalent. Each level consisted of ten questions. The questions were not timed; subjects could consider the sets as long as desired before answering. The subject answered by typing "E" (if equivalent) or "N" (if not equivalent).
On level 1, the notation of the two sets was displayed. On level 2, a set (original set) was presented both visually and aurally. The notation of the original set stayed on the display while a comparison set was then presented visually and aurally. The subject was allowed to compare the two by examining their notation and rehearsing their sound. Level 3 was the same as level 2, only the notation of the original set disappeared before the comparison set was presented. Aural rehearsals were allowed; visual rehearsals were not.

On level 1 the notation of the sets was presented immediately at the beginning of the question. On levels 2 and 3, the subject initiated the presentation of the sets by typing "1" for the first set and "2" for the second. Such subject-control over the presentation of questions avoided playing a set before the subject was ready to hear it.

Instructions.—When the subject first entered the practice module of the program, he was presented with a menu showing the three levels of questions. After choosing one, he was given an option to choose a different level. The instructions explained the task involved and the mode of presentation chosen and reviewed the concept of interval vector.

Practice questions.—The practice questions differed from the actual experimental test in the following ways. The perception test would present multiple choice questions
in which the subject would be required to determine which of three comparison sets was equivalent to the original set. To avoid giving subjects direct practice in this type of question, the tutorial practice questions presented only pairs of sets for the determination of equivalency. Also, a major difference in the practice questions and the actual test to follow was the presence of notation in the former.

The score file from which the practice questions were generated contained thirty three-note sets, six transformations for each of the five set types. In the file, these were arranged in order by set type so that the first six were versions of set type 3-2, the next six were versions of set type 3-3, and so on. The six versions consisted of a set and five transformations of that set. The particular transformations used varied from set type to set type so that a variety of set manipulations were represented. Those used were chosen from among the following: ordered transposition, ordered inversion, various reorderings (rotations and retrogrades) of transpositions and inversions, and reordered inversion with octave displacement. (For actual sets used for question generation, see Appendix D.)

After the subject finished with the instructions, the following message appeared, "One moment please, while I write your questions..." At this point the Question-Writer routine began. This routine resulted in ten set pairs, five
equivalent and five non-equivalent. The equivalent set pairs were created by choosing an original set of a particular set type (chosen at random from the score file) and then choosing a second set of the same set type. The non-equivalent set pairs were created by randomly choosing an original set of a particular set type and then choosing a second set of a different set type.

Controls were placed on the randomization so that no particular set was used more than once and so that each of the five set types would appear as an original set twice, once in an equivalent pair and once in a non-equivalent pair. After the ten pairs were chosen, they were randomized so that the sequence of questions presented to the subject would be a random succession of equivalent and non-equivalent pairs. The same question generation procedure was used regardless of the level of the questions.

Therefore, the difference in difficulty was due not to the actual questions but to the mode of presentation employed.

The basic format of the computer display for the practice questions was the same regardless of the mode of presentation, except for the instructions given in the cue line. The display for Level 2 practice questions is shown in Figure 6. After the subject answered by pressing "E" or "N," the display changed to show the appropriate feedback, as shown for example in Figure 7.
Feedback. Concerning the extent of training to be given in the practice module, it was important to avoid giving the subjects any listening strategies which might confound the results of the perception test. This was an important concern in the decision of what to give as feedback to the subjects on practice questions. Normally, a drill and practice program on set theory (for the purpose of teaching subjects to recognize equivalent set relations) should give feedback such as, "Incorrect, the sets are not equivalent" plus some explanation like, "Although they are
similar in contour, notice that their interval makeup is different," or "No, the sets do have two pitches in common but only one interval." However, such feedback would disclose too much of the design of the experimental test. The perception test was to use non-equivalent sets which were similar in contour or somewhat invariant in pitch or interval content as incorrect answer choices. Of course, the experimenter wanted to avoid disclosing this information prior to the test. Therefore, the following simple feedback was provided: "Correct/Incorrect, the sets are/are not equivalent." In addition, the interval vector for each set was displayed, so that the subject might readily compare the sets' component intervals.

Filing

Information about each subject's use of the tutorial program was saved by the computer and stored in a subject data file on the diskette. Each student record contained the following information:

1. student's name
2. number of times he used the program
3. number of lesson sections completed
4. number of lesson sections reviewed
5. number of practice sets taken
6. best score on practice questions for each level

The file was consulted prior to administering the Perception of Equivalence Test to insure that all subjects taking PET
had completed all five lesson sections and had taken at least two sets of practice questions.
The Perception Ability Test and Tutorial on Set Theory were followed by the Perception of Equivalence Test (PET), in which subjects were required to recognize equivalency relationships aurally. As described earlier, the test paradigm employed in PET involved the presentation of a stimulus (an original set, called the "standard") followed by three comparison stimuli (comparison sets), one of which was transpositionally or inversionally equivalent to the standard, the other two being non-equivalent lures. In this way, each test trial consisted of a multiple-choice question, the correct response being a target which was in an equivalency relationship with the standard.

The test was designed to measure how the recognition of set equivalency (the dependent variable) is affected by the following independent variables:

A. perceptual ability
B. set type
C. set manipulation.

As in all experiments, the dependent variable may be affected by factors other than the specified independent variables. Such undesired sources of variation in an experiment are called nuisance variables. There are several
ways an experimenter may control a nuisance variable: by holding it constant, through randomization, or by making it one of the factors in the experiment. The following discussion describes in detail the design of the test: its standards, targets and lures, the nuisance variables associated with each, and how nuisance variables have been controlled in each case.

Test Design

The Standards

As explained previously, this investigation was limited to three-note sets presented melodically. The sets used have been further restricted to those which are "atonal" in character. The latter restriction was necessary as a means of controlling the nuisance variable of set familiarity. That is, certain sets are more familiar because of their frequent use in common practice period literature. Sets 3-10, 3-11 and 3-12 are familiar to us as the diminished triad, the major and minor triads, and the augmented triad, respectively. Set 3-8 also connotes tertian harmony, sounding like a dominant seventh with no fifth or in its inversion like a half-diminished seventh with no fifth. Set 3-1 is familiar as a subset of the chromatic scale and set 3-6 as a subset of the major diatonic scale (in prime form, according to Kirk, Experimental Design (Belmont, Ca., 1982), p. 6.

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"do-re-mi"). These associations very well might influence a subject's evaluation of relatedness, and for this reason the study was limited to set types without obvious connotations of tertian harmony. It is also possible that the symmetrical sets may be easier to recognize, because of their redundancy in interval content. To control this variable, it was decided to eliminate the symmetrical sets. This restriction ruled out set 3-9 in addition to 3-1, 3-6, 3-10 and 3-12 already mentioned. The remaining asymmetrical set types--3-2, 3-3, 3-4, 3-5 and 3-7--are those used in the study.

The choice of actual sets to be used as standards in the test was primarily governed by the following self-imposed rule: hold constant all factors other than the experimental variable under investigation. Otherwise, variation in performance might be due to some uncontrolled source of variation other than the independent variable under investigation.

For example, consider the following situation in examining the effect of set type on the recognition of equivalency. In one trial the subject is presented with a stimulus (set type 3-2) in a moderate register, followed by three comparison stimuli in the same register, one of which is equivalent. He succeeds in determining which of the three comparison sets was equivalent to the original. On a second trial, the subject is presented with a stimulus (set
type 3-7) in a very low register, followed by three comparison stimuli in the same, low register. He fails to choose the correct answer. How can the experimenter claim (as he wishes to) that the difference in performance was due to the set type of the original? Could not the change in register have been responsible for the subject's failure in the second trial? Obviously, the variable of register should be controlled in an attempt to measure the effect of set type on equivalency recognition. Likewise, other variables such as the range, instrumentation, rhythmic setting, tempo, and contour should be controlled.²

To maximize the effect of the set type used as standard and to minimize the effect of the nuisance variables mentioned above, the following restrictions were placed on the choice of sets used as standards in PET. All standards were:

1. equirhythmic, in equal whole notes,
2. played in a slow tempo (M.M. $J = 92$),
3. produced by a Micro Music digital-to-analog synthesizer board,
4. in a moderate register (from g to d#²),
5. bidirectional in contour, and
6. composed of intervals no larger than a tritone.

²All of these variables, here considered nuisance variables, are potential experimental variables for further research.
Also, the same set was used as the standard for all trials about a particular set type. Otherwise, if both standard and targets were different for different trials about a particular set type, one would not know if a difference in performance were due to the standard or to the target.

The Comparison Sets

For each trial in the test, the standard is followed by three comparison sets, one of which is the target, a set equivalent to the standard, and two of which are lures, or non-equivalent sets. The characteristics of the comparison sets and their relationship to the standard had to be controlled just as rigorously as the choice of standard sets. All comparison sets were treated in the same way as the standard with respect to range, rhythm, tempo, instrumentation and register. (See the discussion above on the restrictions on these parameters.) The following discussion describes the particular restrictions placed on the choice of sets used as targets and lures.

The Targets

Of the many possible ways in which a set may be manipulated with the result being a set equivalent to the original set, this experiment was limited to five set manipulations. These five equivalency relationships were:

1. ordered transposition
2. ordered inversion
3. ordered transposition with octave displacement
4. reordered transposition
5. reordered inversion

Each of the five set types (standards) had five targets, one each of the target types just listed, totalling to twenty-five trials on the test.

Each target was carefully chosen so that the relationship being tested would be distinct. For example, not all transpositions of a set are equally distinct from the original. Some levels of transposition for a set will produce pitch invariance, some will not. If this aspect of the transposition relationship were to be left uncontrolled, then differences in performance could not be attributed solely to the set manipulation.

For example, let us suppose that in one trial a subject correctly identifies an equivalent target set which was an ordered transposition of the original. This hypothetical target also had two pitches in common with the original. In another trial, the subject fails to recognize a reordered transposition of the same original set; however, in this trial the target had no pitch invariance with the original. Can the experimenter justifiably attribute the difference in performance (one correct, one incorrect) to the fact that in one trial the equivalency relationship was an ordered transposition and a reordered transposition in the other? No, the difference in performance might have been due to the
fact that the target on the first trial had pitch invariance, providing similarity between the sets, and that the target for the latter trial had no such pitch invariance. Obviously, the variable of pitch invariance must be controlled if the effect of a particular set manipulation is to be precisely measured. In order to control this nuisance variable, transposition levels for all set manipulations which produce no pitch invariance were chosen.

Another factor which might influence the perceptibility of an equivalency relationship is the distance of a transposition. For example, if one trial were to involve a target which was an ordered transposition of a set, transposed two half-steps away, and another trial involved a reordered inversion, transposed seven half-steps away, the experimenter would not know if a difference in the subject's performance was due to the change in set manipulation or the change in transposition level. To hold this variable completely constant for all trials would require that a constant level of transposition be used for all standard-target relationships. However, this is not possible, since transposition levels producing invariance under transposition and under inversion are different for different set types.

In an effort to keep the transposition distance as constant as possible, the transposition levels for transposition and inversion were kept constant for all trials
about a particular set type. In this way, differences in performance on the three transpositional and two inversional set manipulations of a particular set type could not be due to differences in transposition distance, since that factor was held constant. The actual transposition levels for transposition and inversion for each set type were chosen so that in normal order, the lowest notes of the original and target sets lay no further than a tritone apart, and so that all pitches of the original and its target lay within an octave, excepting the target involving octave displacement.

The direction of transposition was controlled so that all targets about a particular set type were transposed in the same direction. Variety in transposition direction was provided by tranposing targets up for set types 3-2, 3-5 and 3-7 and transposing targets down for set types 3-3 and 3-4.

The manipulation of the standards in producing ordered targets (target types 1 and 2) involved no further nuisance variables requiring control. However, there were additional nuisance variables associated with the set manipulations for target types 3, 4 and 5.

Concerning the third set manipulation (ordered transposition with octave displacement), targets were identical to targets for the first target type (ordered transposition), except that the former included an octave displacement of one note. The manner in which this was carried out was kept constant for all five set types—the
first interval of the ordered transposition target was harmonically inverted so that the second pitch was displaced by an octave. (See Figure 8.)

![Original Transposition](image)

Original | Ordered Trans. | Ordered Trans. with octave displacement

**Fig. 8**—Comparison of original, target 1 and target 3.

The fourth and fifth set manipulations involved reordering. As discussed previously there are six melodic reordering of a three-note set. Four of these involve a rotation in which one of the original successive intervals is replaced by the outside interval. The affect of such a rotation on the recognition of set equivalency was of primary interest to the experimenter.

There are four reordering of a set which may be classified as rotations. (See Figure 9.) Although it would have been interesting to compare a subject's performance on recognition of set equivalency on an ordered transposition versus each of these rotated targets, the number of trials required for such a test was prohibitive. One way to test recognition of all of these rotations and yet to limit the number of trials on the test would be to use a different rotation as the reordered target for each of the five set
Fig. 9—An original set and its rotations.

types. However, this procedure would leave another variable uncontrolled. Some rotations preserve the first of the original successive intervals, while other rotations preserve the second of the original successive intervals. It seems likely that this difference would affect a subject's perception of set equivalency. To control this nuisance variable, one particular rotation was chosen to be used for all reordered targets, namely, the second rotation. The same manner of reordering was used for the fourth and fifth targets for all five set types. The second rotation of a set results in a reordered set which begins with the original set's outside interval and is followed by the original set's first interval. Thus, the fourth target was a second rotation of the first target, and the fifth target was a second rotation of the second target. (See Figure 10.) Controlled in this way, the experimenter could
attribute any differences in the subject's judgment of first and fourth (or second and fifth) targets to the effect of the rotation.

The Lures

It was of interest to the experimenter to see under what conditions the subject would prefer a non-equivalent lure to the actually equivalent target. Each trial included, in addition to the correct answer, two lures, one of which was a pitch-invariant (PI) lure in an Rp relationship with the standard; the other was a same-contour (SC) lure in an R1 or R2 relationship with the standard. The non-equivalent sets used as lures were very carefully chosen.

All trials about a particular set type used the same PI lure and SC lure. This restriction was necessary to insure that differences in subjects' preferences could be
attributed to differences in set manipulation and not to changes in the lures. For example, let us suppose that an experimenter wants to compare a subject's performance on two questions about set type 3-3, one question having an ordered transposition as target with SC lure "A," and a second question having a reordered transposition as target with SC lure "B." If the subject chooses the correct answer (target) on the first question and chooses the incorrect answer (SC lure) on the second question, can the experimenter assume that the difference in performance was due to the effect of reordering the target? That is, was the difference in performance due to the set manipulation? The experimenter cannot make this assumption, because the difference in performance might have been due to the change in the SC lure. Had the SC lure been the same for both questions, then the experimenter could assume with more surety that the subject's preference was influenced by the set manipulations employed.

Therefore, for the five trials about each of the five set types, the standard, SC lure and PI lure were constants, only the target was changed. To counteract the possibility of familiarity with the lures as the subject progressed through the test, each trial about a particular set type was presented in a different "key," and the order of presentation of the three answer choices was randomized, so that, for example, the SC lure did not always follow the target.
The PI lure.—In choosing pitch-invariant lures, it was necessary to decide which of the original set's three pitches would be held invariant. The same procedure was used for all five standards—the first two pitches of the original were reversed in order and used as the first two pitches of the PI lure. The choice of the third pitch was governed by the following criteria:

1. The PI lure will be a non-equivalent set in no similarity relation to the original other than the Rp relationship.

2. It will be different in contour from the original, specifically, unidirectional, since all standards are bidirectional.

3. The intervals between the first and third pitches and the second and third pitches will not be members of the original set's interval content; that is, the PI lure will have only one interval in common with the standard, the interval between the first and second pitches.

The SC lure.—For each set type, a same-contour lure was chosen which could meet all of the following criteria:

1. The SC lure will be a non-equivalent set in an R1 or R2 similarity relation with the standard.

2. The contour of the SC lure will preserve the original set's step-skip or skip-skip sequence; the original direction of the skips and steps will also be preserved.
3. The SC lure will have no pitches in common with the standard (to keep it distinct from the PI lure).

4. It will begin on a pitch different from the first pitch of the ordered transposition target.

The last criterion was included for the following reason. A same-contour R1 or R2 lure sounds very similar to an ordered transposition. If both the SC lure and the ordered transposition target begin on the same pitch, they are especially similar; therefore, it was desired that they begin on different pitches. The choice of a starting pitch for the SC lure was guided by the same criteria used to choose transposition levels for the transposed targets. A starting pitch was chosen which would allow all pitches to lie within an octave of the original set's pitches and which would have no pitch invariance with the original set.

The actual sets used as standards, targets and lures are given in Appendix F. Table II summarizes the control of nuisance variables in the choice of sets used in PET.

Randomization

As mentioned previously, randomization is another method of controlling nuisance variables. Through randomization, unsuspected sources of variation affecting the dependent variable are distributed over the entire experiment, so that they do not affect any particular treatment. PET consisted of twenty-five trials, five trials (one for each target type) for each of the five set types.
<table>
<thead>
<tr>
<th>Concerning...</th>
<th>Variable</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Sets</td>
<td>number of notes</td>
<td>3-note sets</td>
</tr>
<tr>
<td></td>
<td>presentation</td>
<td>melodic only</td>
</tr>
<tr>
<td></td>
<td>rhythmic setting</td>
<td>whole-notes</td>
</tr>
<tr>
<td></td>
<td>tempo</td>
<td>M.M. $j = 92$</td>
</tr>
<tr>
<td></td>
<td>instrumentation</td>
<td>DAC Board</td>
</tr>
<tr>
<td></td>
<td>register &amp; range</td>
<td>g to d#</td>
</tr>
<tr>
<td>Standards</td>
<td>familiarity</td>
<td>&quot;atonal&quot; sets</td>
</tr>
<tr>
<td></td>
<td>contour</td>
<td>bidirectional</td>
</tr>
<tr>
<td></td>
<td>successive inter-val size</td>
<td>no larger than tritone</td>
</tr>
<tr>
<td>All targets</td>
<td>t level</td>
<td>no greater than tritone away</td>
</tr>
<tr>
<td></td>
<td>t direction</td>
<td>constant for all trials about a set type</td>
</tr>
<tr>
<td></td>
<td>pitch invariance</td>
<td>no common tones</td>
</tr>
<tr>
<td>Target 3</td>
<td>note displaced</td>
<td>2nd note, through harmonic inversion of 1st interval</td>
</tr>
<tr>
<td>Targets 4 &amp; 5 only</td>
<td>reordering</td>
<td>2nd rotations</td>
</tr>
<tr>
<td>PI Lure</td>
<td>similarity relation</td>
<td>Rp only</td>
</tr>
<tr>
<td></td>
<td>invariant pitches</td>
<td>1st 2 pitches in reverse order</td>
</tr>
<tr>
<td></td>
<td>contour</td>
<td>unidirectional</td>
</tr>
<tr>
<td></td>
<td>intervals formed by 3rd pitch</td>
<td>not in original interval content</td>
</tr>
<tr>
<td>SC Lure</td>
<td>similarity relation</td>
<td>R1 or R2</td>
</tr>
<tr>
<td></td>
<td>t distance</td>
<td>no farther away than tritone</td>
</tr>
<tr>
<td></td>
<td>pitch invariance</td>
<td>no common tones</td>
</tr>
<tr>
<td></td>
<td>contour</td>
<td>preserves &quot;step-skip&quot; sequence &amp; direction</td>
</tr>
</tbody>
</table>
As described earlier, each trial presented a standard followed by three comparisons, one of which was the target (or correct answer). Two features of the test were subjected to randomization: 1) the position of the target among the comparison sets, and 2) the order of the trials. The randomization procedures for both features involved certain restrictions.

For each trial, the position of the target among the three answer choices was randomized by a computer routine which randomly generated a hundred sequences of the three possible orderings of the numbers, one through three. The numbers represented target (T), SC lure (S) and PI lure (P), respectively. Beginning with the first random sequence, answer choice sequences were assigned to the twenty-five trials. Successive occurrences of identical sequences were discarded as well as any more than two successive occurrences of the target in the same position. A further restriction was placed on the randomization to counterbalance the number of times the target appeared in each position. This procedure was followed until sequences had been assigned to all twenty-five trials. The twenty-five sequences were saved in a twenty-five-by-three matrix and were used in the Question Driver portion of the PET program. (See "Testing," p. 69.)

The procedure used to randomize the order of the twenty-five trials was quite complex. The five set types
used in the test were numbered, one through five, respectively. The five set manipulations were numbered, one through five, representing ordered transposition, ordered inversion, ordered transposition with octave displacement, reordered transposition, and reordered inversion, respectively.

A simple randomization procedure would be to number the twenty-five trials as shown in Table III.

**TABLE III**

**TRIAL NUMBERING FOR SIMPLE RANDOMIZATION**

<table>
<thead>
<tr>
<th>Trial no.</th>
<th>Set type</th>
<th>Set manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>1</td>
<td>1-5</td>
</tr>
<tr>
<td>6-10</td>
<td>2</td>
<td>1-5</td>
</tr>
<tr>
<td>11-15</td>
<td>3</td>
<td>1-5</td>
</tr>
<tr>
<td>16-20</td>
<td>4</td>
<td>1-5</td>
</tr>
<tr>
<td>21-25</td>
<td>5</td>
<td>1-5</td>
</tr>
</tbody>
</table>

For example, trial number 9 would be the trial using set number 2 (set 3-3) as the standard and the fourth set manipulation (reordered transposition) as the target. To randomize the trials, one could simply use a random sequence of the numbers, 1 through 25, to determine the order in which the twenty-five trials would be presented. However, in the preliminary stages of writing the test, this method was found to be unsatisfactory. In one such "random" arrangement, all five trials using set type 3-5 as standard were placed within the last seven questions of the test.
To avoid such unfortunate arrangements, a more complex randomization procedure was adopted. The procedure incorporated the following restrictions:

1. Every five trials will present one question about each set type and one question about each set manipulation, so that the five set types and five set manipulations will be cycled through in random ordered every five questions.

2. No two successive trials will use the same standard (set type).

A computer routine\(^3\) was written which generates two twenty-five-member arrays, one representing the set type to be used and one which indicates the target type to be used for each trial. For example, the resulting arrays might look something like those shown in Figure 11.

\[
\text{SET TYPE} \quad (3,2,4,1,5,2,3,1,5,4,2,5,3,4,1,4,1,3,5,2,5,3,1,4,2) \\
\text{SET MAN.} \quad (4,3,1,2,5,4,1,5,3,2,5,2,3,4,1,3,4,5,1,2,4,2,3,5,1)
\]

Fig. 11—Randomization of set types and set manipulations.

In this example, the first trial would be the question using the third set type (set 3-4) as standard, and the fourth set manipulation (reordered transposition) as target. The second trial would use the second set type (set 3-3) with the third target (ordered transposition with octave

\(^3\)See QUESTION RANDOMIZER, PET program lines 50000–55170, Appendix H, p. 216.
displacement), and so on. The twenty-fifth trial would use
the second set type (set 3-3) with the first target (ordered
transposition). The twenty-five trials were randomized in
this way independently for each subject. 4

Program Description

The program which directed the actions of the computer
is described below. (See Appendix H for the PET program
listing, p. 212.) The PET program was organized in the
following sections: Instructions, Test Preparation,
Testing, Filing and Scoring.

Instructions

After a title screen and a name-input routine, the
instructions began. In the instructions, the subject was
told the object of the twenty-five questions, namely the
identification of which of three comparison sets was
equivalent to an original set. He was given a description
of the test, instructions on how to elicit the playing of
the sets, and how to input his answer. He was also given a
sample question and an option to review the instructions.
He was given no information on the nature of the lures or
the particular set manipulations employed, nor was he given
any listening strategy for determining the correct answers.

4 This is a requirement for the experimental design used
for the data analysis.
As described previously, in this test the standard set was restated between the comparison sets. Otherwise, there would be the possibility that the subject would lose his memory representation of the standard after hearing the first comparison and would compare the second and third comparison sets to one another rather than to the standard.

Test Preparation

After the subject finished reading the instructions, the computer gave him a message instructing him to wait while his questions were being prepared. At this point, the question-randomization routines were run, and the sequence of set types and target types to be used for each of the twenty-five trials was set. This process lasted about 5-7 seconds.

Testing

The QUESTION DRIVER portion of the PET program (lines 1000-1999) controlled the presentation of standards, targets and lures for the twenty-five test trials. For each trial, the standard and target to be used were assigned by consulting the set-type and set-manipulation arrays set up during the test preparation. Then the answer choice matrix (the twenty-five-by-three matrix of S, T and P entries discussed under "Randomization," p. 65) was consulted to assign the order for presentation of the three answer choices (comparison sets).
The display shown to the subject during the test is pictured in Figure 12.

<table>
<thead>
<tr>
<th>PERCEPTION OF EQUIVALENT SETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUESTION #1</td>
</tr>
</tbody>
</table>

| Original Set 1 | Set 2 | Set 3 |

Press <SPACE BAR> to hear the sets.

![Fig. 12—PET display for listening to the sets.](image)

When the subject pressed the space bar, the "Original" label was highlighted and the standard was played. Each time he pressed the space bar a set was played and its label highlighted until all sets had been played. The sets were presented in this order: Original, Set 1, Original, Set 2, Original, Set 3. No rehearsings were allowed, other than the provided restatement of the original. When the subject had completed listening to the sets, the display changed as pictured in Figure 13. The subject then input his answer by using the cursor-movement keys (→ and ←) over his answer choice and by pressing the <SPACE BAR> to enter the answer.

No feedback was given as to the correct answer. Only the cue line changed to display the message "Press <SPACE BAR> for next question." In this manner, the subject proceeded through all twenty-five questions.
PERCEPTION OF EQUIVALENT SETS

QUESTION #1

Original

Set 1  Set 2  Set 3

Use → and ← to move the arrow over the answer & press <SPACE>

Fig. 13—PET display for answer input.

Piling

During the test, the computer saved the subject's responses to each question. The subject's answer choice was in each case T (target), S (same-contour lure) or P (pitch-invariant lure). The subject's response to all trials were saved in a five-by-five matrix, each entry corresponding to the set type (1 through 5) and target type (1 through 5) for each trial. The actual randomized order in which the trials were presented to a subject was also saved in another five-by-five matrix. For example, let us suppose that in the first trial a subject was presented with set type 2 (set 3-3) as standard and the third set manipulation as target, and the subject responded by choosing the same-contour lure. The matrices for this trial would be assigned as shown in Figure 14.
For a completed test, the data matrices might appear as in Figure 15. Saving subjects' responses and question presentation order in this way allowed for easy comparison of subjects' responses. Performances on trials concerning the various set manipulations were also easily compared by comparing columns of the subject response matrix.

Comparing rows of the subject response matrix allowed for comparison of performances on the five set types. (See further discussion under "Data Analysis." ) Within the filing section of the PET program, the subject's name and the two data matrices were written to the disk file.
Scoring

The final section of the PET program gave the subject information on his performance. The nature of the lures used for each question was briefly explained. His scores were then displayed, showing him the percentages for the number of questions answered correctly (T's), the number of same-contour lures (S's) chosen and the number of pitch-invariant lures (P's) chosen.
CHAPTER IV

DATA ANALYSIS

The Perception of Equivalence Test was designed to determine how recognition of set equivalency (the dependent variable) may be affected by three independent variables: perceptual ability of subjects (treatment A), set type used as standard (treatment B) and set manipulation (treatment C). On the basis of the Perceptual Ability Test, subjects were divided into three groups: those with absolute pitch recognition or APR (a1), those without APR and with good interval identification skills (a2), and those without APR and with poor interval identification skills (a3). Five asymmetrical set types were used as standards in the test: set types 3-2, 3-3, 3-4, 3-5 and 3-7 (designated as b1, b2, b3, b4 and b5, respectively). Five set manipulations were used to provide targets for each of the five set types. These five set manipulations (or target types) were ordered transposition (c1), ordered inversion (c2), ordered transposition with octave displacement (c3), reordered transposition (c4) and reordered inversion (c5).

The experimenter was primarily interested in testing the effect of set manipulation on the recognition of equivalency. As discussed previously, it is likely that all equivalency relationships are not heard equally as
"equivalent;" that is, some manipulations result in an equivalent set which seems more similar to the original set than others. The other variables were of lesser importance. The variable of perceptual ability was included as an experimental treatment as a means of controlling the nuisance factor of varying aural abilities among subjects. The variable of set type was included because it was suspected that using different set types for different trials would affect a subject's performance. Differences in performances between trials could not be attributed to the set manipulations employed, unless variance in the set type used as standard was controlled.

Research Hypotheses Defined

The following statements are hypotheses concerning the effect of perceptual ability, set type and set manipulation on the recognition of set equivalency. The hypotheses stated correspond with the experimenter's intuitive feelings about the perception of set equivalency.

The overall hypothesis concerning perceptual ability was: A subject's perceptual ability does influence his ability to recognize set equivalency. Hypotheses for specific comparisons were:

1. Subjects with APR perform better (answer more questions correctly) than subjects without APR.

2. Subjects with good interval recognition skills perform better than subjects with poor recognition skills.
Concerning set type, the experimenter had no strong feeling about whether or not recognition of set equivalency would be affected by the set type used as standard. As mentioned previously, set type was included as a variable as a means of controlling for possible nuisance variation. If the set types chosen for the experiment had differed widely in character, for example, type 3-1 expressed in chromatic steps versus type 3-11 expressed as a major triad, then performance would likely differ. However, set types chosen were similar in nature, all being asymmetrical and "atonal" in character.

On the other hand, to include set type as a variable implies that it could have an effect, and for this reason the following overall hypothesis was tested: Recognition of set equivalency is affected by the set type used as standard.

There were a number of research hypotheses of interest to the experimenter concerning set manipulation. The overall hypothesis was: The manner in which an original set is manipulated in producing the equivalent target set does influence a subject's recognition of equivalency. Hypotheses concerning specific comparisons were:

1. Ordered transposition is the most recognizable set equivalency relationship.

2. Transpositions are intuitively "more equivalent" than inversions.
3. Equivalency produced through ordered manipulations is, in general, more recognizable than that produced through reordered manipulations.

4. Octave displacement disguises set equivalency.

Exploratory Data Analysis

Exploratory data analysis involves simply looking at the data to see what they suggest. As discussed previously, two data matrices were saved for each subject's performance on PET: one which saved the subject's responses to each trial (T, S or P) and the other which preserved the order in which the twenty-five trials were presented. For data analysis, subjects' responses were coded as a one if the target was chosen or as a zero if either the same-contour lure or pitch-invariant lure were chosen. In the discussion which follows, a subject's "performance" refers to the number of trials answered correctly (target chosen) on the test or on a portion of the test.

**Means for Treatment A (Perceptual Ability)**

A mean score for scores on all trials was figured for each of the three perception ability (PA) groups. These are shown in Table IV. Since the score for each trial is either zero or one, a subject's mean score, and hence, a group of subjects' mean score, is a number between zero and one. The mean scores are perhaps more intuitively grasped when each
TABLE IV
MEAN SCORES FOR PA GROUPS

<table>
<thead>
<tr>
<th></th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y..</td>
<td>.77</td>
<td>.46</td>
<td>.34</td>
</tr>
</tbody>
</table>

is considered as the average number of trials answered correctly out of twenty-five total trials, as in Table V.

TABLE V
MEAN NUMBER OF CORRECTLY-ANSWERED TRIALS OUT OF TWENTY-FIVE TOTAL TRIALS

<table>
<thead>
<tr>
<th></th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y.jkl</td>
<td>19.33</td>
<td>11.53</td>
<td>8.44</td>
</tr>
</tbody>
</table>

A cursory look at the mean scores of the three PA groups suggests that performance decreases as perceptual ability decreases. The performance of subjects possessing APR appears to be significantly better than that for subjects without APR. There is a smaller difference in performance between PA groups 2 and 3. (Statistical tests of these contrasts are discussed under "Tests of Main Effects", p. 86.)

Means for Treatment B (Set Type)
The twenty-five trials on PET consisted of five trials for each of the five set types. The means for trials
involving each set type, shown in Table VI, were figured by averaging the numbers of trials answered correctly out of five across subjects and across all levels of treatments A and C.

<table>
<thead>
<tr>
<th>Set Type:</th>
<th>3-2</th>
<th>3-3</th>
<th>3-4</th>
<th>3-5</th>
<th>3-7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b1</td>
<td>b2</td>
<td>b3</td>
<td>b4</td>
<td>b5</td>
</tr>
<tr>
<td>Y..k.</td>
<td>2.33</td>
<td>2.06</td>
<td>1.86</td>
<td>1.94</td>
<td>2.44</td>
</tr>
</tbody>
</table>

There appears to be little variation in performance among the five set types used as standards. Scores for each set type roughly round to two answered correctly out of five trials. The set type used as standard appears to have made little if any difference in subjects' performance. (For statistical test for the effect of treatment B, see "Results of ANOVA," p. 84.)

Means for Treatment C (Set Manipulation)

The twenty-five trials on PET may also be grouped by set manipulation (or target type). For each of the five set manipulations there were five trials on the test. The means for each set manipulation, shown in Table VII, represent the mean number of trials answered correctly out of five, averaged across subjects and across all levels of treatments A and B.
TABLE VII
MEAN NUMBER OF CORRECTLY-ANSWERED TRIALS
OUT OF FIVE FOR EACH SET MANIPULATION

<table>
<thead>
<tr>
<th>Target Type:</th>
<th>c1</th>
<th>c2</th>
<th>c3</th>
<th>c4</th>
<th>c5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{Y} \ldots 1 )</td>
<td>2.92</td>
<td>1.97</td>
<td>2.36</td>
<td>1.86</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Mean performances for the five set manipulation show some variation. Arranged in order of most to least number of trials answered correctly, the five set manipulations are:

- ordered transposition (c1)
- ordered transposition with octave displacement (c3)
- ordered inversion (c2)
- reordered transposition (c4)
- reordered inversion (c5)

Performance on trials involving ordered transposition (c1) seems to be significantly better than performance on trials involving the other target types. It seems noteworthy, also, that the two lowest means are those for trials involving reordered targets (c4 and c5).

The following section describes and presents the results of statistical tests of hypotheses using data from the PET answer choice data matrices. The data were subjected to analysis of variance, tests for contrasts among means, Pearson chi-square tests for homogeneity of proportions, and chi-square tests for contrasts among proportions. A discussion of each follows.
Analysis of Variance

A Note About Dichotomous Data

In testing hypotheses about treatments A, B and C, subjects' responses were coded as zero's or one's, representing incorrect or correct answer choices, respectively. Coded in this manner, the dependent variable—recognition of the equivalent sets—is dichotomous, having only two possible values. One of the assumptions of analysis of variance is that observations be drawn from normally-distributed populations. Distributions of dichotomous data are the ultimate in nonnormality. However, research has indicated that "the F test is quite robust with respect to violation of the normality assumption;"\(^1\) that is, the assumption can be violated without seriously affecting the test.

Studies on the use of analysis of variance with a dichotomous dependent variable have been carried out by Lunney\(^2\) and Hsu & Feldt.\(^3\) Their findings show that

\(^1\)Kirk, op. cit., p. 75.


ANOVA is an appropriate statistical technique for analyzing dichotomous data when the degrees of freedom for error are large, and if the proportion of responses in the two response categories is not extreme. The present experiment does meet the required number of error degrees of freedom and required proportion size for response categories.

To further insure an unbiased analysis of the data, the experimenter has carried out Pearson chi-square tests for equality of proportions as a check on the significant results of the omnibus F-test.

**Experimental Design**

The analysis of variance design employed was a split-plot factorial design, SPF-p.q.r, with repeated measurements. In this design, subjects receive only one of the p levels of treatment A, but they receive all combinations of the q levels of treatment B and the r levels of treatment C.

As discussed previously, treatment A (perceptual ability) had three levels, treatment B (set type) had five levels, and treatment C (set manipulation) had five levels. Thus, the specific design employed was a SPF-3.55 design. A required condition of the split-plot factorial design with repeated measurements is that the sequence of administration of the levels of treatments B and C be randomized.

---

independently for each subject. This condition was met in the present experiment through the randomization procedures of PET. (See previous discussion of randomization, p. 63.)

**Statistical Hypotheses**

To test the research hypotheses stated earlier, each was expressed as a null hypothesis stating that the treatment had no effect. For example, the null hypothesis \( (H_0) \) for treatment A (perceptual ability) states that population means \( (\mu) \) for the three groups are equal, in other words, that the A-treatment effect \( (\alpha_j) \) is equal to zero. The alternative hypothesis \( (H_1) \) corresponds to the experimenter's belief that population means for the three groups are not all equal and that the treatment does have an effect on the dependent variable. These statistical hypothesis are shown in Figure 16.

\[H_0: \mu_1 = \mu_2 = \mu_3 \quad \text{or} \quad H_0: \alpha_j = 0 \text{ for all } j\]

versus

\[H_1: \mu_j \neq \mu_j' \text{ for some } j \text{ or } j' \quad \text{or} \quad H_1: \alpha_j \neq 0 \text{ for some } j\]

Fig. 16—Statistical hypotheses for treatment A.

Likewise, the null hypothesis for treatments B and C (each having five levels) states that the five population means are equal and that the treatment effects \( (\beta_k \text{ for treatment B and } \gamma_k \text{ for treatment C}) \) are equal to zero. These null hypotheses and their alternatives are shown in Figure 17.
For treatment B—

\[ H_0: \mu_{1} = \mu_{2} = \mu_{3} = \mu_{4} = \mu_{5} \]

or \( H_0: \beta_k = 0 \) for all \( k \)

versus

\[ H_1: \mu_k \neq \mu_k', \] for some \( k \) or \( k' \) or \( H_1: \beta_k \neq 0 \) for some \( k \)

For treatment C—

\[ H_0: \mu_{1} = \mu_{2} = \mu_{3} = \mu_{4} = \mu_{5} \]

or \( H_0: \gamma_1 = 0 \) for all \( l \)

versus

\[ H_1: \mu_1 \neq \mu_1', \] for some \( 1 \) or \( 1' \) or \( H_1: \gamma_1 \neq 0 \) for some \( 1 \)

Fig. 17—Statistical hypotheses for treatments B and C.

The ANOVA design employed also tests hypotheses concerning interactions among treatments. Null hypotheses for interactions state that the interaction between the treatment effects are equal to zero. These null hypotheses are given in Figure 18.

\[ H_0: (\alpha \beta)_{jk} = 0 \] for all \( j, k \)
\[ H_0: (\alpha \gamma)_{jl} = 0 \] for all \( j, l \)
\[ H_0: (\beta \gamma)_{kl} = 0 \] for all \( k, l \)
\[ H_0: (\alpha \beta \gamma)_{jkl} = 0 \] for all \( j, k, l \)

Fig. 18—Statistical hypotheses for interactions.

Results of ANOVA

The results of analysis of variance are summarized in Table VIII. The null hypothesis for treatment A (perceptual ability) was rejected \((p < .05)\). The null hypothesis for treatment C (set manipulation) also was rejected \((p < .01)\).

---

5 An interaction is said to occur if differences in performance under the levels of one treatment are different at two or more levels of another treatment.
**TABLE VIII**

ANOVA TABLE, SPF-3.55 DESIGN

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Between blocks</td>
<td>54.332</td>
<td>N-1 = 35</td>
<td>6.509</td>
<td>[2/3] 5.20*</td>
</tr>
<tr>
<td>2 A (perc. ability)</td>
<td>13.018</td>
<td>p-1 = 2</td>
<td>6.509</td>
<td>[2/3] 5.20*</td>
</tr>
<tr>
<td>3 Blocks w. A</td>
<td>41.314</td>
<td>N-p = 33</td>
<td>1.252</td>
<td>[5/7] 2.23</td>
</tr>
<tr>
<td>4 Within blocks</td>
<td>165.680</td>
<td>N(qr-1) = 864</td>
<td>0.063</td>
<td>[6/7] 0.31</td>
</tr>
<tr>
<td>5 B (set type)</td>
<td>1.818</td>
<td>q-1 = 4</td>
<td>0.455</td>
<td>[5/7] 2.23</td>
</tr>
<tr>
<td>6 AB</td>
<td>0.500</td>
<td>(p-1)(q-1) = 8</td>
<td>0.204</td>
<td>[8/10] 9.85**</td>
</tr>
<tr>
<td>7 B x blocks w. A</td>
<td>26.962</td>
<td>(N-p)(q-1) = 132</td>
<td>0.204</td>
<td>[9/10] 0.60</td>
</tr>
<tr>
<td>9 AC</td>
<td>0.990</td>
<td>(p-1)(r-1) = 8</td>
<td>0.124</td>
<td>[11/13] 1.32</td>
</tr>
<tr>
<td>10 C x blocks w. A</td>
<td>27.339</td>
<td>(N-p)(r-1) = 132</td>
<td>0.207</td>
<td>[12/13] 0.99</td>
</tr>
<tr>
<td>11 BC</td>
<td>3.625</td>
<td>(q-1)(r-1) = 16</td>
<td>0.227</td>
<td>[12/13] 0.99</td>
</tr>
<tr>
<td>12 ABC</td>
<td>5.442</td>
<td>(p-1)(q-1)(r-1) = 32</td>
<td>0.170</td>
<td>[12/13] 0.99</td>
</tr>
<tr>
<td>13 B x C x bl. w. A</td>
<td>90.852</td>
<td>(N-p)(q-1)(r-1) = 528</td>
<td>0.172</td>
<td>[12/13] 0.99</td>
</tr>
<tr>
<td>14 Total</td>
<td>220.012</td>
<td>Nqr-1 = 899</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *p < .05  ** p < .01
The null hypothesis for treatment B (set type) could not be rejected.

We can infer from the analysis of variance that recognition of set equivalence is significantly affected by a subject's perceptual ability and by the set manipulation employed. The set type used as standard (of the five set types used in the experiment) does not appear to have made a significant contribution to the recognition of set equivalence. No interactions were found to be significant. This implies that differences in performances among the five set manipulations were not different for subjects of varying perceptual ability. That is, the relative difficulty of recognizing equivalency, produced through the five set manipulations, was the same for all three perceptual ability groups. Likewise, the relative success in performance among the three perceptual ability groups was constant through all trials, regardless of the particular set manipulations employed.

Tests of Main Effects: Contrasts Between Means

The overall F test resulted in a rejection of the null hypotheses for treatments A and C; therefore, it may be inferred that population means for treatments A and C differ. The question remains of how these means differ.

Tests of the main effects of a treatment, that is, contrasts between the levels of a variable, are misleading if that treatment interacts significantly with another
However, no significant interactions were found; therefore, the experimenter proceeded with tests of the main effects of treatments A and C.

The research hypotheses discussed earlier included some hypotheses concerning specific differences between means. Concerning perceptual ability, the experimenter was interested to see 1) if subjects with APR performed better than subjects without APR, and 2) concerning subjects without APR, if those with good interval recognition performed better than those with poor interval recognition. The comparisons for treatment A may be expressed as orthogonal contrasts, as shown in Figure 19.

\[
\hat{\Psi}_{1(A)} = \bar{Y}_{1..} - \frac{(\bar{Y}_{2..} + \bar{Y}_{3..})}{2}
\]

\[
= \frac{1}{2} (\bar{Y}_{1..}) + \frac{-1}{2} (\bar{Y}_{2..}) + \frac{-1}{2} (\bar{Y}_{3..})
\]

\[
\hat{\Psi}_{2(A)} = \bar{Y}_{2..} - \bar{Y}_{3..}
\]

\[
= 0 (\bar{Y}_{1..}) + 1 (\bar{Y}_{2..}) + (-1) (\bar{Y}_{3..})
\]

Fig. 19—Contrasts between A means.

6 A difference between two means for one variable might appear significant when actually it is only significant at one level of the other variable.

7 Orthogonal contrasts are those for which the sum of the products of corresponding coefficients is equal to zero. In our case,

\[
c_{1j} \text{ for } \hat{\Psi}_{1(A)} = 1 -1/2 -1/2
\]

\[
c_{2j} \text{ for } \hat{\Psi}_{2(A)} = 0 1 -1
\]

\[
\sum c_{1j} c_{2j} = 0 -1/2 1/2 = 0
\]
Concerning set manipulation, the researcher was interested in comparing subjects' performance on trials involving:

1. ordered transposition versus all other trials
2. transposition versus inversion
3. ordered manipulations versus reordered manipulations, and
4. ordered transposition versus ordered transposition with octave displacement.

These comparisons are expressed statistically as the non-orthogonal contrasts shown in Figure 20.\(^8\)

\[
\begin{align*}
\hat{\psi}_{1(c)} &= \bar{Y}_{..1} - (\bar{Y}_{..2} + \bar{Y}_{..3} + \bar{Y}_{..4} + \bar{Y}_{..5})/4 \\
\hat{\psi}_{2(c)} &= (\bar{Y}_{..1} + \bar{Y}_{..4})/2 - (\bar{Y}_{..2} + \bar{Y}_{..5})/2 \\
\hat{\psi}_{3(c)} &= (\bar{Y}_{..1} + \bar{Y}_{..2} + \bar{Y}_{..3})/3 - (\bar{Y}_{..4} + \bar{Y}_{..5})/2 \\
\hat{\psi}_{4(c)} &= \bar{Y}_{..1} - \bar{Y}_{..3}
\end{align*}
\]

Fig. 20--Contrasts between C means.

In addition to these contrasts, the following comparisons were also tested: ordered transposition versus reordered transposition, and ordered inversion versus reordered inversion. These contrasts are shown in Figure 21.

\(^8\)These contrasts are non-orthogonal because the products of corresponding coefficients do not sum to zero. For example, \(c_{2j}\) for \(\hat{\psi}_{1(c)} = 1 -1/4 -1/4 -1/4 -1/4\)
\[
\begin{align*}
\sum c_{1j} c_{2j} &= 1/2 1/8 0 -1/8 1/8 \\
&\neq 0
\end{align*}
\]
\[ \hat{\Psi}_{5(c)} = \bar{Y}_{1} - \bar{Y}_{5} \] (ordered transposition versus reordered transposition)

\[ \hat{\Psi}_{6(c)} = \bar{Y}_{2} - \bar{Y}_{5} \] (ordered inversion versus reordered inversion)

Fig. 21—Additional contrasts between C means.

**Statistical Hypotheses for Contrasts**

Tests for contrasts between means test null hypotheses of the form, \( H_{0}: \Psi = 0 \). This null hypothesis states that the contrast is equal to zero; that is, there is no difference between the means in question. In testing contrasts of interest, the experimenter hopes to reject the null hypothesis.

**Results of Main-Effects Tests**

Differences among means may be tested through a number of multiple comparison tests. Multiple-t tests are appropriate for a priori orthogonal contrasts. For a priori non-orthogonal contrasts, the Dunn-Sidak procedure\(^9\) is more appropriate. In either case, the null hypothesis is tested using a \( t \) statistic, \( t = \hat{\Psi}_{i} / \hat{\sigma}_{\Psi} \), where \( \hat{\Psi} \) is the value of the contrast between means and \( \hat{\sigma}_{\Psi} \) is the standard error of the contrast. The critical value which must be exceeded by the \( t \) statistic for the contrast to be declared significant was obtained from Student's \( t \) distribution for multiple-\( t \) test; for the Dunn-Sidak procedure, the table of percentage

\[^9\text{Kirk, op. cit., pp. 106-111.}\]
Results of testing contrasts among A means and C means are shown in Table IX.

The results of testing the two contrasts among A means showed that subjects with APR performed significantly better.

**TABLE IX**
CONTRASTS AMONG TREATMENT A MEANS AND TREATMENT C MEANS

<table>
<thead>
<tr>
<th>Means</th>
<th>MSerror</th>
<th>df</th>
<th>Critical values</th>
<th>t statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.252</td>
<td>33</td>
<td><em>t</em>.05,33 = 1.692</td>
<td><em>t</em> = <em>( \frac{\hat{y}<em>1(A)}{\hat{\sigma}</em>{\text{MS}(A)}} ) = 2.769</em>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>t</em>.01,33 = 2.442</td>
<td><em>t</em> = *( \frac{\hat{y}<em>2(A)}{\hat{\sigma}</em>{\text{MS}(A)}} ) = 1.579</td>
</tr>
<tr>
<td>C</td>
<td>0.207</td>
<td>132</td>
<td><em>tDS</em>.05,6132 = 2.675</td>
<td><em>tDS</em> = <em>( \frac{\hat{y}<em>1(C)}{\hat{\sigma}</em>{\text{MS}(C)}} ) = 5.201</em>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>tDS</em>.01,6132 = 3.215</td>
<td><em>tDS</em> = <em>( \frac{\hat{y}<em>2(C)}{\hat{\sigma}</em>{\text{MS}(C)}} ) = 3.767</em>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>tDS</em> = <em>( \frac{\hat{y}<em>3(C)}{\hat{\sigma}</em>{\text{MS}(C)}} ) = 4.664</em>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>tDS</em> = *( \frac{\hat{y}<em>4(C)}{\hat{\sigma}</em>{\text{MS}(C)}} ) = 2.317</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>tDS</em> = <em>( \frac{\hat{y}<em>5(C)}{\hat{\sigma}</em>{\text{MS}(C)}} ) = 4.402</em>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>tDS</em> = *( \frac{\hat{y}<em>6(C)}{\hat{\sigma}</em>{\text{MS}(C)}} ) = 1.852</td>
</tr>
</tbody>
</table>

**p < .01

10Kirk, op. cit., p. 813 and pp. 843-845.
than subjects without APR (p < .01). The test also indicated that among subjects without APR, those with better interval recognition skills did not perform significantly better. This lack of significant difference is possibly due to the fact that there was not a distinct division of scores among subjects without APR; that is, the lower PAT scores for subjects in PA group 2 were very close to the higher scores for subjects in PA group 3.

The results of testing the six contrasts among C means indicated that the null hypothesis may be rejected (p < .01) for the first three of the four research hypotheses (listed above, p. 76). The original research hypothesis which was not shown significant is that of ordered transposition versus ordered transposition with octave displacement, \( \Psi_{4(\omega)} \).

In addition, the contrast of ordered transposition versus reordered transposition, \( \Psi_{5(\omega)} \), was shown significant (p < .01). However, the contrast of ordered inversion versus reordered inversion, \( \Psi_{6(\omega)} \), was not significant. This suggests that, although the ordered targets were in general more easily perceived, the difference was due to the specific contrast of ordered versus reordered transposition. Since the equivalency of the inverted targets in general was more difficult to perceive, it is possible that reordering an inverted target did not make the task appreciably more difficult.
Pearson Chi-Square Tests for Equality of Proportions

As discussed previously, there has been some discussion about the appropriateness of analysis of variance with dichotomous data. To provide a check on the results of the F test and tests for contrasts, the data was also analyzed using the Pearson chi-square test for equality of proportions.

The null hypothesis for this test states that proportions of a criterion variable are equal across categories of another variable. In our case, the criterion variable is a subject's performance, his success or failure in identifying target sets. With this test, the proportion of correct to incorrect answers may be evaluated across the levels of our experimental variables.

The proportions of correct to incorrect answers for the p=3 levels of treatment A (perceptual ability) are given in the form of a contingency table, shown in Table X. The null hypothesis for this test states that the proportion is the same for all subjects, across all three perception ability groups. The significant test \( p < .01 \) confirms the results of the omnibus-F test for treatment A, that perceptual ability contributed significantly to a subject's performance in recognizing equivalency between sets.

A check on the t-tests for A-mean contrasts was carried out by performing a chi-square test for multiple contrasts
TABLE X
PERFORMANCE (CORRECT:INCORRECT) BY PERCEPTUAL ABILITY

<table>
<thead>
<tr>
<th></th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct</td>
<td>77.33</td>
<td>46.13</td>
<td>33.78</td>
<td>157.24</td>
</tr>
<tr>
<td>Incorrect</td>
<td>22.67</td>
<td>53.87</td>
<td>66.22</td>
<td>142.76</td>
</tr>
<tr>
<td></td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>300.00</td>
</tr>
</tbody>
</table>

\[ \chi^2 = \frac{\sum (O_j - E_j)^2}{E_j} = 40.395^{**} \]
\[ df = c - 1 = 2 \]
\[ **p < .01 \]
\[ \chi^2_{0.05,2} = 5.991; \chi^2_{0.01,2} = 9.210 \]

described in Marascuilo.\(^{11}\) This procedure results in a 
\( (1-\alpha) = .95 \) set of simultaneous confidence intervals. If a 
confidence interval includes zero, the null hypothesis that 
the contrast is equal to zero may not be rejected.

Confidence intervals for contrasts, \( \hat{\Psi}_{1(A)} \) and \( \hat{\Psi}_{2(A)} \) are 
given in Figure 22.

\[ \hat{\Psi}_{1(A)} = .37375 \pm 2.448 \sqrt{.002930} = .37375 \pm .13251 \]
\[ \hat{\Psi}_{2(A)} = .12350 \pm 2.448 \sqrt{.004722} = .12350 \pm .16822 \]

Fig. 22--Confidence intervals for A-mean contrasts

The contrast of subjects with APR versus those without, 
\( \Psi_{1(A)} \), does not include zero; therefore, the null hypothesis 
may be rejected. The contrast of non-APR subjects with good

versus poor interval recognition skills, $\Psi_{2(A)}$, does contain zero; therefore the null hypothesis may not be rejected. These findings confirm the multiple-t tests for contrasts between means for treatment A discussed earlier.

The proportions of correct to incorrect answers for the $r = 5$ levels of treatment C (set manipulation) are shown in Table XI.

**TABLE XI**

PERFORMANCE (CORRECT:INCORRECT) BY SET MANIPULATION

<table>
<thead>
<tr>
<th></th>
<th>c1</th>
<th>c2</th>
<th>c3</th>
<th>c4</th>
<th>c5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct</td>
<td>58.33</td>
<td>38.89</td>
<td>47.22</td>
<td>37.22</td>
<td>30.56</td>
<td>212.22</td>
</tr>
<tr>
<td>Incorrect</td>
<td>41.67</td>
<td>61.11</td>
<td>52.78</td>
<td>62.78</td>
<td>69.44</td>
<td>287.78</td>
</tr>
</tbody>
</table>

100.00 100.00 100.00 100.00 100.00 500.00

$X^2 = 18.68^{**}$

df = c-1 = 4; $X^2_{.05,4} = 9.488; X^2_{.01,4} = 13.277$

$^{**}p < .01$

The significant test ($p < .01$) confirms the results of the omnibus-$F$ test for treatment C, that the set manipulation employed contributed significantly to a subject's performance in recognizing equivalency between sets.

The contrasts between C-means, tested earlier by the Dunn-Sidak procedure, were also checked by finding confidence intervals based on the chi-square statistic. The $(1-\alpha) = .95$ set of simultaneous confidence intervals for the six contrasts among C-means are given in Figure 23. Confidence
intervals not containing zero are those for $\Psi_1(c)$, $\Psi_2(c)$, $\Psi_3(c)$, and $\Psi_5(c)$; therefore, the null hypotheses for these contrasts may be rejected ($p < .05$). These findings confirm the Dunn-Sidak multiple comparison tests for contrasts among C-means.

$$
\begin{align*}
\Psi_1(c) &= .1972 \pm 3.08 \sqrt{0.001675} = .1972 \pm .1261 \\
\Psi_2(c) &= .1278 \pm 3.08 \sqrt{0.001289} = .1278 \pm .1106 \\
\Psi_3(c) &= .1444 \pm 3.08 \sqrt{0.001070} = .1444 \pm .1007 \\
\Psi_4(c) &= .1111 \pm 3.08 \sqrt{0.002735} = .1111 \pm .1610 \\
\Psi_5(c) &= .0888 \pm 3.08 \sqrt{0.002506} = .0888 \pm .1542
\end{align*}
$$

Fig. 23—Confidence intervals for C-mean contrasts

In fact, all chi-square tests performed merely confirmed the results of the overall $F$ test and tests for contrasts. This suggests that the analysis of variance was, after all, quite appropriate for the analysis of PET data.

Tests for the Effect of the Lures

In the omnibus $F$ test and tests for contrasts, each subject's score was based on the number of trials for which he correctly identified the target, the set equivalent to the original set. This test showed that a subject's ability to identify set equivalence was affected by his perceptual ability and by the particular set manipulation undergone by the original set in producing the equivalent set. It was
also of interest to the experimenter to examine what preference a subject had when he did not choose the correct answer. Was his choice between the lures affected by the set manipulation employed in the trial? Under what conditions did subjects prefer the pitch-invariant (PI) lure rather than the same-contour (SC) lure? This involves the question not only of when does a subject prefer an incorrect answer over the correct one, but also which incorrect answer does he choose and when?

To investigate these questions, the experimenter began by performing a Pearson chi-square test for homogeneity of population proportions. This is an extension of the test of equality of proportions to the case in which the criterion variable has more than two response categories. In our case, the criterion variable, answer choice, had three response categories: T, S and P. The manipulated variable of interest is set manipulation (target types 1, 2, 3, 4 and 5). The null hypothesis states that the proportion of answer choices (target, same-contour lure or pitch-invariant lure) is the same for all five set manipulations; that is, the answer choice was not affected by set manipulation.

The results of the Pearson chi-square test for homogeneity of proportions are given in Table XII. The null hypothesis was rejected ($p < .01$). This implies that the proportion of answer choices (T:S:P) was not the same for all five set manipulations.
TABLE XII
SUBJECT RESPONSE (T:S:P) BY SET MANIPULATION

<table>
<thead>
<tr>
<th></th>
<th>c1</th>
<th>c2</th>
<th>c3</th>
<th>c4</th>
<th>c5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>58.33</td>
<td>38.89</td>
<td>47.22</td>
<td>37.22</td>
<td>30.56</td>
<td>212.22</td>
</tr>
<tr>
<td>S</td>
<td>35.56</td>
<td>51.67</td>
<td>41.11</td>
<td>50.00</td>
<td>55.00</td>
<td>233.34</td>
</tr>
<tr>
<td>P</td>
<td>6.11</td>
<td>9.44</td>
<td>11.67</td>
<td>12.78</td>
<td>14.44</td>
<td>54.44</td>
</tr>
</tbody>
</table>

100.00 100.00 100.00 100.00 100.00 500.00

$X^2 = 20.1518^{**}$

$df = (r-1)(c-1) = (2)(4) = 8; X^2_{.05,8} = 15.507; X^2_{.01,8} = 20.090$

**p < .01

This finding simply confirms the significant test of treatment C (set manipulation) in the omnibus-F test. The real question at hand requires further investigation. Was this significant difference in proportions (T:S:P) due to differences in the number of correct answers chosen (T's) or to differences in preference for incorrect answer choices (S's and P's)? The difference might be due to varying percentages of correct vs. incorrect answer choices or to varying percentages of same-contour versus pitch-invariant lures chosen.

The test for equality of the proportion of correct versus incorrect answer choices across the five levels of the set manipulation variable had already been carried out.
(See Table XI.) The null hypothesis was rejected ($p < .01$), implying that proportions of correct and incorrect answers are different depending on the set manipulation involved. Therefore, differences in the proportion of student responses (T:S:P), shown in Table XII, may be accounted for by proportions of correct (T) versus incorrect (S and P) choices.

However, the question remains: are percentages of SC and PI lures chosen different depending on the set manipulation employed? Of the trials on which an incorrect answer was chosen, was the proportion of SC and PI lures different for different set manipulations? The contingency table and results of the Pearson chi-square test for equality of proportions of incorrect answer choices across the levels of the set manipulation variable are given in Table XIII.

**TABLE XIII**

INCORRECT RESPONSES (S:P) BY SET MANIPULATION

<table>
<thead>
<tr>
<th>Set Manipulations</th>
<th>c1</th>
<th>c2</th>
<th>c3</th>
<th>c4</th>
<th>c5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>85.34</td>
<td>84.55</td>
<td>77.89</td>
<td>79.64</td>
<td>79.21</td>
<td>406.63</td>
</tr>
<tr>
<td>P</td>
<td>14.66</td>
<td>15.45</td>
<td>22.11</td>
<td>20.36</td>
<td>20.79</td>
<td>93.37</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>500.00</td>
</tr>
</tbody>
</table>

$X^2 = 3.005; \, df = c-1 = 4; \, X^2_{.05,4} = 9.488$

In the contingency table, each observed score is the percentage of S or P responses out of the total number of
incorrect responses (S and P) for trials involving the set manipulation heading its column. The null hypothesis stating that the proportion of same-contour to pitch-invariant lures was the same across the five categories of set manipulation was not rejected. That is, subjects' choice between the lures on trials in which they did not choose the target was not affected by the set manipulations employed in the trials. On trials in which an incorrect answer was chosen, subjects preferred the SC lure approximately eighty-one percent of the time, regardless of the target type.
CHAPTER V

A SECOND RUN OF THE EXPERIMENT

Questions of Interest

Two questions, arising from the results of the data analysis, prompted a revision of the Perception of Equivalence Test for a second run of the experiment. The first question concerned the lack of a significant difference in performance on trials involving ordered transposition versus trials involving ordered transposition with octave displacement. The second question concerned how performance might be affected by using a lure preserving the standard's interval succession in place of the same-contour lure. A discussion of each follows.

Ordered Transposition and Octave Displacement

It was the experimenter's belief that performance would be greatest on trials in which the target set was a simple, ordered transposition of the original, and that performance would be significantly poorer on trials in which the target set also underwent octave displacement of its second pitch. However, the test of the contrast of ordered transposition and ordered transposition with octave displacement, \( \psi_{4(c)} \), was not found significant, that is subjects did not perform significantly poorer on trials involving ordered
transposition with octave displacement than they did on trials involving simple, ordered transposition.

For trials involving octave displacement, the experimenter had expected the subjects to reject the set with the displaced note as a possible equivalent target, since its character differed so radically from the small-interval standard. However, it is likely that the reaction was just the opposite. Because the displaced set was so different, perhaps subjects thought it was a "trap" and therefore a correct answer. It is also quite possible that targets which were ordered transpositions with octave displacement were too obvious. In actuality, the five trials involving octave displacement were the only five trials on the test which used intervals larger than a tritone.

To solve this problem, it was decided that the revision of PET should include other sets with intervals larger than a tritone, so that the displaced target would not draw quite so much attention. Rather than change the interval size of the standards and targets on the experimental trials, it was decided to include a group of dummy questions which would depart from the pattern of the actual test trials. Performance on the dummy trials would not be included in the data analysis. Each dummy trial included a large-interval foil in place of one of the lures. It was hoped that subjects would reject the large-interval foil, choose instead a small-interval set, and thus "learn" not to expect
large-interval sets always to be the correct answer. It was also expected that the increased exposure to large-interval sets would mitigate the obvious difference of the targets with octave displacement.

A Lure Preserving the Standard's Interval Succession

The data analysis of PET showed that the same-contour lure was the most-preferred answer choice. The percentages of target, same-contour lure and pitch-invariant lure answer choices, pooled across all levels of perceptual ability, set type and set manipulation, are given in Table XIV.

### Table XIV

<table>
<thead>
<tr>
<th></th>
<th>No. of responses</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>383</td>
<td>42.5556%</td>
</tr>
<tr>
<td>SC Lure</td>
<td>419</td>
<td>46.5556</td>
</tr>
<tr>
<td>PI Lure</td>
<td>98</td>
<td>10.8888</td>
</tr>
</tbody>
</table>

The test for equality of proportions of incorrect answer choices also showed that, irrespective of the set manipulation involved, the same-contour lure was chosen on approximately eighty-one percent of the trials in which an incorrect answer was chosen. (See Table XIII.) Thus, the "luring" effect of a non-equivalent, same-contour set clearly had been demonstrated.

It was of further interest to the experimenter to examine performance in the absence of the same-contour (SC)
The revision of PET

The following discussion describes revisions in the Perception of Equivalence Test. Factors not discussed can be assumed to be the same as in the original test.
Standards and II Lures

The major changes in the test were due to the inclusion of the invariant-interval succession lure (II lure) in place of the same-contour lure of the original test. Preserving the interval succession of a set without creating an equivalent set requires changing the direction of one of the original's successive intervals. It was decided arbitrarily to hold constant the original's first interval's direction and change the direction of the second interval, as in Figure 24.

The transposition level of the II lure was designed to be in a constant relationship to its trial for each set type. The first two pitches of the II lure were the same as the first two pitches of the ordered inversion target but in reverse order. Controlled in this way, the pitch level of the II lure was not more "out of range" for some trials than for others.

Because the standards used in PET were all bidirectional in contour, the II lure was necessarily unidirectional. The experimenter could have changed the standards to be unidirectional, but such a change would have caused the targets with octave displacement to have compound intervals. It was felt that the introduction of compound intervals into the experiment was unnecessary and undesirable.
Given that standards were bidirectional, and II lures were as a result unidirectional, it was desired that standards should not consist of successive skips. If they had, the II lure resultingly might have been a set with strong tonal implications, as in Figure 25.

![Fig. 25--Hypothetical II lure with tonal implications.](image)

To avoid such unfortunate arrangements, the standards were rewritten so that the major or minor second of the set was one of the successive intervals. In rewriting the standards, care was taken so as to choose the most "atonal" of the possible arrangements of the set's members. That is, all of the set types can be stated as sets which may be interpreted tonally, but some sets sound more tonal than others. The choice of a standard for set type 3-4 was particularly difficult. Figure 26 shows the four possible bidirectional sets of set 3-4, using the step as a successive interval.

![Fig. 26--Possible standards for set type 3-4.](image)
Examples a) and b) above, both ending with the resolution of a pitch of the dominant harmony, sound particularly tonal.
From examples c) and d), c) was chosen because its step-skip contour made it more similar to the standards chosen for the other set types.

The Pitch-Invariant Lure

Pitch-invariant (PI) lures were also used on trials in PET2. It was felt that pitch invariance perhaps would become a stronger factor of association between two sets in the absence of a same-contour lure.

In the original test, the PI lure held invariant the first two pitches of the standard, but reversed their order. The third pitch was chosen so as to form a set which was unidirectional in contour (to distinguish it from the contour of the same-contour lure). In the revision, the third pitch was chosen so as to created a bidirectional set. Otherwise, both the II and PI lures would have been unidirectional in contour. Performance on the original test indicated that subjects listened primarily for contour. It was felt that if both lures were unidirectional (distinctly different in contour from the bidirectional standards) then subjects listening primarily for shape would not be particularly lured by the incorrect answers. Designing the lures in this way avoided using a same-contour lure and yet prevented both lures from being so different in contour that
they ceased to be lures. The resulting contour of the PI lure was "flipped" from that of the standard.

**Dummy Trials**

The experimenter felt that the length of the test should not increase even with the addition of dummy questions. It seemed that subjects would not tolerate a longer test well and that performance might suffer because of fatigue or disinterest. Therefore, it was decided to exclude one of the set types from the experiment and use it instead as a standard for five dummy trials.

The set type to be used for the dummy trials was determined in designing the actual experimental trials for the revised test, as described above. Set type 3-5 could not be stated as a set which could meet the criteria for standards and II lures. Because of its tritone, it is impossible to find a bidirectional set with a successive step (a standard) for which there is a non-equivalent set having the same interval succession (II lure). (See Figure
28.) It is impossible to preserve the half-step-tritone (or tritone-half-step) sequence without creating an equivalent

\[ \text{Standards} \quad \text{II Lures} \]

\[ \text{Fig. 28--Equivalent sets (type 3-5) preserving interval succession.} \]

set. This property made set 3-5 the perfect choice as the set type to be used for the dummy questions.

Since the purpose of the dummy trials was to disguise the organization of the test, the trials were designed to depart from the pattern of the actual experimental trials. They differed in the following ways:

1. the standard (set type 3-5) was unidirectional;
2. therefore, the reordered targets were bidirectional;
3. a large-interval foil was used instead of the II lure;
4. thus, trials involving octave displacement had two large-interval answer choices, one of which obviously was incorrect. (For actual dummy trials used in the test, see Appendix G.) No change was made in the PET routines for randomization of trials, and thus, one dummy trial was randomly presented among every five trials.

**Transposition Direction and Levels for Targets**

It was felt that the lack of a significant difference in performance on target 1 (ordered transposition) from target 3 (ordered transposition with octave displacement) may have been due to the transposition levels chosen on the original test. The effect of octave displacement was exaggerated by transposing the target in the same direction as the direction of octave displacement. For example, see Figure 29.

![Fig. 29--Standard-target 3 relationship on PET trial.](image)

In the revised test, the transposition direction chosen for each set type was opposite to the direction of octave displacement for the third targets. In this way, the effect of inverting the successive intervals of the standard could be measured without making the target so obvious because of pitches in extreme ranges. This again was an attempt to
lessen the conspicuous nature of trials involving octave displacement.

The distance of transposition chosen for targets was governed by the same criteria used in the construction of trials on the original test. In addition, one further control was placed on the choice. On the revised test, no two answer choices on any particular trial begin on the same pitch.

Randomization of Answer Choices

As mentioned previously, no changes were made in the PET procedures for randomizing trials. The procedures for randomizing answer choices within a trial were also retained for the revised test, except that all references to "S" (representing the same-contour lure) were changed to "I" (representing invariant-interval succession lure).

Scoring Messages

All parts of the PET program visible to the subject were identical to the original test except the closing section in which his scores were presented. That is, subjects received the same instructions, and the presentation of the questions and required input were the same. The brief explanation of lures and the text on the score page was of course changed to give information about the II lure instead of the SC lure.
Evaluation of PAT Scores

Forty-three subjects completed both the Perception Ability Test and the Tutorial and were thereby eligible to take the Perception of Equivalence Test. The criteria used to divide these subjects into three Perception Ability (PA) groups were different from those used for the first run of the experiment. Whereas the total score was used in the first run to place subjects in PA1, in the second run only the scores for section III (Absolute Pitch Recognition) were considered. At first, the score of twenty (out of a possible twenty-five) on section III was to be used as the criterion for PA1 subjects. Dividing subjects according to this criterion resulted in a group of five subjects with an aptitude approaching absolute pitch recognition. However, an additional student who had a score of 17.5 on section III (seven out of ten questions answered correctly) was admitted into PA1. Through discussion with this subject and with his ear-training instructor, it was determined that this subject's ability approached absolute pitch recognition.

Another difference in the division of PAT scores for the second run concerned the inclusion of scores on section IV (Melodic Memory). The majority of subjects (forty of the forty-three) answered all questions correctly in this section. Thus, scores on this section did not really contribute any information as to differences in subjects' perceptual abilities. Therefore, placement of subjects in
PA2 and PA3 was based on performance on sections I and II, the questions concerning interval recognition. Scores for sections I and II were summed for each subject; the best possible total was fifty. Subjects with scores of forty or greater were placed in PA2; those with scores of less than forty were placed in PA3. The score of forty was chosen as delimiter because it allowed for a fairly equal distribution of subjects between PA2 and PA3. The division of subjects according to the criteria described above resulted in groups of size 6, 20, and 17, for PA1, PA2 and PA3, respectively.

Data Analysis

The changes made in the Perception of Equivalence Test for the second run of the experiment required only a few changes in the statistical analysis of data. In the data analysis of the original test, the effect of set type used as standard (variable B) was not shown to be significant. Although the PET2 standards were revised, they were, being bidirectional and made of small intervals, very similar to those of the original test. Therefore, since set type did not contribute to differences in performance on the original test, it was not included as an experimental variable in the data analysis of the second run. Thus, the experimental design of PET2 involved only two experimental variables: treatment A (perceptual ability) and treatment B (set manipulation). (In the discussion of data analysis to follow, treatment B refers to the variable of set manipulation,
which corresponds to treatment C of the original data analysis.)

As before, treatment A had three levels: subjects with APR (a1), subjects without APR and with good interval recognition skills (a2), and subjects without APR and with poor interval recognition skills (a3). The levels of the set-manipulation treatment were the same as before: ordered transposition (b1), ordered inversion (b2), ordered transposition with octave displacement (b3), reordered transposition (b4) and reordered inversion (b5).

The revised test involved twenty-five trials, five trials (corresponding with the five set manipulations) for each of five set types. However, one set of trials—the five trials for set type 3-5—were dummy trials. Subjects' performance on dummy trials was not included in the data analysis. Thus, each subject's performance on only twenty trials, four trials for each set manipulation, was subjected to statistical analysis.

**Exploratory Data Analysis**

Mean scores for the three perceptual ability groups were figured as follows. A subject's best possible total score was 20. For each of the five types of trials he could answer from 0-4 trials correctly. Averaging across the levels of treatment B and across all subjects within each perceptual ability group resulted in a mean score representing the average number of trials answered correctly.
out of four. Figured in this way, each subject's average score and thus each group's average score was a number between zero and four. These means are shown in Table XV.

### TABLE XV

**MEAN SCORE FOR PERCEPTUAL ABILITY GROUPS**  
(AVERAGE NUMBER OF CORRECTLY-ANSWERED TRIALS OUT OF FOUR)

<table>
<thead>
<tr>
<th></th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y.j.</td>
<td>2.40</td>
<td>1.66</td>
<td>1.14</td>
</tr>
</tbody>
</table>

However, subjects' average performance is perhaps more intuitively understood by viewing their average total scores, that is the average number of correctly-answered trials out of twenty total trials. These means are shown in Table XVI.

### TABLE XVI

**MEAN SCORES FOR PERCEPTUAL ABILITY GROUPS**  
(AVERAGE NUMBER OF CORRECTLY-ANSWERED TRIALS OUT OF TWENTY-FIVE TOTAL TRIALS)

<table>
<thead>
<tr>
<th></th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y.jk</td>
<td>12.00</td>
<td>8.30</td>
<td>5.71</td>
</tr>
</tbody>
</table>

The mean scores suggest that performance was affected by subjects' perceptual ability. Performance of subjects with APR appears to be significantly better than performance of non-APR subjects, and there also appears to be a
significant difference in performance between subjects with good and poor interval recognition skills.

Mean scores for treatment B (shown in Table XVII) represent the mean number of trials answered correctly out of four, averaged across all subjects and all levels of treatment A.

**TABLE XVII**

MEAN SCORES FOR SET MANIPULATIONS
(MEAN NUMBER OF CORRECTLY-ANSWERED TRIALS OUT OF FOUR FOR EACH SET MANIPULATION)

<table>
<thead>
<tr>
<th>Target type</th>
<th>b1</th>
<th>b2</th>
<th>b3</th>
<th>b4</th>
<th>b5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y..k</td>
<td>2.65</td>
<td>1.40</td>
<td>1.09</td>
<td>1.21</td>
<td>1.44</td>
</tr>
</tbody>
</table>

The mean scores for treatment B reflect some variation in performance due to the set manipulation employed in the trials. Arranged in order of successful to less successful performance, the five set manipulations are:

- ordered transposition (b1)
- reordered inversion (b5)
- ordered inversion (b2)
- reordered transposition (b4)
- ordered transposition with octave displacement (b3)

Oddly, performance on reordered inversion was slightly higher than performance on ordered inversion. It is also unusual that performance on trials involving reordered inversion was better than on trials involving reordered
transposition. However, the difference in performance was small and possibly insignificant. (See later discussion of statistical tests for the significance of these differences.)

The most noticeable difference in performance was that of trials involving ordered transposition versus all other trials. The ranked order of set manipulations above is perhaps misleading because differences among target types other than ordered transposition were actually quite small, ranging only from 1.44 to 1.09, or roughly one out of four trials answered correctly.

The following section gives the results of statistical tests of hypotheses about treatments A and B using data from the PET2 answer choice data matrices. The data were subjected to analysis of variance and to tests for contrasts between means. (In the first run, chi-square tests were carried out to confirm the results of ANOVA and tests of contrasts and in every case the original results were confirmed. The chi-square tests were redundant, provided no new information and simply confirmed the appropriateness of ANOVA for PET data. Therefore, these tests were not carried out for PET2 data.)

**Experimental Design**

The analysis of variance design employed was a split-plot factorial, SPF-p.q, design with repeated measurements.
In this two-treatment design, subjects receive only one of the p levels of treatment A and all q levels of treatment B. Since treatment A had three levels and treatment B had five levels, the specific design employed was a SPF-3.5 design.

**Analysis of Variance**

The research hypotheses for treatments A and B correspond to those for treatments A and C in the original data analysis. That is, the experimenter was still interested to see if there were significant differences in the recognition of set equivalency due to perceptual ability of the subjects and to the set manipulations used in the trials. (See research hypotheses, pp. 75-77.)

The overall null hypothesis for treatment A states that performance was not affected by perceptual ability, that is, the three A-population means did not differ. Stated in statistical notation, this null hypotheses and its alternative hypothesis are as shown in Figure 30.

\[
H_0: \mu_1 = \mu_2 = \mu_3 \quad \text{or} \quad H_0: \alpha_j = 0 \quad \text{for all } j
\]

\[
H_1: \mu_1 \neq \mu_2 \text{ for some } j \text{ or } j' \quad \text{or} \quad H_1: \alpha_j \neq 0 \text{ for some } j
\]

---

The overall null hypothesis for treatment B states that performance was not affected by set manipulation, that is, the five B-population means did not differ. Expressed as
statistical hypotheses, the null hypothesis and its alternative are as shown in Figure 31.

\[ H_0: \mu_{.1} = \mu_{.2} = \mu_{.3} = \mu_{.4} = \mu_{.5} \]

or \( H_0: \beta_k = 0 \) for all \( k \)

\[ H_1: \mu_k \neq \mu_{k'} \) for some \( k \) or \( k' \) or \( H_1: \beta_k \neq 0 \) for some \( k \)

Fig. 31—Statistical hypotheses for treatment B; second run.

The null hypothesis concerning the interaction of treatments A and B states that there was no interaction. Expressed statistically, the null hypothesis for interaction and its alternative are shown in Figure 32.

\[ H_0: (\alpha\beta)_{jk} = 0 \] for all \( j,k \)

\[ H_1: (\alpha\beta)_{jk} \neq 0 \) for some \( j,k \)

Fig. 32—Statistical hypotheses for interactions; second run.

The results of the analysis of variance are summarized in Table XVIII.

The null hypotheses for treatment A (perceptual ability) and treatment B (set manipulation) were rejected (\( p < .01 \)). The null hypothesis for the interaction of treatments A and B was not rejected; that is, the interaction was not found to be significant.

We can infer from the analysis of variance that recognition of set equivalency was affected by the subjects' perceptual ability and by the set manipulations employed in
### Table XVIII

**ANOVA Table, SPF-3.5 Design**

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Between blocks</td>
<td>127.423</td>
<td>N-1  = 42</td>
<td>18.537</td>
<td></td>
</tr>
<tr>
<td>2 A (Perc. ability)</td>
<td>37.073</td>
<td>P-1  = 2</td>
<td>18.537</td>
<td>[2/3] 8.21**</td>
</tr>
<tr>
<td>3 Blocks w. A</td>
<td>90.350</td>
<td>N-p  = 40</td>
<td>2.259</td>
<td></td>
</tr>
<tr>
<td>4 Within blocks</td>
<td>219.600</td>
<td>N(q-1) = 172</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 B (Set manipulatn.)</td>
<td>67.628</td>
<td>q-1  = 4</td>
<td>16.907</td>
<td>[5/7] 18.89**</td>
</tr>
<tr>
<td>6 AB</td>
<td>8.793</td>
<td>(p-1)(q-1) = 8</td>
<td>1.099</td>
<td>[6/7] 1.23</td>
</tr>
<tr>
<td>7 B x blocks w. A</td>
<td>143.179</td>
<td>(N-p)(q-1) = 160</td>
<td>0.895</td>
<td></td>
</tr>
<tr>
<td>8 Total</td>
<td>347.023</td>
<td>Nq-1 = 214</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**p < .01**
the trials. The lack of significant interaction implies that the relative difficulty of perceiving set equivalency under the various set manipulations was the same for all three perceptual ability groups; that is, certain set manipulations were more difficult to perceive than others, regardless of the perceptual ability of the subject. It also implies that the relative success in performance among the three perceptual ability groups was not affected by the set manipulations employed; that is, at least one perceptual ability group performed better than another throughout the test, regardless of variance in performance due to the set manipulations.

Contrasts Between Means

A significant overall F test implies that population means differ, but it does not indicate which of the means are significantly different. Since the overall F test described above was significant and the interaction was not significant, the experimenter could proceed to test specific comparisons of means.

The research hypotheses tested concerning contrasts between means were identical to those for the original data analysis (see pp. 75-77) and for this reason, they are not restated here. As before, the two contrasts concerning treatment A were orthogonal and could be tested using multiple-t tests. The contrasts for treatment B (formerly
treatment C) were non-orthogonal and were tested using the Dunn-Sidak procedure.

In addition to the two contrasts concerning perceptual ability and the six contrasts concerning set manipulation tested previously, a seventh contrast for treatment B was included. As mentioned earlier, the mean performance on trials involving reordered inversion (b5) was slightly higher than performance on trials involving reordered transposition (b4). Because this result was unexpected, the experimenter wanted to test if the difference in performance was significant or only due to chance variation in the scores. This contrast, expressed statistically, is:

$$\Psi_{(b)} = \bar{Y}_{5} - \bar{Y}_{4}$$

This particular contrast was not originally of interest but rather was suggested only through examining the data after the experiment had been run. Spjøtvoll and Stoline's $T'$ test is appropriate for a posteriori contrasts with unequal n's, and was used to test the seventh B-mean contrast.

The results of testing A-mean and B-mean a priori contrasts are given in Table XIX. The results of testing the two contrasts among treatment-A means were significant. These tests show that subjects with APR performed significantly better than subjects without the facility, and that among subjects without APR, those with good interval recognition skills performed significantly better than those with poor interval recognition skills.
### Table XIX

**Contrasts among Treatment A Means and Treatment B Means**  
**Second Run**

<table>
<thead>
<tr>
<th>Means</th>
<th>MSerror</th>
<th>df</th>
<th>Critical values</th>
<th>t statistics</th>
</tr>
</thead>
</table>
| A     | 2.259   | 40 | $t_{.05,40} = 1.684$  
$t_{.01,40} = 2.423$ | $t = \frac{\hat{\gamma}_1(A)}{\hat{\delta}_\psi(A)} = 3.379^{**}$  
$t = \frac{\hat{\gamma}_2(A)}{\hat{\delta}_\psi(A)} = 2.345^*$ |
| B     | 0.895   | 160| $t_{DS,05,160} = 2.653$  
$t_{DS,01,160} = 3.179$ | $t_{DS} = \frac{\hat{\psi}(_{5})_{(b)}}{\hat{\delta}_\psi(b)} = 8.478^{**}$  
$t_{DS} = \frac{\hat{\psi}(_{3})_{(b)}}{\hat{\delta}_\psi(b)} = 3.535^{**}$  
$t_{DS} = \frac{\hat{\psi}(_{2})_{(b)}}{\hat{\delta}_\psi(b)} = 2.923^*$  
$t_{DS} = \frac{\hat{\psi}(_{1})_{(b)}}{\hat{\delta}_\psi(b)} = 7.646^{**}$  
$t_{DS} = \frac{\hat{\psi}(_{0})_{(b)}}{\hat{\delta}_\psi(b)} = 7.058^{**}$  
$t_{DS} = \frac{\hat{\psi}(_{-1})_{(b)}}{\hat{\delta}_\psi(b)} = -.196$ |

**Note:**
* $P < .01$  
* $P < .05$

All but one of the contrasts among treatment-B means were shown to be significant. The null hypothesis could not be rejected for the contrast of ordered inversion ($b_2$) versus reordered inversion ($b_5$), $\hat{\psi}_{b_5}$. This result was not surprising considering the fact that the mean for ordered inversion and the mean for reordered inversion were very close in value, 1.40 and 1.44, respectively.
The a posteriori contrast, \( \hat{\Psi}(\theta) \), was tested according to Spjøtvoll and Stoline's procedure, described below. The critical difference, \( \hat{\Psi}(T') \), which must be exceeded for a contrast to be declared significant, is figured as

\[
\hat{\Psi}(T') = q' \sqrt{\frac{MS_{error}}{n_{min}}}
\]

where \( p \) equals the total number of treatment means and \( v \) is the degrees of freedom associated with the error term. In our case, \( q'_{.05,5,150} = 3.917 \) and \( \hat{\Psi}(T') = 3.917 \sqrt{.895/6} = 1.513 \). The value of the contrast (the difference between \( b_4 \) and \( b_5 \) means) was 1.127. Since the contrast did not exceed the critical difference, \( (T') \), it is not significant. This confirmed the experimenter's expectation that although performance was better for reordered inversion than for reordered transposition, the difference was so slight as to be insignificant and due only to chance variation in the scores.

**Tests for the Effect of the Lures**

As in the first run of the experiment, it was of interest to the researcher to see how recognition of set equivalency might be affected by the inclusion of incorrect answer choices which were non-equivalent and yet in some way similar to the original set. The same-contour lure of the original test was replaced with a lure preserving the interval succession of the original set. It was felt that in the absence of the same-contour lure, the pitch-invariant lure would be a more viable answer choice. Subjects'
responses were examined to determine which lure was more preferred and to see if the preference was influenced by perceptual ability or set manipulation.

The subject-response data matrices contained every subject's response (target, interval-invariant lure or pitch-invariant lure) to every trial. A simple average of all responses averaged over all subjects and all trials is shown in Table XX. In general, the II lure was preferred to the PI lure. However, these percentages do not show whether preference varied due to perceptual ability of the subjects or to the set manipulation of the trials.

**TABLE XX**

PERCENTAGES OF RESPONSES OUT OF 860 TOTAL RESPONSES

<table>
<thead>
<tr>
<th></th>
<th>No. of responses</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>335</td>
<td>38.95%</td>
</tr>
<tr>
<td>II Lure</td>
<td>307</td>
<td>35.70%</td>
</tr>
<tr>
<td>PI Lure</td>
<td>218</td>
<td>25.35%</td>
</tr>
</tbody>
</table>

Perceptual ability and lure preference.---To measure the effect of perceptual ability of subjects' preference for one lure over the other, it was necessary first to insure that proportions of answer choices were different across the levels of perceptual ability. Proportions of answer choices for the three perceptual ability groups and the results of the Pearson chi-square test for homogeneity of population proportions are given in Table XXI.
TABLE XXI

SUBJECT RESPONSE (T:I:P) BY PERCEPTUAL ABILITY

<table>
<thead>
<tr>
<th>Perceptual Ability</th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>60.00</td>
<td>41.50</td>
<td>28.53</td>
</tr>
<tr>
<td>I</td>
<td>28.33</td>
<td>36.00</td>
<td>37.94</td>
</tr>
<tr>
<td>P</td>
<td>11.67</td>
<td>22.50</td>
<td>33.53</td>
</tr>
<tr>
<td></td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

\[ X^2 = 23.6446^{**} \]
\[ df = (r-1)(c-1) = (2)(2) = 4 \]
\[ X_{0.05,4}^2 = 9.488 \]
\[ X_{0.01,4}^2 = 13.277 \]

**\[ p < .01 \]

This test showed that the proportion of answer choices was significantly different across the levels of perceptual ability (\( p < .01 \)). This result simply confirmed the significant test of treatment A in ANOVA. It appeared likely, however, that this difference was due to variance in the proportions of correct answer (T's) chosen by the respective groups. For example, the target was the most preferred answer choice by PA1 and PA2 groups, whereas the II lure was most preferred by PA3 subjects.

To test if the difference in proportions was in any part due to differences in preference for the lures, proportions of incorrect answer choices were figured for each of the perceptual ability groups. In Table XXII, each entry is the percentage of I or P responses out of the total number of incorrect responses (I and P) for each perceptual
ability group. These proportions show that as perceptual ability decreased, the proportion of PI lures chosen increased. However, the chi-square test for equality of proportions was not significant; that is, the null hypothesis stating that there was no difference in the proportion of I and P responses across the levels of perceptual ability could not be rejected. There was actually no significant difference in preference for the II or PI lure due to perceptual ability. Regardless of the

**TABLE XXII**

INCORRECT RESPONSES (I:P) BY PERCEPTUAL ABILITY

<table>
<thead>
<tr>
<th>Perceptual Ability</th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>70.83</td>
<td>61.54</td>
<td>55.12</td>
<td>187.49</td>
</tr>
<tr>
<td>P</td>
<td>29.17</td>
<td>38.46</td>
<td>44.88</td>
<td>112.51</td>
</tr>
<tr>
<td></td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>300.00</td>
</tr>
</tbody>
</table>

$\chi^2 = 5.324; \quad df = c-1 = 2$

$\chi^2 .05,2 = 5.991$

perceptual ability of the subject, the II lure was the more preferred incorrect answer choice.

Set manipulation and lure preference.—Subject responses were also grouped by trials for each of the five set manipulations and were analyzed to see if preference for incorrect answer choices was affected by the set manipulation employed. First, proportions of all answer choices
(target, II lure and PI lure) were figured for each of the five set manipulations. A Pearson chi-square test for homogeneity of proportions was carried out. The results are given in Table XXIII.

The significant test (p < .01) implies that answer-choice preference was affected by set manipulation; specifically, it shows that proportions of responses (T:I:P) were significantly different across the levels of set manipulation. This test simply confirmed the significant test of treatment B in ANOVA.

**TABLE XXIII**

SUBJECT RESPONSE (T:I:P) BY SET MANIPULATION

<table>
<thead>
<tr>
<th>Set Manipulation</th>
<th>b1</th>
<th>b2</th>
<th>b3</th>
<th>b4</th>
<th>b5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>66.28</td>
<td>34.88</td>
<td>27.33</td>
<td>30.23</td>
<td>36.05</td>
<td>194.77</td>
</tr>
<tr>
<td>I</td>
<td>14.53</td>
<td>37.79</td>
<td>45.93</td>
<td>43.02</td>
<td>37.21</td>
<td>178.48</td>
</tr>
<tr>
<td>P</td>
<td>19.19</td>
<td>27.33</td>
<td>26.74</td>
<td>26.75</td>
<td>26.74</td>
<td>126.75</td>
</tr>
<tr>
<td></td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>500.00</td>
</tr>
</tbody>
</table>

\[ x^{**} = 44.2902; \quad \text{df} = (r-1)(c-1) = (2)(4) = 8 \]
\[ x_{.05,8}^2 = 15.507 \quad x_{.01,8}^2 = 20.090 \]

**p < .01**

To see whether this difference in proportions was due in part to differing preferences for II and PI lures, proportions of incorrect answer choices (I:P) were figured for each target type. (See Table XXIV.) The null hypothesis that proportions were equal across the levels of set
manipulation was rejected ($p < .05$). The significant test implies that the lure chosen was affected by the set manipulation of the trial.

**TABLE XXIV**

**INCORRECT RESPONSES (I:P) BY SET MANIPULATION**

<table>
<thead>
<tr>
<th>Set Manipulation</th>
<th>b1</th>
<th>b2</th>
<th>b3</th>
<th>b4</th>
<th>b5</th>
<th>284.19</th>
<th>215.81</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>43.10</td>
<td>58.04</td>
<td>63.20</td>
<td>61.67</td>
<td>58.18</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P</td>
<td>56.90</td>
<td>41.96</td>
<td>36.80</td>
<td>38.33</td>
<td>41.82</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>100.00</strong></td>
<td><strong>500.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

$x^2 = 10.4272^*$  \( df = c-1 = 4 \);  \( x^2_{.05,4} = 9.488 \)

*\( p < .05 \)

A cursory look at the data in Table XXIV suggested that the significant difference in proportions was due to performance on trials involving ordered transposition (b1). For trials involving ordered transposition when the target was not chosen, the PI lure was preferred. The II lure was preferred on all other trials. The chi-square test for equality of proportions indicated that proportions differed, but not specifically which proportions differed. To determine where differences in proportions lay and to test the significance of the seeming difference for ordered-transposition targets, further contrasts between these proportions were tested.
The contrast between ordered-transposition trials and all others was tested by performing the chi-square test for contrasts between proportions. The \((1-\alpha) = .95\) confidence interval for this contrast is shown in Figure 33.

\[
\hat{\psi}_1 = \hat{p}_4 - (\hat{p}_2 + \hat{p}_3 + \hat{p}_4 + \hat{p}_5) / 4
= .4310 - (.5804 + .6320 + .6167 + .5818) / 4
= -.1717
\]

\[
\hat{\psi}_2 = \hat{\psi}_1 \pm \sqrt{\chi^2_{0.05, \nu}} (SE\hat{\psi}_1)
= -.1717 \pm 3.08 (.0552) = -.1717 \pm .1700
\]

Fig. 33—Chi-square test for contrast between ordered transposition trials and all others.

Because the confidence interval did not include zero, the null hypothesis was rejected \((p < .05)\). From this test we can conclude that the preference for the PI lure on trials involving ordered transposition was significantly different than lure preference on all other trials.

Other contrasts between incorrect-answer proportions for trials other than those involving ordered transposition were carried out, but no significant contrasts were found. This was to be expected since proportions of lures chosen for all targets other than ordered transposition were very close in value; roughly sixty percent were II lures and forty percent PI lures. (See Table XXIII, b2-b5.) It was concluded that the significant difference in proportions illustrated in Table XXIII was due to the preference for PI
lures on ordered transposition targets versus the preference for II lures on all other trials. Further implications of this test and all other statistical tests are discussed in the chapter to follow.
CHAPTER VI

DISCUSSION AND CONCLUSION

In the discussion which follows, the researcher presents the results of the two runs of the experiment (PET and PET2) for comparison, summarizes the findings of the experiment as a whole, discusses implications of the investigation for aural pedagogy and analysis and makes suggestions for further research.

A Comparison of PET and PET2

Before comparing the results of the two runs of the experiment, it was necessary to make a comparison of the two groups of subjects. If the two groups were very different in their aural capabilities or experience, a comparison of their performance on the Perception of Equivalence Test would be questionable.

Homogeneity of Subjects

All subjects, whether participating in the first or second run, were students in sophomore ear-training courses at North Texas State University. A comparison of the subjects' overall performance on the Perception Ability Test (PAT) was carried out to further insure that subjects who participated in PET were generally comparable in ability to subjects who participated in PET2. The overall mean score
on the Perception Ability Test for each group was used as a measure of general ability. A t-test was carried out on the data, as shown in Figure 34.

<table>
<thead>
<tr>
<th></th>
<th>PAT1</th>
<th>PAT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{x}$</td>
<td>65.07</td>
<td>67.50</td>
</tr>
<tr>
<td>n</td>
<td>36</td>
<td>43</td>
</tr>
</tbody>
</table>

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\sigma^2_{\text{pooled}}}{1/n + 1/n}}} = \frac{65.07 - 67.50}{\sqrt{202.67(1/36 + 1/43)}} = -2.43 = -0.755$$

df = (36-1) + (43-1) = 77; $t_{0.05,77} = -1.668$

Fig. 34—T-test on overall PAT scores.

The null hypothesis stating that the difference in population means was equal to zero could not be rejected. In other words, the mean performance on the Perception Ability Test of the first group of subjects was not significantly different from that of the second group of subjects. Since first-run subjects were of comparable perceptual ability to second-run subjects, the experimenter could proceed to make comparisons of their performance on the Perception of Equivalence Test.

The Effect of PET2 Revisions

It was of interest to see how changes in the Perception of Equivalence Test affected subjects' performance. The two major changes in the test for the second run were 1) the inclusion of dummy questions with large-interval foils and 2) the replacement of the same-contour lure with a lure.
preserving the interval succession of original sets. As described in chapter V, it was concluded that first-run subjects believed ordered transposition targets with octave displacement to be "trick questions" and thus chose them as correct answers. This made scores on trials involving octave displacement not significantly different from trials involving simple ordered transposition. It was expected that the inclusion of large-interval incorrect answer choices would make the displaced targets less obvious and would thereby accentuate differences in performance. This expectation was confirmed by the results of PET2. Whereas in the first run of the experiment there had been no significant difference in performance for ordered transposition versus ordered transposition with octave displacement, performance on the second test did show a significant difference (p < .01). This finding confirmed the researcher's hypothesis that octave displacement disguises set equivalency.

The second revision involved replacing the same-contour lure with a new lure. Since the same-contour lure was such a preferred answer choice on the first test, it was of interest to see how its absence would affect subjects' answer choices. Would overall performance on the test improve? Would the pitch-invariant lure become a more viable answer choice?
The answer to these questions required a direct comparison of PET and PET2 performance. The mean percentage of trials answered correctly out of the total number of trials was used as a descriptor of the overall performance on PET and on PET2. These percentages were previously given as a percentage of T responses in Tables XIV and XX. A t-test was carried out to see if the mean performance on PET was significantly different from that on PET2. The results are shown in Figure 35.

<table>
<thead>
<tr>
<th></th>
<th>PET</th>
<th>PET2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{X} )</td>
<td>42.56</td>
<td>38.95</td>
</tr>
<tr>
<td>( n )</td>
<td>36</td>
<td>43</td>
</tr>
</tbody>
</table>

\[ df = 77; \quad t_{0.05,77} = 1.668; \quad t = .723 \]

Fig. 35—T-test on overall PET scores.

At first glance it appeared that performance did not at all increase on PET2 but rather that it decreased. However, the null hypothesis could not be rejected, indicating that the two means were not significantly different. The absence of the same-contour lure apparently did not affect overall performance on the test.

It was interesting to compare answer-choice preference for the two tests. Percentages of target (T), same-contour lure (S), pitch-invariant lure (P) and interval-invariant lure (I) responses are given in Table XXV. A cursory look at these percentages indicates that the same-contour lure
TABLE XXV

COMPARISON OF RESPONSES ON PET AND PET2

<table>
<thead>
<tr>
<th></th>
<th>PET</th>
<th>PET2</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>42.56%</td>
<td>38.95%</td>
</tr>
<tr>
<td>S</td>
<td>46.56</td>
<td>35.70</td>
</tr>
<tr>
<td>P</td>
<td>10.89</td>
<td>25.35</td>
</tr>
</tbody>
</table>

was the most-preferred answer choice on the first run of the test, whereas the targets were most preferred on PET2. Apparently, successive interval invariance (I response) was not as strong a lure as similarity in contour (S response). Thus, although the absence of the confusing same-contour lure did not affect overall performance (meaning the percentage of correctly-answer trials), it did seem to affect preference for the pitch-invariant lure. The percentages of answer-choice preference for the two tests does reflect an increase in preference for the PI lure. A test for the significance of this increase was carried out, the results of which are shown in Table XXVI.

TABLE XXVI

PI LURE PREFERENCE ON PET AND PET2

<table>
<thead>
<tr>
<th></th>
<th>PET</th>
<th>PET2</th>
</tr>
</thead>
<tbody>
<tr>
<td>P's</td>
<td>10.89</td>
<td>25.35</td>
</tr>
<tr>
<td>Other</td>
<td>89.11</td>
<td>74.65</td>
</tr>
</tbody>
</table>

100.00  100.00  200.00

\[ x^2 = 7.046^{**} \quad df = 1; \quad x^2_{.05,1} = 3.841; \quad x^2_{.01,1} = 6.635 \]

** p < .01
The chi-square test for equality of proportions resulted in a rejection of the null hypothesis ($p < .01$). This test indicates that there was a significant increase in the number of P responses in the second test, in the absence of the same-contour lure.

Summary of Findings

Performances on the Perception of Equivalence Test supported the hypothesis that recognition of set equivalency may be affected by listener characteristics and by the degree of manipulation involved in the equivalency relationship. As expected, all equivalent sets were not heard "equally as equivalent," but rather some equivalency relationships seemed aurally "more equivalent" than others. Also, non-equivalent sets with similarity in contour or interval succession were perceived as being more related than equivalent sets. The findings of PET and PET2 are given as general statements in Table XXVII.

In addition to the findings shown in Table XXVII, the set type of the standard (of the five set types used in the experiment) was not shown to have a significant effect on the recognition of set equivalency.

Although the findings of this investigation are given as general statements about the perception of set relations, one should be careful in generalizing and not assume them to apply to all sets or to all set relationships. The
### TABLE XXVII

**SUMMARY OF FINDINGS**

<table>
<thead>
<tr>
<th>Factors Affecting Perception of Set Equivalency</th>
<th>PET</th>
<th>PET2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perceptual Ability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Subjects with an aptitude for absolute</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>pitch recognition identify equivalency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with more accuracy than do subjects</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>without it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Subjects with good interval recognition</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>skills perform better than subjects with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>poor skills.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Set Manipulation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Ordered transposition is the most</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>recognizable of the set manipulations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Transpositional equivalencies are</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>more discernable than inversional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>equivalencies.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Reordering disguises set equivalency.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4. Octave displacement disguises set</td>
<td>-✓</td>
<td>✓</td>
</tr>
<tr>
<td>equivalency.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Non-Equivalent Lures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Non-equivalent sets which are similar in</td>
<td>✓</td>
<td>NT</td>
</tr>
<tr>
<td>contour may be heard as being equivalent.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Sets with the same interval succession</td>
<td>NT</td>
<td>✓</td>
</tr>
<tr>
<td>may be heard as being equivalent.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Pitch-invariance is not as strong a factor</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>of association between sets as contour or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interval succession.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*due to problems in test design, "✓" = significant test result, "-" = not significant, "NT" = not tested.

The experiment was carried out according to a fixed-effects model in which a specific population of subjects, specific set types and specific set manipulations were tested. In the alternative random-effects model, subjects and set types
and set manipulations are randomly sampled from the total populations of subjects, set types and set manipulations. The results of such a random-effects experiment can be legitimately generalized to make statements about treatment levels not actually included in the experiment. To avoid overgeneralization, one should not lose sight of the conditions and restrictions of this experiment in considering its findings.

Implications for Aural Pedagogy

This study has shown that to a certain extent the perception of set relations is influenced by the perceptual ability of the listener. Should one then conclude that a listener either can or can not hear set relationships and close discussion, or is the perception of set relationships in any way trainable? Can we say, as Hans Keller would have us say, that anything visually perceptible is also aurally perceptible?

Although this experiment was not specifically designed to measure the effect of training and practice on the perception of set relationships, it has indirectly provided some information about it. The researcher was present during the administration of the Tutorial and heard quite a few comments from subjects as they concluded the practice questions. Many of the subjects commented on the increased difficulty of perceiving the relationships only aurally, in the absence of the notation. Although, the tutorial
practice questions were not designed to provide a measure of
the effect of notation, subjects' comments confirmed the
argument that set relationships are surely easier to see
than to hear.

Also, many of the subjects commented that the questions
were difficult, but that their performance improved with
practice. Subjects seemed to believe that with more
practice they could learn to hear equivalency relationships
with accuracy. It would be difficult to deny that per-
ception of set equivalencies is trainable when subjects who
participated in this experiment believed it to be.

Based on the performance of subjects on the Perception
of Equivalence Test, the researcher makes the following
suggestions for aural training in the recognition of three-
ote note set equivalencies. It is the researcher's belief that
any aural technique should include information about common
pitfalls in addition to or as a part of the listening
strategy. For example, in teaching perception of common-
practice-period chord progressions, do we not point out the
aural similarity of the dominant-seventh chord and the
leading-tone triad in order to instruct students not to
mistake the two (if it is purposed that they make the dis-
tinction)? What are the common errors in the perception of
set relationships?

This experiment has pointed out some perceptual charac-
teristics of set relationships which could be incorporated
into a technique for the perception of set equivalency. Since various set manipulations result in equivalencies of varying perceptibility, students should not be taught to expect every pair of equivalent sets to sound obviously "equivalent" but should be made aware of such variability. Students should also be made aware that non-equivalent sets which have some similarity in contour or interval succession (or presumably in register or rhythm, though this remains to be tested) may be mistaken as being equivalent. Students should not be misled to believe that equivalent sets are obviously more similar than any other relationships between sets.

This study has also demonstrated the tendency for subjects to listen primarily to relationships between adjacent pitches. This was evidenced by subjects' preference for the lure which preserved the original set's interval succession. From casual comments made during the administration of the Perception Ability Test, the experimenter learned that the exercise of identifying the interval between the first and third notes of a three-note melody was a new experience for many. Every subject involved had been instructed in the aural recognition of intervals, but few had previously considered recognition of intervals between non-adjacent pitches. It seems that training in non-adjacent pitch relationships would be valuable (if not essential) in the pedagogy of hearing set
relationships (as well as in strengthening students' concept of structural relationships as expounded by Schenker).

A listening strategy for hearing three-note set equivalencies was not provided to the subjects in the experiment, but may be offered here.

1. Memorize the set.
2. Analyze the adjacent intervals and the outside interval.
3. Think of the inversional equivalents of these intervals.
4. Analyze the component intervals of the second set.
5. Is any one interval of a different interval class from those of the original set?
6. If not, they are equivalent.

This strategy is expressed as a flowchart in Figure 36.

An alternative listening strategy is that of mentally arranging the sets in normal order and analyzing the adjacent intervals of the normalized forms. For sets of more than three pitches, this method may be preferable, as aurally analyzing the total interval content of four- or five-note sets would be quite tedious.

Implications for Analysis

Forte, in his theory of set relations, has reduced the enormously large number of possible collections of pitches into a manageable number of set types, and has thereby
Memorize & analyze 1st set

Analyze 2nd set

Different interval?

N

Different interval class?

N

EQUIVALENT

Y

NON-EQUIVALENT

Fig. 36—Listening strategy for determining three-note set equivalency.

provided for the analyst tools and labels for identifying pitch relationships in atonal music. In so doing, he created a limited number of categories (set types), each of which has an almost infinite number of "equivalent" realizations. In this study it has been demonstrated that pairs of equivalent sets (even sets as limited in character as those used in the experiment) possess varying amounts of aural equivalency. It can be assumed that this is only more true of sets actualized in a musical composition, complete with rhythmic, registral and timbral variety.
Unfortunately, Forte's set-theoretic method of analysis does not provide for the identification of the variants of a set type. Beyond the identification of equivalent sets, the nature of the equivalency relationship is often left unexplained. As valuable as the identification of set types is for finding structural relationships in atonal music, if analysis stops there it is no better than mere chord labeling in the analysis of common-practice-period literature. If analysis is to "illuminate our immediate musical experience," what is needed is some further identification and explanation of the nature of equivalency relationships in music. How are the sets equivalent? Are they transpositions or inversions; is the original order preserved or reversed or rotated? At least in twelve-tone analysis, the variants of the row are identified with labels describing their relationship with the original—inversion, retrograde or retrograde-inversion—and the level of transposition involved. Without such descriptive labels, twelve-tone analysis would consist of statements such as "Here's the row. Here it is again. Well, here it is again." Labels such as those illustrated in Figure 37 could provide a minimum of information about the nature of identified equivalency relationships. Even so, aspects of the relationships such as rhythm and register are left unexplained. Any simple label cannot possibly account for

1 From Fay, op. cit., 112, quoted earlier on p. 9.
the complexities of a musical relationship. Thus, such an analysis should be accompanied by a descriptive analysis

\[ O = \text{ordered} \quad R = \text{reordered} \]
\[ T = \text{transposition} \quad I = \text{inversion} \]
\[ \text{no.} = \text{transposition level} \]

Fig. 37——Descriptive labels for equivalent sets

which further explains the nature of the relationships identified.

The results of the Perception of Equivalence Test also demonstrated the perceptual importance of contour and interval succession. The significant preference for the same-contour and interval-invariant lures indicated that non-equivalent sets with such similarity to the original may sound "more equivalent" than an actually-equivalent set. Though not tested in this experiment, it is likely also that rhythmically related, non-equivalent sets would have an "equivalent" effect. Such relationships should not be ignored in the analysis of atonal music. Set-theoretic analyses should perhaps be accompanied by motivic analyses in which non-equivalent, aurally-apparent variants of a motive are identified. An analysis of atonal music should
acknowledge intuitive, motivic relationships as well as abstract equivalency, similarity and complementary set relationships, if it is to more closely describe and guide our aural experience of the music.

Suggestions for Further Research

Many questions about the perception of set relations remain. Because of the nature of test design and statistical analysis, many limitations were placed on the sets and set relationships tested in this study, and every limitation left an unanswered question. Here these questions are presented as suggestions for further research.

Concerning sets used as standards: how does performance on trials using standard sets with tonal implications compare with trials using "atonal" standards? Are "tonal" sets easier to remember, and thus is it easier to recognize equivalent sets? Or because "tonal" sets have "atonal" equivalencies, is the recognition of equivalent sets more difficult? How would performance compare on trials using symmetrical standards versus asymmetrical standards? Are symmetrical sets, because of their redundant interval content, easier to remember, and thus to recognize in equivalent forms? Does symmetry serve any perceptual advantage when the equivalent set is in an asymmetrical arrangement? How perceptible are equivalency relationships involving four-, five- and six-note sets, harmonically
presented sets, large-interval or registrally displaced sets, rhythmically manipulated sets?

Concerning set manipulations: how do the various rotational manipulations producing equivalent sets compare as to perceptibility? Are rotations preserving the original set's first interval more recognizable than those preserving the original's second interval?

Which is the better listening strategy for aural recognition of set relationships—interval content analysis or normal order analysis?

Questions concerning the perceptibility of extended set-theoretic concepts such as subsets, complements, and set complexes also remain to be investigated.

A consideration of the composer's intent raises yet further questions. If negative criteria are at work in the composition of atonal music, is it not possible that the composer might intentionally use aurally obscure transformations? In this way, the composer could focus the listener's attention away from the crafting of the work and at the same time provide unity that might be perceived only subconsciously. Do the actual set equivalencies employed in atonal compositions indicate a preference for particular set transformations? If so, are the preferred transformations aurally obvious or obscure? Is the preference consistent for several compositions by a composer or particular to
single compositions? Are there transformations which are rarely or never used in atonal music?

Although perhaps more questions have been posed than answered, it is hoped that this investigation has stimulated some thought and provided some insight on the perceptual aspects of set theory. If the composer could always compose with the ears of his listener, and if the listener could always hear with the mind of the composer, there would be no need for studies such as this one. But communication between composer and listener is, unfortunately, not so perfect. As theorists learn more about how musical relationships are perceived, as well as how musical materials are structured, the gap between composer and listener may be narrowed. Then not only may listeners be better informed, but composers may wittingly employ structures of varying perceptibility, fully aware of their effect on the listener. May the work of theorists continue to reveal organizational procedures in music, but may it as well always seek to better understand the human receptor of that organization.
APPENDIX A

PERCEPTION ABILITY TEST QUESTIONS

Section I: Interval Recognition I

\[
\begin{align*}
\text{\textit{Note: In the second run, this series of pitches was}} \\
\text{\textit{randomly transposed to begin on A, as shown here, or on Bb,}} \\
\text{\textit{or on B.}}
\end{align*}
\]
Section IV: Melodic Memory

Original  Pitch-invariant  Same-contour

\[ \begin{array}{c}
\text{Original} \\
\text{Pitch-invariant} \\
\text{Same-contour}
\end{array} \]
APPENDIX B

PROGRAM LISTING FOR PERCEPTION ABILITY TEST

1 REM *** PAT—VERSION 1.2
2 ONERR GOTO 63000
3 DATA 32,234,5,162,2,173,0,224,201,76,240,7,202,15
7,128,192,16,243,10,212,176,18,212
4 FOR L1OOP = 952 TO 975: READ TEMP: POKE L1OOP,TEMP:
6 NEXT L1OOP
7 TEMP = INT (952 / 256): POKE 1010,952 - TEMP * 256
8: POKE 1011,TEMP: IF PEEK (-3) = 250 THEN CALL
9 HIMEM: 16384: GOTO 10010
10 CALL MSGF',0: CALL MS6P, PSTR, M0M$, 90, 11: RETURN
11 POKE -- 16368,0: GET R$: IF ASC (R$) < > 78 AND
12 ASC (R$) < > 89 THEN 40
13 RETURN
14 FOR I = 1 TO 5: COL = ACCCOL(I): GOSUB 110: NEXT:
15 RETURN
16 VTAB 22: PRINT "PRESS <SPACE BAR> TO CONTINUE": GOSUB
17 230: RETURN
18 VTAB 20: PRINT "TO THE LAB MONITOR ONLY!": PRINT
19 "PRESS <SPACE BAR> FOR INSTRUCTIONS": GOSUB
20 230: RETURN
21 CALL MSGP,TXT,TTBLE,TNUM,ROW,COL,DI: RETURN
22 CALL MSGP,GFIX,CHAR,ROW,COL,0: RETURN
23 CALL MSGP,1,0,25,69,1,38: RETURN
24 CALL MSGP,1,0,153,189,2,37: RETURN
25 HPL0T 1,24 TO 278,24: CALL MSGP,TXT,TTBLE,TNUM,1
26 ,COL,DI: RETURN
27 T$ = "Use " + CHR$ (12) + " or " + CHR$ (14) + " to move the arrow (" + CHR$ (13) + ")": CALL
28 MSGP,PSTR,T$,161,3
29 CALL MSGP,PSTR,"over the answer & press <SPACE B
30 AR>",173,3: RETURN
31 CALL MSGP,PSTR,"Press <SPACE BAR> to go on",167,
32 7: RETURN
33 CALL MSGP,PSTR,"Press <H> to hear",167,12: RETURN
34 CALL MSGP,0: HGR2 : HCOLOR= 7: HPL0T 1,1 TO 1,19
35 0 TO 278,190 TO 278,1 TO 1,1: HPL0T 1,152 TO 278
36 ,152: RETURN
37 T$ = "Use " + CHR$ (12) + " or " + CHR$ (14) + " to move the arrow (" + CHR$ (13) + ")": CALL
38 MSGP,PSTR,T$,161,3
39 CALL MSGP,PSTR,"over the answer & press <SPACE B
40 AR>",173,3: RETURN
41 CALL MSGP,PSTR,"Press <SPACE BAR> to go on",167,
42 7: RETURN
43 CALL MSGP,PSTR,"Press <H> to hear",167,12: RETURN
44 CALL MSGP,0: HGR2 : HCOLOR= 7: HPL0T 1,1 TO 1,19
45 0 TO 278,190 TO 278,1 TO 1,1: HPL0T 1,172 TO 278
46 ,172: CALL MSGP,PSTR,"Press <SPACE BAR> to go on ",178,7: RETURN

150
CALL MSGP, PSTR, "Press <H> to hear again", 161, 9: CALL MSGP, PSTR, "(LAST TIME)", 173, 15: RETURN

CALL MSGP, SETUP, STAFF, TLNE, LCOL, RCOL, CLEF, KEY, MODE: CALL MSGP, PLAY, QTBLE, QNUM, NVOICES, TMPO, WAVTBL, SDFF, ACTIVC: RETURN

CALL MSGP, TXT, TTBLE, 5, 161, 4, 13: T$ = "Use " + CHR$ (12) + " or " + CHR$ (14) + " then <SPACE> to answer": CALL MSGP, PSTR, T$, 174, 4: RETURN

REM * WAIT FOR -> *
POKE - 16363, 0: GET R$: IF ASC (R$) < 32 GOTO 205

POKE - 16368, 0: GET R$: IF ASC (R$) < 49 OR ASC (R$) > 51 THEN 210
RETURN

CALL MSGP, PSTR, "Press <H> to hear the Original.", 165, 5: RETURN

CALL MSGP, PSTR, "Press <H> to hear Original again.", 161, 4: CALL MSGP, PSTR, "(LAST TIME)", 171, 15: RETURN

POKE - 16368, 0: GET S$: IF ASC (S$) < 32 THEN 220
POKE - 16368, 0: GET S$: IF ASC (S$) < 32 AND ASC (S$) < 32 AND ASC (S$) < 21 THEN 235
RETURN

POKE - 16368, 0: GET R$: IF ASC (R$) < 21 GOTO 205

REM * GET H *
POKE - 16368, 0: GET R$: IF ASC (R$) < 78 AND ASC (R$) < 89 THEN 265
RETURN

POKE - 16368, 0: GET S$: S = ASC (S$): IF (S < 49 OR S > 51) AND S < 21 THEN 270
RETURN

REM * GET H *
POKE - 16368, 0: GET R$: IF ASC (R$) < 72 THEN 275
RETURN

CALL MSGP, 1, 0, 30, 170, 1, 38: RETURN

GOSUB 230: GOSUB 245: RETURN

POKE - 16368, 0: GET S$: S = ASC (S$): IF (S < 49 OR S > 51) AND S < 21 THEN 270
RETURN

REM * GET H *
POKE - 16368, 0: GET R$: IF ASC (R$) < 72 THEN 275
RETURN

CALL MSGP, 1, 0, 30, 170, 1, 38: CALL MSGP, PSTR, "Good! Let's begin.", 100, 11: GOSUB 230: RETURN

CALL MSGP, 0: HPLUT 1, 1 TO 1, 190 TO 278, 190 TO 278, 1 TO 1, 1: RETURN

X = 2: IF APR = 1 THEN X = 1

GOTO 370
310 CALL MSGP,GFIX,13,ROW,COL,0: RETURN
320 CALL MSGP,GFIX,13,ROW,COL,1: RETURN
330 GOSUB 320:N = N + 1: IF N > MAX THEN N = MAX
340 COL = N * 3 + X: GOSUB 310: RETURN
350 GOSUB 320:N = N - 1: IF N < 1 THEN N = 1
360 COL = N * 3 + X: GOSUB 310: RETURN
370 N = 1:COL = N * 3 + X: GOSUB 310
375 POKE -16368,0: GET R$
380 R = ASC (R$): IF R < > 32 AND R < > 21 AND R < > 8 THEN GOTO 375
385 IF R = 21 THEN GOSUB 330
390 IF R = 8 THEN GOSUB 350
395 IF R = 32 THEN GOSUB 320: RETURN
397 GOTO 375
400 CALL MSGP,PSTR,"Original",70,16: RETURN
405 TNUM = 13:ROW = 124:COL = 5: GOSUB 100: RETURN
410 CALL MSGP,1,1,122,132,4,13: RETURN
420 CALL MSGP,1,1,122,132,15,24: RETURN
430 CALL MSGP,1,1,122,132,26,25: RETURN
500 CALL MSGP,1,1,48,78,15,24:QNUM = MM(Q): GOSUB 190: RETURN
510 GOSUB 410:QNUM = MM(Q + 1): GOSUB 190: GOSUB 410: RETURN
520 GOSUB 420:QNUM = MM(Q + 2): GOSUB 190: GOSUB 420: RETURN
530 GOSUB 430:QNUM = MM(Q + 3): GOSUB 190: GOSUB 430: RETURN
540 N$ = "": GOSUB 100: RETURN
550 N$ = LEFT (N$): CALL MSGP,PSTR,N$,VERT,LCOL: GOTO 610
570 N$ = LEFT$ (N$): RETURN
580 SPACE = LCOL + LEN (N$) - 1: IF LN < 0 THEN RETURN
585 IF LN = 0 THEN N$ = "": GOTO 630
590 N$ = LEFT$ (N$):RETURN
595 RETURN
600 GOTO 750
610 CALL MSGP,GFIX,13,ROW,COL,0: RETURN
620 CALL MSGP,GFIX,13,ROW,COL,1: RETURN
630 GOSUB 320:N = N + 1: IF N > MAX THEN N = MAX
640 COL = (N - 1) * 11 + 8: GOSUB 310: RETURN
650 GOSUB 320:N = N - 1: IF N < 1 THEN N = 1
660 COL = (N - 1) * 11 + 8: GOSUB 310: RETURN
750 N = 1; COL = (N - 1) * 11 + 8: GOSUB 310
760 GOSUB 235
770 IF ASC (S$) = 21 THEN GOSUB 710
780 IF ASC (S$) = 8 THEN GOSUB 730
790 IF ASC (S$) = 32 THEN GOSUB 320: RETURN
795 GOTO 760
1010 GOSUB 35: PRINT: PRINT CHR$ (4); "LOAD PATTERN T2.ASM"
1020 CALL MSGP,0: GOSUB 180: TNUM = 0: COL = 10: GOSUB 140
1030 TNUM = 1: ROW = 44: COL = 3: GOSUB 100: GOSUB 230
1032 TNUM = 9: ROW = 104: GOSUB 100: GOSUB 220
1035 TNUM = 2: ROW = 44: GOSUB 100: GOSUB 230
1038 CALL MSGP,PSTR,"Same up...",90,3: FOR PAUSE = 1 TO 1000: NEXT: CLEF = 0: QNUM = 11: GOSUB 190
1040 TNUM = 3: ROW = 90: COL = 14: GOSUB 100: FOR PAUSE = 1 TO 1000: NEXT: QNUM = 12: GOSUB 190: GOSUB 220
1050 TNUM = 4: ROW = 44: COL = 2: GOSUB 100: TNUM = 5: ROW = 135: COL = 5: GOSUB 100: GOSUB 250
1060 TNUM = 6: ROW = 44: COL = 12: GOSUB 100: GOSUB 250
1070 TNUM = 7: ROW = 44: COL = 2: GOSUB 100: ROW = 116: COL = 2: GOSUB 310: GOSUB 235: CALL MSGP,1,0,30,1,10,1,33
1085 IF N < > 8 THEN CALL MSGP>PSTR,"Sorry! Try again.": COL = 2: GOSUB 310: GOTO 1080
1090 GOSUB 245: ROW = 45: COL = 2: GOSUB 260: IF R$ = "Y" GOTO 1020
1100 GOSUB 280
1120 SC = 0
1140 GOSUB 150: TNUM = 0: COL = 10: GOSUB 140
1150 TNUM = 5: ROW = 100: COL = 5: GOSUB 100
1170 FOR L1O0P = 1 TO 10
1180 Q$ = "QUESTION " + STR$ (L1OP): CALL MSGP,PSTR ,0$,40,15
1190 GOSUB 130: GOSUB 175: GOSUB 275
1210 GOSUB 130: GOSUB 160
1215 ROW = 94: COL = 2: GOSUB 310: GOSUB 205: GOSUB 320
1220 ROW = 94: MAX = 11: GOSUB 300
1230 IF N = ANSWER THEN SC = SC + 1
1235 IF N = 10 THEN A1$ = A1$ + "A": GOTO 1260
1240 IF N = 11 THEN A1$ = A1$ + "B": GOTO 1260
1250 A1$ = A1$ + STR$ (N)
1260 GOSUB 130: GOSUB 170: GOSUB 230
1270 GOSUB 130: GOSUB 120
1280 NEXT L100P
1290 SI = SC * 2.5
1310 RETURN
2010 GOSUB 35: PRINT : PRINT CHR$ (4); "LOAD PATTEX T3.ASM"
2020 CALL MSGP,0: GOSUB 180: TNUM = 0: COL = 9: GOSUB 140
2040 TNUM = 3: ROW = 44: COL = 2: GOSUB 100: GOSUB 220
2045 TNUM = 4: ROW = 44: GOSUB 100: FOR PAUSE = 1 TO 1000: NEXT
2050 CLEF = 0: QNUM = 23: GOSUB 190: GOSUB 230
2070 TNUM = 7: ROW = 122: COL = 2: GOSUB 100: GOSUB 100: GOSUB 220
2080 TNUM = 8: ROW = 44: COL = 2: GOSUB 100: TNUM = 9: ROW = 136: COL = 5: GOSUB 100: GOSUB 250
2090 TNUM = 10: ROW = 44: COL = 2: GOSUB 100: ROW = 120: COL = 2: GOSUB 310: GOSUB 235: GOSUB 245
2095 TNUM = 11: ROW = 44: COL = 2: GOSUB 100: GOSUB 205: ROW = 120: COL = 2: GOSUB 100: MAX = 11: GOSUB 300
2098 IF N <> 2 THEN CALL MSGP, PSTR, "Sorry! Try again.", 80, 11: COL = 2: GOSUB 310: GOTO 2095
2100 GOSUB 245: ROW = 45: COL = 2: GOSUB 260: IF R$ = "Y" THEN 2020
2110 GOSUB 280
2120 SC = 0
2130 GOSUB 150: TNUM = 0: COL = 9: GOSUB 140
2140 TNUM = 9: ROW = 100: COL = 5: GOSUB 100
2150 FOR L200P = 1 TO 5
2160 O$ = "QUESTION " + STR$(L200P): CALL MSGP, PSTR, O$, 40, 15
2180 GOSUB 130: GOSUB 175: GOSUB 275
2200 GOSUB 130: GOSUB 160
2210 ROW = 84: COL = 2: GOSUB 310: GOSUB 205: GOSUB 320: MAX = 11: GOSUB 300
2220 IF N = ANSWER THEN SC = SC + 1
2225 A2$ = A2$ + STR$(N)
2250 GOSUB 130: GOSUB 170: GOSUB 230
2260 GOSUB 130: GOSUB 120
2270 NEXT L200P
S2 = SC * 5
RETURN
GOSUB 35: PRINT; PRINT CHR#(4); "LOAD PATTEX.T.ASM"; APR = 1
CALL MSGP,0: GOSUB 180: TNUM = 5: COL = 7: GOSUB 140
TNUM = 18: ROW = 44: GOSUB 100: GOSUB 220
TNUM = 10: ROW = 44: COL = 2: GOSUB 100
TNUM = 6: ROW = 132: COL = 4: DI = 10: GOSUB 100: DI = 16
CHAR = 27: ROW = 124: GOSUB 50
CHAR = 25: ROW = 144: GOSUB 50
GOSUB 230: CALL MSGP,1,0,30,110,1,38,11
ROW = 44: COL = 2: GOSUB 100: GOSUB 250
GOSUB 205: ROW = 116: COL = 2: GOSUB 320
MAX = 12: GOSUB 300: N = N - 1: IF N < 3 THEN CALL MSGP, PSTR, "Sorry! Try again.", 80, 11, COL = 2: GOSUB 110: GOTO 3115
GOSUB 245: ROW = 45: COL = 2: GOSUB 260: IF R$ = "Y" GOTO 3020
GOSUB 280
SC = 0
GOSUB 150: TNUM = 5: COL = 7: GOSUB 140
TNUM = 6: ROW = 88: COL = 4: DI = 10: GOSUB 100: DI = 16
CHAR = 27: ROW = 80: GOSUB 50
CHAR = 25: ROW = 100: GOSUB 50
K = INT(RND(1) * 3) + 1: KEY = KEY(K)
FOR L300P = 1 TO 10
Q$ = "QUESTION " + STR$(L300P): CALL MSGP, PSTR
GOSUB 130: GOSUB 160
ROW = 72: COL = 0: GOSUB 300: N = N - 1
IF N = ANSWER THEN SC = SC + 1
IF N = 10 THEN A3$ = A3$ + "A": GOTO 3330
IF N = 11 THEN A3$ = A3$ + "B": GOTO 3330
A3$ = A3$ + STR$(N)
GOTO 3330
3330
3340
3350
3360
3370
3380
3390
3400
3410
3420
3430
3440
3450
3460
3470
3480
3490
3500
3510
3520
3530
3540
3550
3560
3330 GOSUB 130: GOSUB 170: GOSUB 230
3340 GOSUB 130: GOSUB 120
3350 NEXT L300P
3360 S3 = SC * 2.5
3370 KEY = 17
3380 APR = 0: RETURN
4005 GOSUB 35: PRINT: PRINT CHR$ (4);"LOAD PATTEX\nT4.ASM"
4010 CALL MSGP,0: GOSUB 180:TNUM = 0:COL = 13: GOSUB 140
4020 TNUM = 1:ROW = 40:COL = 3: GOSUB 100: GOSUB 220
4050 CALL MSGP,0: GOSUB 150:TNUM = 0:COL = 13: GOSUB 140
4055 Q = 1:CLEF = 0
4060 GOSUB 400: GOSUB 405: CALL MSGP,TXT,TTBLE,6,32,2,10: CALL MSGP,1,1,30,40,1,38
4065 GOSUB 215: GOSUB 275: GOSUB 500
4068 GOSUB 120: CALL MSGP,TXT,TTBLE,7,32,4,10: CALL MSGP,1,1,30,40,5,34
4070 FOR I = 1 TO 3: GOSUB 120:T$ = "Now, type " + STR$(I) + ", to hear Melody " + STR$(I) + ":"; CALL MSGP,PSTR,T$;32,6: CALL MSGP,1,1,30,40,5,34
4072 POKE -16368,0: GET R$: IF ASC (R$) < > ASC (STR$(I)) GOTO 4072
4075 ON I GOSUB 510,520,530: NEXT I
4080 GOSUB 120: CALL MSGP,TXT,TTBLE,11,32,5,10: CALL MSGP,1,1,30,60,4,36
4082 ROW = 94:COL = 2: GOSUB 310
4085 GOSUB 205: GOSUB 320
4090 MAX = 3:ROW = 94: GOSUB 700
4115 IF N < > 2 THEN GOSUB 120: CALL MSGP,TXT,TTBLE,11,32,5,10: CALL MSGP,1,1,30,60,4,36: GOTO 4082
4120 GOSUB 120:ROW = 32:COL = 2: GOSUB 260
4129 IF R$ = "Y" GOTO 4010
4130 CALL MSGP,1,0,30,150,1,38: CALL MSGP,PSTR,"Good ! Let's get started.",100,8: GOSUB 130: GOSUB 170: GOSUB 230: CALL MSGP,1,0,30,150,1,38
4150 CALL MSGP,0: GOSUB 150:TNUM = 0:COL = 13: GOSUB 140:CLEF = 0:SC = 0: GOSUB 400: GOSUB 405
4160 FOR L400P = 1 TO 5
4170 Q$ = (L400P * 4 + 1):MEL = 0
4175 Q$ = "QUESTION " + STR$(L400P): CALL MSGP,PSTR
4180 GOSUB 130: GOSUB 215: GOSUB 275: GOSUB 500
GOSUB 130: GOSUB 216: GOSUB 275: GOSUB 500
GOSUB 130: GOSUB 200: ROW = 94: COL = 2: GOSUB 31

GOSUB 270: IF MEL = 0 AND (S < 49 OR S > 51) THEN
GOSUB 130: CALL MSGP, TXT, TTBLE, 15, 161, 13; CALL
MSGP, 1, 1, 159, 184, 5, 35: GOSUB 210: GOSUB 130: GOSUB 200: GOTO 4220

IF S = 21 THEN ROW = 94: COL = 2:
GOSUB 320: MAX = 3: GOSUB 700: GOTO 4250

MEL = MEL + 1: ON VAL (ST)
GOSUB 510, 520, 530: GOTO 4200

ANSWER = A4 (L400P): IF N = ANSWER THEN SC = SC + 1
A4$ = A4$ + STR$ (N)
GOSUB 130: GOSUB 170: GOSUB 230: CALL MSGP, 1, 0,
25, 55, 1, 35

NEXT L400P
S4 = SC * 5
RETURN

HOME: VTAB 6: HTAB 3: PRINT "AURAL PERCEPTION
OF SET RELATIONS": VTAB 9: HTAB 12: PRINT "PREP
ARATORY QUIZ": VTAB 17: HTAB 13: PRINT "JANA K.
MILLAR": VTAB 19: HTAB 18: PRINT "1983"

VTAB 1: FOR I = 1 TO 37: PRINT "-": NEXT: PRINT
VTAB 22: FOR I = 1 TO 38: PRINT " "; NEXT

GOSUB 60005
GOSUB 40010
GOSUB 40200
GOSUB 1010
GOSUB 2010
GOSUB 3010
GOSUB 4005
TSCRE = S1 + S2 + S3 + S4

IF TSCRE > 80 THEN P = 1: GOTO 10130
IF (TSCRE - S3) > 60 THEN P = 2
IF (TSCRE - S3) = 60 OR (TSCRE - S3) < 60 THEN
P = 3

GOSUB 35: GOSUB 20010
GOSUB 40300: REM CLOSING
END

TEMP$ = " 
N$ = F$ + " "+ L$ + NAME$ = LEFT$ (N$ + TEMP$, 2)
PP$ = STR$ (PP)
S1$ = LEFT$ (STR$ (S1) + TEMP$, 4)
S2$ = LEFT$ (STR$ (S2) + TEMP$, 4)
S3$ = LEFT$ (STR$ (S3) + TEMP$, 4)
S4$ = LEFT$ (STR$ (S4) + TEMP$, 4)
TSCRE$ = LEFT$ (STR$ (TSCRE) + TEMP$, 4)
P$ = STR$ (P)
20090 FINAL$ = NAME$ + PP$ + S1$ + S2$ + S3$ + S4$ +
TSCORE$ + P$ + A1$ + A2$ + A3$ + A4$
20095 D$ = CHR$ (13) + CHR$ (4)
20100 PRINT D$; "OPEN PATFILE, L80"
20110 PRINT D$; "READ PATFILE, R0"
20120 INPUT REX
20130 REX = REX + 1
20140 PRINT D$; "WRITE PATFILE, R"; REX
20150 PRINT INT D$; " READ PATFILE, R0"
20160 PRINT REX;
20170 PRINT D$; "CLOSE PATFILE"
20180 RETURN
40010 GOSUB 180: CALL MSGP, TXT, TTBLE, 14, 64, 3, 16: GOSUB 230
40020 GOSUB 290: CALL MSGP, TXT, TTBLE, 15, 40, 6, 10: VERT = 66; LCOL = 14: GOSUB 600
40025 GOSUB 690: IF LEN (N$) < 2 GOTO 40020
40028 F$ = N$
40030 CALL MSGP, TXT, TTBLE, 16, 86, 6, 10: VERT = 112; LCOL = 14: GOSUB 600
40035 GOSUB 690: IF LEN (N$) < 2 THEN CALL MSGP, PSTR, T$, 146, 3: CALL MSGP, PSTR, "your correct name?", 156, 8
40038 L$ = N$
40040 N$ = F$ + " " + L$: IF LEN (N$) > 25 THEN T$ = "Is " + N$: CALL MSGP, PSTR, T$, 146, 3: CALL MSGP, PSTR, "Is " + N$: CALL MSGP, PSTR, "your correct name?", 156, 11
40050 IF LEN (N$) > 13 AND LEN (N$) < 26 THEN T$ = "Is " + N$: CALL MSGP, PSTR, T$, 146, 6: CALL MSGP, PSTR, "Is " + N$: CALL MSGP, PSTR, "your correct name?", 156, 11
40055 IF LEN (N$) < 13 OR LEN (N$) = 13 THEN T$ = "Is " + N$: CALL MSGP, PSTR, T$, 150, 3
40060 CALL MSGP, PSTR, "Type Y for yes or N for no", 17, 0, 6: GOSUB 40: IF R$ = "N" GOTO 40020
40065 GOSUB 290: CALL MSGP, TXT, TTBLE, 17, 40, 3, DI
40070 IF R$ = "Y" THEN PP = 0
40080 GOSUB 40: IF R$ = "Y" THEN PP = 0
40090 GOSUB 180: CALL MSGP, TXT, TTBLE, 14, 32, 2, 14: ROW = 60
40305 T$ = STR$(S1 * 4) + ";": GOSUB 40390: T$ = STR$(S2 * 4) + ";": GOSUB 40390: T$ = STR$(S3 * 4) + ";": GOSUB 40390: T$ = STR$(S4 * 4) + ";": GOSUB 40390: GOSUB 170: GOSUB 230
40310 GOSUB 240: GOSUB 130: CALL MSGP, TXT, TTBELE, 16, 3 2, 2, 14
40320 CALL MSGP, PSTR, F$ + ";": GOSUB 144, 21
40380 RETURN
40390 ROW = ROW + 14: CALL MSGP, PSTR, T$, ROW, 30: RETURN
40399 RETURN
59999 :
60020 PRINT : PRINT CHR$ (4): "BLOAD MSGP": PRINT : PRINT CHR$ (4): "BLOAD PATTEXT.ASM"
60021 HCOLOR = 7: HGR2 = 6: GOSUB 290: CALL MSGP, 5, 0, 87, 1, 33, 9, 17, 0: CALL MSGP, 8, 0, 2, 4: CALL MSGP, 1, 0, 96, 104, 5, 36
60022 CALL MSGP, TXT, TTBELE, 19, 56, 1, 20: CALL MSGP, TXT, TTBELE, 20, 150, 1, 20
60024 PRINT : PRINT CHR$ (4): "BLOAD WAVE.FIVE": PRINT : PRINT CHR$ (4): "BLOAD PATMUSIC.ASM"
60025 FOR I = 1 TO 5: READ ACCCOL(I): NEXT
60030 DIM A(3, 20): FOR I = 1 TO 3: FOR J = 1 TO 20: READ A(I, J): NEXT I
60040 DIM A2(20): FOR I = 1 TO 20: READ A2(I): NEXT
60050 DIM A3(10): FOR I = 1 TO 10: READ A3(I): NEXT
60060 DIM MM(24): FOR I = 1 TO 24: READ MM(I): NEXT
60065 DIM A4(5): FOR I = 1 TO 5: READ A4(I): NEXT
60068 DIM KEY(3): FOR I = 1 TO 3: READ KEY(I): NEXT
60070 DATA 8, 14, 23, 29, 35
60080 DATA 1, 9, 0, 5, 0, 11, 1, 5, 0, 2, 0, 1, 1, 4, 1, 10, 0, 0, 1, 6
60081 DATA 1, 10, 0, 4, 0, 0, 1, 6, 0, 3, 0, 2, 1, 5, 1, 11, 0, 1, 1
60082 DATA 1, 11, 0, 5, 0, 1, 7, 0, 4, 0, 3, 1, 6, 1, 0, 0, 2, 1, 8
60085 DATA 0, 4, 1, 1, 0, 9, 0, 5, 1, 6, 0, 2, 1, 8, 0, 11, 1, 1, 3, 0
60090 DATA 0, 3, 1, 2, 1, 4, 0, 6, 1, 1
60095 DATA 31,32,31,33
60099 RETURN
60100 DATA 34,35,36,34
60110 DATA 37,39,37,38
60120 DATA 40,42,41,40
60130 DATA 43,43,44,45
60140 DATA 46,47,46,48
60150 DATA 3,2,3,1,2
60160 DATA 17,11,19
60999 RETURN
63000 HOME : TEXT : ER = PEEK (222) : VTAB 10 : CALL 5
4915
63099 REM DOS & SYSTEM ERRORS
63100 IF ER = 255 THEN PRINT "PLEASE DON'T TYPE <CONTROL> C AGAIN!" : GOTO 63700
63105 IF ER = 4 THEN PRINT "I AM UNABLE TO RECORD YOUR VISIT TODAY." : PRINT : PRINT "PLEASE TELL THE LAB MONITOR THAT THIS" : PRINT : PRINT "DISKETTE IS 'WRITE-PROTECTED.'" : GOSUB 70
63110 IF ER = 5 THEN PRINT "THERE IS SOMETHING WRONG WITH MY FILE." : PRINT : PRINT "PLEASE TELL THE LAB MONITOR." : GOTO 63700
63115 IF ER = 9 THEN PRINT "MY FILE IS FULL." : PRINT : PRINT "PLEASE ASK THE LAB MONITOR FOR HELP." : GOSUB 70
63118 IF ER = 9 THEN HOME : VTAB 10 : PRINT "1. REMOVE DISK FROM DRIVE" : PRINT : PRINT "2. PUT IN A DIFFERENT COPY OF PAT DISK" : GOSUB 60 : HGR2 : GOTO 10
63120 IF ER = 8 THEN PRINT "IS THE DISK DOOR CLOSED" ?" : GOTO 63700
63125 IF ER = 20 THEN PRINT "PLEASE DON'T PRESS THE RESET BUTTON!" : GOTO 63700
63700 GOSUB 60 : POKE 216,0 : PRINT : PRINT CHR$ (4) ; "RUN PAT"
APPENDIX C

TEXT FOR TUTORIAL: "INTRODUCTION TO SET THEORY"

Note: In the actual program for student use, the text was presented in page displays as shown below.

<table>
<thead>
<tr>
<th>Section 1: Definition of a Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Let's begin by listening to the opening measures of a composition by Arnold Schoenberg (1874-1951).</td>
</tr>
</tbody>
</table>

However, for the purposes of this appendix, text is given in paragraph form. The double slash is used to indicate the end of a page display. Sometimes, several sentences are listed which coordinate with a musical example. In these cases, in the actual program a portion of the display was cleared, and the new text replaced the old. In this appendix, the single slash is used to indicate that the following text replaced previous text on the current page. Also, (not shown below) at the end of each section the following message appeared, "Would you like to see this section again before going on (Y/N)?"
Introduction

Hello, <student's name>!

This lesson includes five short lesson sections and some practice questions. Each lesson section should take about five minutes to complete.

It is recommended that you

- take the whole lesson
- review any sections you are unsure of, then
- take some practice questions.

If you don't have time for everything today, you may leave the lesson early and finish it another time.

If you want to quit a section before completing it, you may press the <ESCAPE> key (upper left corner of the keyboard, marked ESC).

In the lesson, you will be given some text to read and some musical examples to listen to.

When taking the lesson, you will use two keys—<R>.............to rehear an example, and <SPACE BAR>....to continue.
Section 1: Definition of a Set

Let's begin by listening to the opening measures of a composition by Arnold Schoenberg (1874-1951).

Here are the opening measures of Schoenberg's "Three Piano Pieces," op. 11, written in 1909.

\[ \text{\includegraphics[width=\textwidth]{schoenberg_op11_measures.png}} \]

It would be difficult to describe this passage using tonal terminology. An analysis using triads and major or minor scales just wouldn't apply.

Schoenberg's op. 11 piano pieces are considered to be ATONAL compositions; they do not have a particular TONIC or key.

In general, ATONAL musical structures cannot be described in terms of the TERTIAN STRUCTURES (triads and seventh chords) and DIATONIC SCALES (major or minor) which we use to describe TONAL music.

New tools are needed to describe new music...
To provide such new tools, Allen Forte has applied mathematical SET THEORY to atonal music. These ideas are found in his work, *The Structure of Atonal Music*.

SET THEORY provides a means of describing and comparing non-tertian, non-diatonic collections of pitches.

In set theory, a chord or melody is considered as a SET of different pitches. For example, a chord or melodic motive with 3 different pitches is called a 3-note SET.

Consider the following examples...

Even though we see 4 notes in the first example and 7 notes in the second, there are actually only 3 different pitches represented---F, F# and A. (F# = Gb).

Therefore, both are examples of the same set---F F# (Gb) A.

In summary, a SET is a representation of a chord or melodic motive as a collection of different pitches.

In the next section we will see more specifically how sets may be described.
Section 2: Pitch Class & PC Set

The term PITCH CLASS (abbreviated "pc") refers to all pitches which are in unison or are octaves apart.

For example, all F's in any octave as well as all enharmonic E#'s and Gbb's are members of the same pitch class.

Therefore, out of all possible pitches there are only 12 PITCH CLASSES (pc's), one for each of the 12 half-steps in the octave. In set theory, these are assigned numbers, 0 - 11, beginning on C.

\[
\begin{array}{cccccccccccc}
\text{Pc0} & \text{C} & \text{Db} & \text{D} & \text{Db} & \text{F} & \text{Gb} & \text{A} & \text{B} & \text{Bb} & \text{C} & \text{Db} & \text{D} & \text{Db} \\
0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11
\end{array}
\]

Pc0 not only contains all C's in any octave but all B#'s and Dbb's as well. Pc1 contains all C#'s, Db's and Bx's, and so on.

Let's look again at our 3-note set—F, F# (Gb), A.

\[
\begin{array}{cccccccccccc}
\text{F} & \text{F#} & \text{Gb} & \text{A} \\
5 & 6 & 6 & 9
\end{array}
\]

We may refer to this set by its pc numbers—F = 5, Gb = 6, A = 9. Therefore, this is the pc set (5,6,9).
Of course, any rearrangement of the three pitches still would be considered the same set of pc's. In other words, all reorderings of a set are EQUIVALENT.

The set of pitches-- F, Gb, A-- may be stated in many ways...

If we list the 3 notes of each set in ascending order in their "tightest" arrangement (within the octave), we get (F, Gb, A) or (5,6,9).

This closely-packed arrangement is a standard listing order called NORMAL ORDER. Listing the notes of these sets in NORMAL ORDER reveals that they are all the same set-- (5,6,9).

A set may be described not only by its pc numbers but by the intervals between the notes of the set.

In the next section we will see how sets can be described in terms of their interval makeup.
Section 3: Interval Content

The INTERVAL CONTENT of a set is a count or tally of the intervals between the notes of a set.

Intervals may be labeled by the number of half-steps between the two pitches of the interval.

There are only 11 interval sizes.

These are the most common names for the 11 intervals...

<table>
<thead>
<tr>
<th>Half-Steps</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor 2nd</td>
</tr>
<tr>
<td>2</td>
<td>Major 2nd</td>
</tr>
<tr>
<td>3</td>
<td>Minor 3rd</td>
</tr>
<tr>
<td>4</td>
<td>Major 3rd</td>
</tr>
<tr>
<td>5</td>
<td>Perfect 4th</td>
</tr>
<tr>
<td>6</td>
<td>Tritone</td>
</tr>
<tr>
<td>7</td>
<td>Perfect 5th</td>
</tr>
<tr>
<td>8</td>
<td>Minor 6th</td>
</tr>
<tr>
<td>9</td>
<td>Major 6th</td>
</tr>
<tr>
<td>10</td>
<td>Minor 7th</td>
</tr>
<tr>
<td>11</td>
<td>Major 7th</td>
</tr>
</tbody>
</table>

In set theory, the 11 intervals are reduced to 6 INTERVAL CLASSES, as each interval is considered to be in the same class as its inversion.

We know, for example, that the perfect 5th is related to the perfect 4th.
"Flipping" the two pitches of the 5th produces the 4th. The perfect 4th and the perfect 5th are inversions of one another. Thus, they are considered to be members of the same INTERVAL CLASS.

Here are the 6 INTERVAL CLASSES (abbreviated "ic") used in set theory to describe the interval content of a set.

<table>
<thead>
<tr>
<th>ic</th>
<th>INTERVAL (no. of 1/2-steps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Min 2nd (1) or Maj 7th (11)</td>
</tr>
<tr>
<td>2</td>
<td>Maj 2nd (2) or Min 7th (10)</td>
</tr>
<tr>
<td>3</td>
<td>Min 3rd (3) or Maj 6th (9)</td>
</tr>
<tr>
<td>4</td>
<td>Maj 3rd (4) or Min 6th (8)</td>
</tr>
<tr>
<td>5</td>
<td>Per 4th (5) or Per 5th (7)</td>
</tr>
<tr>
<td>6</td>
<td>Aug 4th (6) or Dim 5th (6), Tritone</td>
</tr>
</tbody>
</table>

For example, ic3 includes the minor 3rd, its inversion the major 6th, as well as their enharmonic equivalents, the augmented 2nd and diminished 7th.

As we defined earlier, the interval content of a set is a tally of the intervals between the notes of the set.

Any 3-note set has 3 intervals—1 between the 1st and 2nd notes, 1 between the 2nd and 3rd notes, and 1 between the 1st and 3rd notes.
Let's look at the interval content of our example (F, F#, A)... 

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>INT. NAME</th>
<th>1/2-STEPS</th>
<th>IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>F ↑ F#</td>
<td>Min 2nd</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>F# ↑ A</td>
<td>Min 3rd</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>F ↑ A</td>
<td>Maj 3rd</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Counting the number of intervals from each class, we find one interval from each of the classes 1, 3 and 4 and no intervals from the other classes.

The interval content is pictured in what Forte calls the INTERVAL VECTOR, a series of 6 numbers in brackets. Each space in the bracket represents one of the 6 interval classes.

\[
ic < 1 \ 2 \ 3 \ 4 \ 5 \ 6>
\]

Numbers placed in the spaces are a tally of how many intervals of each class are contained in the set.

For our set, we would place a 1 in the interval vector for each of the classes 1, 3 and 4... and a 0 for each of the other classes.

Thus, the interval vector for (F, F#, A) is...

\[
<1 \ 0 \ 1 \ 1 \ 0 \ 0>
\]
Any way we order the set (F, F#, A) it will have the same INTERVAL CONTENT.

For example, if we order it as follows...

\[
\begin{array}{l}
\text{the component intervals are...} \\
\end{array}
\]

\[
\begin{array}{l}
\text{M6th} \quad \text{m6th} \quad \text{m2nd} \\
\end{array}
\]

The large intervals—Maj 6th and Min 6th are in the same interval classes as their inversions—Min 3rd and Maj 3rd.

Therefore, the INTERVAL CLASSES represented are still 1 (Min 2nd), 3 (Min 3rd) and 4 (Maj 3rd).

We have seen how REORDERING a set does NOT affect the set's interval content. All reorderings of a set have the same interval content and are EQUIVALENT.

Two sets may have the same interval content not only when they are reorderings of one another but in other ways as well. In the next section we will begin looking at how sets may be related through TRANSPOSITION and INVERSION.
Section 4: Transpositional Equivalence

Two sets are considered to be EQUIVALENT if they are TRANSPOSITIONS or INVERSIONS of one another. First we will look at transpositionally-equivalent sets...

The 2nd example is a TRANSPOSITION of the 1st example. Each note of the 1st example has been moved up 5 half-steps (up a perfect 4th).

The sets are related through transposition...They are TRANSPOSITIONALLY EQUIVALENT and have the same interval content.

In set theory, any reordering of these 2 sets would still be considered EQUIVALENT.

Any ordering of (F, F#, A), for example...

is TRANSPOSITIONALLY EQUIVALENT to any ordering of (Bb, B D), for example...
This relationship may be better understood by examining the interval content of the 2 pc sets.

We have already found the interval content of \( F\sharp \downarrow A \uparrow \) to be

\[<1 \ 0 \ 1 \ 1 \ 0 \ 0>\]

Let's analyze the interval content of our reordered transposition (D, B, Bb).

The intervals between the notes are...

\[
\begin{array}{c|c|c}
\text{m3rd} & \text{d8ve} & \text{m6th} \\
1/2\text{-steps:} & 3 & 11 & 8 \\
ic: & 3 & 1 & 4 \\
\end{array}
\]

Again, we have 1 interval from each of the ic's—1, 3 and 4.

Thus, the interval vector for the reordered transposition is the same—

\[<1 \ 0 \ 1 \ 1 \ 0 \ 0>\]
In summary, a set is considered to be EQUIVALENT to any of its 11 transpositions, with any ordering of its members. In the next section we will see how sets may be EQUIVALENT through INVERSION.

Section 5: Inversional Equivalence

A set is also considered to be EQUIVALENT with its INVERSION. You are probably familiar with the term "INVERSION," but the sense of the term used in set theory is very specific.

In set theory, INVERSION refers to the mirror image of a group of pitches. For example...

To invert the set (F, F#, A) using F as the axis or point of inversion, we build the same sequence of intervals in the opposite direction.

Thus, (F, E, Db) is an INVERSION of (F, F#, A).

You can already imagine that the interval content of an inversion is the same as the original, since all we have done is reversed the direction of each interval. But let's
check the interval content of our inversion (F, E, Db) to make sure.

The interval content of the original, you remember, was <1 0 1 1 0 0>.

Original Vector: <1 0 1 1 0 0>

The intervals between members of our inversion (F, E, Db) are:

```
1/2-steps:  1  3  4
ic:        1  3  4
```

The inversion consists of 1 interval from the same 3 interval classes. Thus, the interval vector is the same.

The inverted form of a set may also be TRANSPOSED so that its 1st pitch is any of the 12 pc's in the octave. Transposing an inversion does NOT affect the set's interval content.
Transposed Inversions

All of the transposed inversions above are EQUIVALENT to the original. They all have the same interval content—
<1 0 1 1 0 0>.

Our example illustrates what is true of all sets—
Any TRANSPOSITION of the INVERSION of a set (i.e., any transposed inversion) is EQUIVALENT to the original set.

Also, just as with transpositionally-related sets, any REORDERING of inversionally-related sets are still considered to be equivalent.

Changing the order of the pitches in a set does not change its identity nor its relationship with equivalent sets.

Summary

To summarize:

EQUIVALENT sets are identical in interval content.

A given set has many possible EQUIVALENT forms...

It has 12 TRANSPositions; that is, it may be stated on any of the 12 pc's in the octave.
It has 12 TRANSPOSED INVERSIONS; that is, it may be inverted and transposed in its inverted form to any of the 12 pc's in the octave.

These 24 versions of a set—12 TRANSPOSITIONS and 12 TRANSPOSED INVERSIONS—may also be REORDERED without changing their equivalence.

No matter how you rearrange the pitches of a set, its interval content and its relationship with equivalent sets remains the same.

You have come to the end of the lesson. Now, you should take some practice questions on recognizing EQUIVALENT SETS.

Would you like to review any sections of the lesson before proceeding to the questions? (Type Y or N)

[If the subject chose to review at this point, he would see the following review menu.]

Which section would you like?

1 Definition of a Set
2 Pitch Class & pc Set
3 Interval Content
4 Transpositional Equivalence
5 Inversional Equivalence
Type the no. of your choice (1-5)

(Press <ESC> to quit reviewing.)

//

[If the subject chose not to review or if the subject was finished reviewing, the following message appeared.]

On the next page, you will see a "menu" of choices. To take the practice questions, you will choose "3" from the menu.

//

WOULD YOU LIKE TO:

1 Retake the whole lesson
2 Review a lesson section
3 Take some practice questions
4 End the program

Type the no. of your choice (1-4)
APPENDIX D

SCORE FILE FOR PRACTICE QUESTION GENERATION

Set Type 3-2

Set Type 3-3

Set Type 3-4

Set Type 3-5

Set Type 3-7

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APPENDIX E

PROGRAM LISTINGS FOR TUTORIAL

Tutorial

1 REM *** TUTORIAL.....10/14/83 ***
3 ONERR GOTO 63000
6 DATA 32,234,3,162,2,173,0,224,201,76,240,7,202,15
7,128,192,16,243,2,162,20,76,13,212
7 FOR LOOP = 952 TO 975: READ TEMP: POKE LOOP,TEMP
9 : NEXT LOOP
8 TEMP = INT ((952 / 256): POKE 1010,952 - TEMP * 256
9 : POKE 1011,TEMP: IF PEEK (-3) = 250 THEN CALL
10 - 1167
10 TEXT : HOME : HTAB 11: FOR I = 1 TO 39: PRINT
12 : NEXT : HTAB Is VTAB 23: FOR I = 1 TO 39: PRINT
11 "_";: NEXT
12 VTAB 7s HTAB 7; PRINT "INTRODUCTION TO SET THEORY
13 "; VTAB 13: HTAB 20: PRINT "BY": VTAB 18: HTAB 1
15 PRINT "JANA K. MILLAR": VTAB 20: HTAB 19: PRINT
16 "1983"
14 HIMEM: 16384: GOTO 10010
35 HGR2 : CALL MSGP,0: CALL MSGP,PSTR,MOM*,90,11: RETURN
39 REM * Y OR N *
40 POKE -16368,0: GET R$: IF ASC (R*) < > 78 AND
41 ASC (R*) < > 89 GOTO 40
45 RETURN
50 POKE -16368,0: GET R$: IF ASC (R*) < > 32 THEN
52 RETURN
50 VTAB 22: PRINT "PRESS <SPACE BAR> TO CONTINUE": GOSUB
50: RETURN
60 VTAB 20: PRINT "TO THE LAB MONITOR ONLY:": PRINT
61 : PRINT "PRESS <SPACE BAR> FOR INSTRUCTIONS": GOSUB
60: RETURN
99 REM * DISPLAY TEXT *
100 CALL MSGP,TXT,TTBLE,TNUM,ROW,COL,DI: RETURN
150 CALL MSGP,0: CALL MSGP,PSTR,"But we just got sta
160 rted!",40,7: CALL MSGP,PSTR,"Are you ready to qu
170 it now?",80,7: CALL MSGP,PSTR,"Type Y for YES or
180 N for NO",96,7
160 GOSUB 40: IF R$ = "Y" THEN QUIT = 1

179
170 CALL 54915: GOTO 19998
229 REM  * WAIT FOR SPACEBAR & CLEAR PAGE *
230 POKE -16368,0: GET R$: IF ASC (R$) = 27 THEN
       GOSUB 150
232 IF ASC (R$) < > 32 GOTO 230
235 CALL MSGP,1,0,2,170,1,33: RETURN
239 REM  *  PLAIN BORDER *
240 HPL0T 1,1 TO 1,190 TO 278,190 TO 278,1 TO 1,1: RETURN
249 REM  *  GET Y OR N *
250 POKE -16368,0: GET R$: IF ASC (R$) < > 78 AND
       ASC (R$) < > 89 THEN 250
255 RETURN
290 CALL MSGP,0: HPL0T 1,1 TO 1,190 TO 278,190 TO 27
8,1 TO 1,1: RETURN
599 REM  *  GET NAME & DISPLAY IT *
600 see = """
610 POKE -16368,0: GET R$: R = ASC (R$): IF R < >
       8 AND R < > 45 AND R < > 13 AND R < > 32 AND
       (R < 65 OR R > 90) GOTO 610
612 IF ASC (R$) = 8 THEN GOSUB 650: GOTO 610
615 IF ( ASC (R$) = 13 OR ASC (R$) = 32) AND N$ = ""
       GOTO 610
620 IF ASC (R$) = 13 THEN RETURN
640 N$ = N$ + R$: CALL MSGP,PSTR,N$,VERT,LCOL: GOTO 610
650 LN = LEN (N$) - 1: IF LN < 0 THEN RETURN
660 IF LN = 0 THEN N$ = "": GOTO 650
670 N$ = LEFT$ (N$,LN)
680 SPACE = LCOL + LEN (N$): CALL MSGP,1,0,VERT,VERT
       + SPACE,S0,PSTR: RETURN
690 IF ASC (RIGHT$ (N$,1)) = 32 THEN LN = LEN (N$)
       - 1: N$ = LEFT$ (N$,LN)
695 RETURN
10000 REM  **************** MAIN DRIVER **************
***
10001:
10009 REM  *** INITIALIZE VARIABLES & LOAD BFILES **
       *
10010 GOSUB 60010: REM  SET VARIABLES; BLOAD MSGP &
       TEXT FILES
10028:
10029 REM  *** INTRODUCTION ***
10030 GOSUB 40020: REM  GET NAME
10040 GOSUB 40100: REM  CHECK FILE
10050 CALL MSGP,0: GOSUB 240: CALL MSGP,PSTR,"Do you
       want instructions?",85,6: CALL MSGP,PSTR,"Type
       Y for yes or N for no.",100,6: GOSUB 40: IF R$ =
       "N" GOTO 10500
10060 GOSUB 40300: REM  INSTRUCTIONS
CALL MSGP,0: GOSUB 240: TNUM = 11: ROW = 70: COL = 6: GOSUB 100: GOSUB 40: IF R# = "Y" GOTO 10060
CALL MSGP,0: GOSUB 35: PRINT D#: "LOAD MAIN.AS"
IF SCT < 6 THEN PRINT D#: "RUN LESSON"
PRINT D#: "RUN MENU"
IF QUIT = 0 GOTO 10060
TEXT : HOME : HTAB 5 : VTAB 10 : PRINT "SEE YOU LATER, ": PRINT F#: : PRINT ": END
REM *** ONE-TIME SUBROUTINES ***
GOSUB 290: CALL MSGP, TXT, TTBLE, 1, 40, 6, 10: VERT = 66: LCOL = 14: GOSUB 600
GOSUB 690: IF LEN (N#) < 2 GOTO 40020
F# = m
CALL MSGP, TXT, TTBLE, 2, 86, 6, 10: VERT = 112: LCOL = 14: GOSUB 600
CALL MSGP, 1, 0, 106, 180, 1, 38: GOTO 40020
L# = N#
N# = F# + ": Is " + L#: IF LEN (N#) > 25 THEN T$ = "Is " + N#: CALL MSGP, PSTR, T$, 146, 3: CALL MSGP, PSTR, "your correct name?", 156, 6
IF LEN (N#) > 13 AND LEN (N#) < 26 THEN T$ = "Is " + N#: CALL MSGP, PSTR, T$, 146, 6: CALL MSGP, PSTR, "your correct name?", 156, 11
IF LEN (N#) < 13 OR LEN (N#) = 13 THEN T$ = "Is " + N#: CALL MSGP, PSTR, T$, 150, 3
CALL MSGP, PSTR, "Type Y for yes or N for no", 17, 0, 6: GOSUB 40: IF R$ = "N" GOTO 40020
RETURN
REM * CHECK TUTFILE *
CALL MSGP, 0: CALL MSGP, PSTR, "Checking my file.
", 80, 11
PRINT D#: "OPEN TUTFILE, L40"
PRINT D#: "READ TUTFILE, RO"
INPUT RX: IF RX = 0 GOTO 40180
FOR RLOOP = 1 TO RX
INPUT FINAL#: NAME# = LEFT# (FINAL#, LEN (N#))
NEXT RLOOP
PRINT D#: "READ TUTFILE, R": RLOOP
INPUT FINAL#: NAME# = LEFT# (FINAL#, LEN (N#))
IF NAME# = N# THEN RKRD = RLOOP: RLOOP = RX
NEXT RLOOP
PRINT D#: "CLOSE TUTFILE"
IF RKRD > 0 THEN SCT# = MID# (FINAL#, 27, 1): RV * = MID# (FINAL#, 23, 2): PR# = MID# (FINAL#, 30, 2): PI# = MID# (FINAL#, 32, 2): P2# = MID# (FINAL#, 34, 2): P3# = MID# (FINAL#, 36, 2): TIME# = MID# (FINAL#, 38, 2)
REM * SAVE STUDENT INFO *
POKE 768,RKRD:SCF = VAL (SCF$): POKE 769,SCF:
REVIEW = 0: POKE 770,REVIEW: POKE 771, VAL (RV$):
POKE 772, VAL (PR$): POKE 773, VAL (P1$): POKE
774, VAL (P2$): POKE 775, VAL (P3$)
TIME = VAL (TIME$) + 1: POKE 776,TIME
POKE 777, LEN (F$): POKE 778, LEN (L$)
FOR LOOP = 1 TO LEN (F$): POKE 778 + LOOP, ASC
(MID$ (F$,LOOP,1)): NEXT: FOR LOOP = 1 TO LEN
(L$): POKE 778 + LEN (F$) + LOOP, ASC (MID$ (L
*,LOOP,1)): NEXT
RETURN
REM * INTO FOR 1ST-TIMERS *
CALL MSGP,0: HPLQ1 1,1 TO 1,190 TO 278,190 TO
278,1 TO 1,1: HPLQ1 1,172 TO 278,172: CALL MSGP,
TXT,TTBLE,3,179,7,DI
HEL$ = "HELLO " + F$ + "!": CALL MSGP,PSTR,HEL$,
20,2:TNUM = 4:ROW = 60:COL = 2: GOSUB 100: GOSUB
230
TNUM = 6:ROW = 32:DI = 12: GOSUB 100:TNUM = 7:R
OW = 68:COL = 0: GOSUB 100: CALL MSGP,2,12,68,5,
0: CALL MSGP,2,12,92,5,0: CALL MSGP,2,12,128,5,0
:DI = 16: GOSUB 230
TNUM = 8:ROW = 40:COL = 2: GOSUB 100: GOSUB 230
TNUM = 9: GOSUB 100: GOSUB 230
TNUM = 10:ROW = 20: GOSUB 100: GOSUB 230
RETURN
REM *** INITIALIZE VARIABLES ***
MSGP = 24576: PSTR = 3: MOM# = "One moment please
...": D$ = CHR$ (13) + CHR$ (4): TTBLE = 33024:
TXT = 4:DI = 16
FOR LOOP = 1 TO 7: POKE 767 + LOOP,0: NEXT
PRINT ("BLOAD MSGP": PRINT CHR$ (4):"BLOAD INTRO.ASM"
HGR2 = HCOLOR= 7: GOSUB 290: CALL MSGP,5,0,87,
1,36,0,17,0: CALL MSGP,8,0,2,4: CALL MSGP,1,0,96
, 104,5,30
CALL MSGP,TXT,TTBLE,0,56,1,20: CALL MSGP,TXT,T
TBLE,5,150,1,20
PRINT CHR$ (4):"BLOAD WAVE.FIVE": FOR PA = 1 TO
1000: NEXT: RETURN
HOME = TEXT :ER = PEEK (222): VTAB 10: CALL 5
4915
IF ER = 20 THEN PRINT "PLEASE DON'T PRESS THE
RESET BUTTON!": GOTO 63700
IF ER = 8 THEN PRINT "IS THE DISK DRIVE DOOR
CLOSED?": GOTO 63700
GOSUB 60: POKE 214,0: HGR2 : GOTO 10030
Menu

1 REM *** MENU.....10/14/83 ***
2 ONERR GOTO 63000
3 DATA 32,234,3,162,2,173,0,224,201,76,240,7,202,15
4 7,128,192,16,243,2,162,20,76,18,212
5 FOR L100P = 952 TO 975: READ TEMP: POKE LI00P,TEMP : NEXT LI00P
6 TEMP = INT (952 / 256): POKE 1010,952 - TEMP * 256 : POKE 1011,TEMP: IF PEEK (-3) = 250 THEN CALL
7 - 1169
8 HIMEM: 16384: GOTO 10010
9 REM * One moment please *
10 HGR2: CALL MSGP,0: CALL MSGP,PSTR,MOM$,90,11: RETURN
11 REM * GET Y OR N *
12 POKE -16368,0: GET R#: IF ASC (R#) < > 78 AND
13 ASC (R#) < > 89 GOTO 40
14 RETURN
15 VTAB 22: PRINT "PRESS <SPACE BAR> TO CONTINUE": GOSUB
16 230: RETURN
17 VTAB 20: PRINT "TO THE LAB MONITOR ONLY:"; PRINT
18 : PRINT "PRESS <SPACE BAR> FOR INSTRUCTIONS": GOSUB
19 230: RETURN
20 REM * GET MAIN MENU CHOICE *
21 GET R#: IF ASC (R#) < 49 OR ASC (R#) > 52 THEN
22 90
23 RETURN
24 REM *** DISPLAY TEXT ***
25 CALL MSGP,TXT,TTBLE,TNUM,ROW,COL,DI: RETURN
26 REM *** PLAIN BORDER SUBROUTINE ***
27 CALL MSGP,0: HGR2: HCOLOR= 7: HPLOT 1,1 TO 1,19
28 0 TO 278,190 TO 278,1 TO 1,1: RETURN
29 REM * PSTRINGER *
30 CALL MSGP,PSHR,T#,ROW,COL: RETURN
31 POKE -16368,0: GET R#: IF ASC (R#) < > 32 GOTO
32 230
33 232 RETURN
34 10000 REM **************** MAIN DRIVER ************
35 ***
36 10009 REM *** INITIALIZE VARIABLES & LOAD BFILES **
37 *
38 10010 GOSUB 60010: REM SET VARIABLES
39 10025 CALL MSGP,0: HGR2:TTBLE = 33024
10030 IF SCT < 6 THEN GOSUB 35: GOTO 19000: REM
   IF YOU HAVEN'T FINISHED THE LESSON, YOU CAN'T G
   ET THE MENU
10098:
10099 REM *** MAIN MENU ***
10105 GOSUB 160:TNUM = 0;ROW = 32;COL = 3: GOSUB 100
   : REM PRINT MAIN MENU
10110 GOSUB 90;R = VAL.(R$> ; IF R = 4 THEN GOSUB 3
   5; GOTO 19000: REM RECORDKEEPING & END
10112 ON R GOTO 10113,10114,10115
10113 GOSUB 35: PRINT : PRINT CHR$ (4);"RUN LESSON"

10114 REVIEW = 1: GOSUB 35: POKE 770,REVIEW: PRINT : PRINT
   CHR$ (4);"RUN LESSON"
10115 GOSUB 35: PRINT : PRINT CHR$ (4);"RUN PRACTICE"
10116 TTBLE = 33024: GOTO 10105
10117:
19000 GOSUB 40000: REM RECORDKEEPING
19010 FILE = 1: GOSUB 20000
19998 GOSUB 160: CALL MSGP,TXT,33024,7,30,2,DI: CALL
   MSGP,PSTR,F$ + ":",158,21
19999 END
20000 GOSUB 160: CALL MSGP,TXT,33024,7,30,2,DI: CALL
   MSGP,PSTR,F$ + "!",158,21
20005 ROW = 100: HPLOT 1,90 TO 278,90
20010 CALL MSGP,TXT,33024,3,20,2,DI:RROW = 28
20015 IF SCT > 4 AND RV > 0 THEN GOTO 20070: REM
   NO RECOMMENDATIONS FOR NEXT TIME
20020 IF SCT > 4 AND RV = 0 GOTO 20040
20030 RROW = RROW + 12: CALL MSGP,PSTR,"Go through le
   sson section",RROW,2;T$ = ":;E$ = ":; IF SCT = 4 
   THEN E$ = ""
20035 FOR I = (SCT + 1) TO 5;T$ = I$ + ":" + STR$(I):
   NEXT I: CALL MSGP,PSTR,E$ + T$;RROW,27
20040 RROW = RROW + 12: CALL MSGP,TXT,33024,5,RROW,2, 
   DI: IF P1 < 0 AND P2 < 0 AND P3 < 0 THEN ROW = 60: GOTO 20070
20050 RROW = RROW + 12: IF PR < > 0 THEN CALL MSGP,
   PSTR,"Take Practice Level",RROW,2;T$ = "":E$ = 
   "s": IF (P1 < > 0 AND P2 < > 0) OR (P1 < > 0 AND 
   P3 < > 0) OR (P2 < > 0 AND P3 < > 0) THEN E$ = 
   ""
20055 IF PR < > 0 THEN GOSUB 20100: CALL MSGP,PSTR
   ,E$ + T$;RROW,21: GOTO 20070
20060 CALL MSGP,TXT,33024,4,RROW,2,DI
20070 CALL MSGP,PSTR,"IMPORTANT! Please make a note 
   ",RROW,2: CALL MSGP,TXT,33024,6,ROW + 20,4,12: CALL
   MSGP,PSTR,DISK*,ROW + 20,21
20072 HPLOT 1,164 TO 278,164
20075 CALL MSGP,PSTR,"Press <SPACE BAR> to go on",17
20080 POKE 16368,0: GET R$: IF ASC(R$) <> 32 THEN
20080 RETURN
20100 IF P1 = 0 THEN T1$ = "1"
20110 IF P2 = 0 THEN T2$ = "2"
20120 IF P3 = 0 THEN T3$ = "3"
20130 T# = T1$ + T2$ + T3$: RETURN
39999 REM *** WRITE TO FILE ***
40005 PRINT D$;"OPEN TUTFILE,L40"
40010 PRINT D$;"READ TUTFILE,RO"
40020 INPUT RX
40025 IF RKRD > RX GOTO 40040
40030 IF RKRD > 0 THEN PRINT D$;"READ TUTFILE,R";RKRD
40040 RX = RX + 1: RKRD = RX
40045 P1$ = LEFT$(N$ + TEMP$,26): SCT$ = STR$(SCT$ + TEMP$,2): PR$ = LEFT$(PR$ + TEMP$,2)
40050 P2$ = LEFT$(P2$ + TEMP$,2): P3$ = LEFT$(P3$ + TEMP$,2): TIME$ = LEFT$(TIME$ + TEMP$,2)
40060 NAME$ = LEFT$(N$ + TEMP$,26): SCT$ = STR$(SCT$): RV$ = LEFT$(RV$ + TEMP$,2): P2$ = LEFT$(P2$ + TEMP$,2): P3$ = LEFT$(P3$ + TEMP$,2): TIME$ = LEFT$(TIME$ + TEMP$,2)
40070 FINAL$ = NAME$ + SCT$ + RV$ + PR$ + P1$ + P2$ + P3$ + TIME$ + TEMP$ + TEMP$
40080 PRINT D$;"WRITE TUTFILE,RO"; RKRD
40090 PRINT FINAL$
40095 PRINT CHR$(4): REM TERMINATE WRITE OPERATI
40100 PRINT D$;"WRITE TUTFILE,RO"
40110 PRINT RX
40115 PRINT CHR$(4)
40120 PRINT D$;"CLOSE TUTFILE"
40130 RETURN
59999:
60000 REM *** INITIALIZE VARIABLES ***
60010 DISK$ = "2": MSGP = 24576: TTBLE = 33024: PTTBLE = 34048: TXT = 4: PSTR = 3: DI = 16: MOM$ = "One momen
Lesson

1 REM *** LESSON.....1/25/84 *
3 ONERR  GOTO 63000
10 HIMEM: 38399: LOMEM: 37647: GOTO 10010
20 GOSUB 230: CALL MSGP,0: RETURN
35 CALL MSGP,0: CALL MSGP,PSTR,MOM$,90,11: RETURN
40 CALL MSGP,PSTR,"Would you like to see this section again before going on? (Y/N)",ROW,2: CALL MSGP,PSTR,"Would you like to see this section again before going on? (Y/N)",ROW + 16,2: GOSUB 90: RETURN
45 CALL MSGP,1,0,173,188,1,38: RETURN
50 RHR$ = "<R> to REHEAR": CALL MSGP,PSTR,RHR$,180,2: RETURN
55 CALL MSGP,1,0,173,188,1,17: RETURN
58 CALL MSGP,1,0,173,188,10,38: RETURN
60 POKE -16368,0: GET S$: IF ASC (S$) = 27 THEN GOSUB 90: GOTO 60
IF ASC ($S$) < > 32 AND ASC ($S$) < > 82 THEN 6

CALL MSGP, 2, CHAR, ROW, COL, 0: RETURN
CALL MSGP, 1, 1, ROW - 2, ROW + 6, COL, COL: CALL MSGP, 1, 0, ROW - 2, ROW + 6, COL, COL: GOSUB 70: RETURN
CALL MSGP, 1, 0, 173, 198, 1, 38: CALL MSGP, PSTR, "Quit this section (Y/N)?", 178, 8: GOSUB 90: IF R$ = "Y" THEN CALL 54915: GOTO 19999
CALL MSGP, 1, 0, 173, 188, 1, 38: GOSUB 182: RETURN
POKE - 16368, 0: GET R$: IF ASC (R$) < > 78 AND ASC (R$) < > 89 GOTO 90
RETURN
REM * REHEAR FOR SECTION 4, P. 5 *
GOSUB 60: IF S$ = "R" THEN MNUM = 5: TMP0 = 60: GOSUB 130: FOR PAUSE = 1 TO 1000: NEXT : MNUM = 4: TMP0 = 40: GOSUB 130: GOTO 95
RETURN
CALL MSGP, TXT, TTBLE, TNUM, ROW, COL, DI: RETURN
CALL MSGP, SETUP, STAFF, TLNE, LCOL, RCOL, CLEF, KEY, MODE: CALL MSGP, DR, STAFF, LCOL + 1, LCOL + 3: RETURN
CALL MSGP, DPLAY, MTABLE, MNUM, NVOICES, FWIDTH, FDUR, NCOL, SOFF, S1, S2, MUP, MLO, SBEET, PBARS, ACTIVC: RETURN
CALL MSGP, PLAY, MTABLE, MNUM, NVOICES, TMP0, WAVTBLE, SOFF, ACTIVC: RETURN
CALL MSGP, SETUP, STAFF, TLNE, LCOL, RCOL, CLEF, KEY, MODE: RETURN
CALL MSGP, 0: HGR2: HCOLOR = 7: HPL0T 1, 1 TO 1, 19 O TO 278, 190 TO 278, 1 TO 1, 1: RETURN
CALL MSGP, 0: HGR2: HCOLOR = 7: HPL0T 1, 1 TO 1, 19 O TO 278, 190 TO 278, 1 TO 1, 1: HPL0T 1, 24 TO 278, 24: RETURN
CALL MSGP, 0: HGR2: HCOLOR = 7: HPL0T 1, 1 TO 1, 19 O TO 278, 190 TO 278, 1 TO 1, 1: HPL0T 1, 172 TO 278, 172
CALL MSGP, PSTR, "<SPACE BAR> to go on", 180, 18: RETURN
HPL0T 1, 24 TO 278, 24: RETURN
CALL MSGP, 1, 0, 2, 167, 1, 38: RETURN
GOSUB 60
IF S$ = "R" THEN GOSUB 130: GOTO 200
RETURN
GOSUB 230: GOSUB 190: RETURN
POKE - 16368, 0: GET S$: IF ASC (S$) = 27 THEN GOSUB 80: GOTO 230
IF ASC (S$) < > 32 THEN 230
RETURN
239:
24A:
250 GOSUB 35: PRINT : PRINT CHR$ (4);"BLOAD DEF.ASM
";TITLE = LTABLE
255 GOSUB 180: GOSUB 185:A = FRE (0): GOTO 380
260 T$ = P$ + "": CALL MSGP,PSTR,T$,10,5:TNUM = 0:R
OW = 10:COL = 16: GOSUB 100
264 TNUM = 1:ROW = 60:COL = 2: GOSUB 100
265 GOSUB 20: GOSUB 180: RETURN
270 TNUM = 2:ROW = 24:COL = 1: GOSUB 100: GOSUB 230
MPO = 100:S1 = 0:S2 = 1:FDUR = 8:FWIDTH = 2:ACTIVVC = 15
274 GOSUB 110
276 STAFF = 1:TLNE = 136:CLEF = 1
278 GOSUB 110
280 MNUM = 0: GOSUB 120
282 CALL MSGP,2,7,136,18,0: CALL MSGP,2,8,146,39,0
284 FOR I = 1 TO 500: NEXT : GOSUB 130
285 GOSUB 50: GOSUB 200: CALL MSGP,1,0,2,80,1,38
290 TNUM = 3: GOSUB 100: GOSUB 200: CALL MSGP,1,0,2,8
0,1,38
295 TNUM = 4:COL = 2: GOSUB 100: GOSUB 200: GOSUB 55:
GOSUB 190: RETURN
300 TNUM = 5:ROW = 48:COL = 1: GOSUB 100: GOSUB 220: RETURN
305 TNUM = 6:ROW = 24: GOSUB 100: GOSUB 220: RETURN
310 TNUM = 7:ROW = 20:COL = 2: GOSUB 100: HPLOT 49,92
TO 252,92: GOSUB 220: RETURN
315 TNUM = 8: GOSUB 100: GOSUB 230:TNUM = 9:ROW = 150
: GOSUB 100: GOSUB 220: RETURN
320 STAFF = 0:TLNE = 20:RCOL = 11:NCOL = 8:CLEF = 0:M
UP = 4:SBEET = 1:TMPO = 80:S2 = 0:FDUR = 8 + 128
:FWIDTH = 2
325 GOSUB 110:MNUM = 1: GOSUB 120
1:S1 = 1:S2 = 1:ACTIVVC = 1
332 GOSUB 110:MNUM = 2: GOSUB 120
335 GOSUB 370
340 TNUM = 10:ROW = 82: GOSUB 100: CALL MSGP,2,27,139
,11,0: CALL MSGP,2,27,139,23,0: CALL MSGP,2,25,1
39,28,0
350 GOSUB 50: GOSUB 60: IF S$ = "R" THEN GOSUB 370:
GOT0 350
355 CALL MSGP,1,0,60,170,1,38:TNUM = 11:ROW = 100: GOSUB
100: CALL MSGP,2,27,124,18,0: CALL MSGP,2,25,124
,22,0
358 GOSUB 60: IF S$ = "R" THEN GOSUB 370: GOTO 358
359 GOSUB 55: RETURN
360 GOSUB 190:TNUM = 12:ROW = 20: GOSUB 100: GOSUB 2
30: RETURN

380 FOR PG = 1 TO 8
385 ON PG GOSUB 260, 270, 300, 305, 310, 315, 325, 360
390 NEXT PG
392 GOSUB 45: ROW = 140: GOSUB 40: IF R$ = "Y" GOTO 255
393 IF SCT > 0 THEN RV = RV + 1
395 IF SCT < 1 THEN SCT = 1
399 CALL MSGP, 0: RETURN

410 GOSUB 35: PRINT : PRINT CHR$(4): "LOAD FC.ASM"
415 TTABLE = LTABLE
420 T$ = P$ + "2": CALL MSGP, PSTR, T$, 10, 5: TNUM = 0: RV = 16: COL = 16: GOSUB 100
440 TNUM = 2: ROW = 16: COL = 3: GOSUB 100: GOSUB 230
450 STAFF = 0: TLNE = 122: LCOL = 1: RCOL = 33: NCOL = 3:
CLEF = 0: NVIOCES = 1: MUP = 4: MLO = 16: SBEET = 1:
TMPO = 80: S1 = 0: S2 = 0: FDUR = 16: FWIDTH = 3: ACTIVC = 1
455 GOSUB 110: MNUM = 3: GOSUB 120:
459 PC$ = "0 1 2 3 4 5 6 7 8 9 10 11": CALL MSGP, PSTR, PC$, 156, 4: GOSUB 130
459 GOSUB 50
460 GOSUB 200: CALL MSGP, 1, 0, 2, 116, 1, 39
465 TNUM = 3: ROW = 24: GOSUB 100: CALL MSGP, 2, 27, 32, 2
6, 0: CALL MSGP, 2, 24, 32, 35, 0: CALL MSGP, 2, 27, 50, 3
1, 0: CALL MSGP, 2, 25, 65, 4, 0: CALL MSGP, 2, 28, 68, 13
0, 0: GOSUB 200: GOSUB 55: GOSUB 190: RETURN
470 TNUM = 4: ROW = 16: COL = 2: GOSUB 100: CALL MSGP, 2
27, 24, 11, 0: CALL MSGP, 2, 25, 24, 15, 0
471 TLNE = 60: LCOL = 12: RCOL = 28: TMPO = 40: NCOL = 16:
MUP = 3: MLO = 64: FDUR = 64: GOSUB 110: MNUM = 4:
GOSUB 120: FOR PAUSE = 1 TO 600: NEXT: GOSUB 1
30
472 GOSUB 50: GOSUB 200
475 TNUM = 5: ROW = 100: CALL MSGP, 2, 25, 124, 16, 0: GOSUB 100: GOSUB 200: GOSUB 55: GOSUB 190: RETURN
480 TNUM = 6: ROW = 20: GOSUB 100: CALL MSGP, 2, 25, 124,
27, 0: GOSUB 220: RETURN
16: FDUR = 16: FWIDTH = 2: TMPO = 60: GOSUB 110:
MNUM = 5: GOSUB 120: GOSUB 130
490 GOSUB 50: GOSUB 200
495 TNUM = 7: ROW = 64: GOSUB 100: CALL MSGP, 2, 25, 104,
14, 0
190

497 TLNE = 130; LCOL = 12; RCOL = 28; TMPO = 40; NCOL = 1
   MUP = 3; MLO = 64; FDUR = 64; FWIDTH = 3; GOSUB 1
   10; MNUM = 4: GOSUB 120
498 GOSUB 95: CALL MSGP, 1, 0, 56, 120, 1, 38
500 FOR LOOP = 8 TO 9
502 TNUM = LOOP: GOSUB 100: IF R$ = "Y" GOTO 4
   15
503 NEXT LOOP
504 HPLG 59, 48 TO 141, 122: HPLG 115, 48 TO 141, 122:
   HPLG 171, 48 TO 141, 122: HPLG 227, 48 TO 141, 12
507 GOSUB 95: GOSUB 55: GOSUB 190: RETURN
510 TNUM = 10; ROW = 20: GOSUB 100: GOSUB 230: RETURN
550 FOR PG = 1 TO 6
560 ON PG GOSUB 420, 440, 470, 480, 485, 510
570 NEXT PG
575 GOSUB 45: ROW = 140: GOSUB 40: IF R$ = "Y" GOTO 4
   15
578 IF SCT > 1 THEN RV = RV + 1
580 IF SCT < 2 THEN SCT = 2
598 CALL MSGP, 0: RETURN
603 GOSUB 35: PRINT: PRINT CHR$(4); "BLOAD IC1.ASM"
   "TABLE = LTABLE
606 GOSUB 100: GOSUB 185; A = FRE (0); GOTO 785
609 T$ = P$ + "3;": CALL MSGP, FSTR, T$, 10, 6; TNUM = 0: R
   OW = 10; COL = 17: GOSUB 100
612 TNUM = 1; ROW = 66; COL = 2: GOSUB 100: GOSUB 20: GOSUB
   180: RETURN
616 TNUM = 3; ROW = 40: GOSUB 100: GOSUB 220: RETURN
618 TNUM = 4: ROW = 16: GOSUB 100
621 DI = 8: TNUM = 5; ROW = 60; COL = 6: GOSUB 100; DI =
   16: GOSUB 220: RETURN
624 TNUM = 6; ROW = 40; COL = 2: GOSUB 100: GOSUB 220: RETURN
627 TNUM = 7; ROW = 20; COL = 4: GOSUB 100: GOSUB 230
630 STAFF = 0: TLNE = 116; LCOL = 13; RCOL = 28; S1 = STA
   FF; S2 = STAFF; NCOL = 17; NVICES = 2; ACTIVC = 3; M
   UP = 2; MLO = 64; FWIDTH = 4; FDUR = 64; TMPO = 40; S
   BEET = 1
633 MNUM = 9: GOSUB 110: GOSUB 120: GOSUB 130
636 GOSUB 50: GOSUB 200
637 CALL MSGP, 1, 0, 2, 90, 1, 38
639 TNUM = 8; COL = 2: GOSUB 100: GOSUB 200: GOSUB 55:
   GOSUB 190: RETURN
642 TNUM = 9: GOSUB 100; DI = 8; TNUM = 10; ROW = 94: GOSUB
   100: HPLG 8, 88 TO 271, 88; DI = 16: GOSUB 230: CALL
   MSGP, 1, 0, 2, 88, 1, 38
645 TNUM = 11; ROW = 20: GOSUB 100: GOSUB 220: RETURN
CALL MSGP,PSTR,"INTERVAL CONTENT cont'd",10,2: GOSUB 185:
TNUM = 1: ROW = 40: GOSUB 100: GOSUB 20: GOSUB 180: RETURN
TNUM = 2: GOSUB 100: GOSUB 220: RETURN
TNUM = 3: GOSUB 100: CALL MSGP,2,27,48,21,0: GOSUB 230
TNUM = 4: TI = 8: ROW = 122: GOSUB 100: CALL MSGP,2,
27,134,8,0: CALL MSGP,2,27,142,3,0: HPLOT 7,115
to 272,115
CHAR = 15: COL = 5: ROW = 136: FOR I = 1 TO 3: GOSUB
70: ROW = ROW + 9: NEXT I: GOSUB 230: CALL MSGP,1,
0,2,89,1,38
N1 = 16: TNUM = 5: ROW = 20: COL = 2: GOSUB 100: GOSUB
220: RETURN
TNUM = 6: GOSUB 100: GOSUB 230: CALL MSGP,1,0,2,9
6,1,38: TNUM = 7: GOSUB 100: GOSUB 230: CALL MSGP
1,0,2,96,1,38
TNUM = 8: GOSUB 100: GOSUB 230: CALL MSGP,1,0,115
1,125,14,24: FOR PA = 1 TO 1000: NEXT N: CHAR = 49:
ROW = 116: FOR I = 1 TO 3: COL = IVCOL(I): GOSUB
70: GOSUB 75: FOR J = 1 TO 350: NEXT J: FOR I = 1
TO 3: COL = IVCOL(I): FOR J = 1 TO 350: NEXT J: NEXT I
TNUM = 9: ROW = 60: COL = 5: GOSUB 100: CALL MSGP,2,27,68,9,0: CALL MSGP,1
0,124,140,8,24: GOSUB 220: RETURN
TNUM = 10: ROW = 48: COL = 2: GOSUB 100: CALL MSGP,
2,27,40,31,0: GOSUB 220: RETURN
TNUM = 11: ROW = 48: COL = 2: GOSUB 100: CALL MSGP,
2,27,40,31,0: GOSUB 220: RETURN
TNUM = 12: TLINE = 66: LCOL = 3: RCOL = 31: NCOL = 8:
MUP = 4: SL = 1: S2 = 1: FDUR = 32
TNUM = 13: ROW = 118: DI = 12: GOSUB 100: GOSUB 758
: CALL MSGP,1,0,112,167,1,38: TNUM = 14: ROW = 122
: GOSUB 100: DI = 16: GOSUB 758
GOSUB 55: GOSUB 190: RETURN
GOSUB 50: GOSUB 60: IF S# = "R" THEN MNUM = 10: GOSUB
130: FOR PAUSE = 1 TO 1000: NEXT N: MNUM = 11: GOSUB
130: GOTO 758
RETURN
TNUM = 15: ROW = 20: GOSUB 100: GOSUB 220: RETURN
770 TNUM = 16: ROW = 12: GOSUB 100: GOSUB 230: RETURN

785 FOR PB = 1 TO 6: ON PB GOSUB 609, 616, 618, 624, 627, 642: NEXT PB

790 CALL MSGP, 0: CALL MSGP, PSTR, "To be continued...", 90, 11: PRINT: PRINT CHR$ (4); "BLOAD IC2.ASM": TTABLE = LTABLE: GOSUB 180

792 FOR PB = 1 TO 8: ON PB GOSUB 650, 660, 670, 690, 720, 730, 760, 770: NEXT PB

794 GOSUB 45: ROW = 146: GOSUB 40: IF R$ = "Y" GOTO 605

795 IF SCT > 2 THEN RV = RV + 1

796 IF SCT < 3 THEN SCT = 3

798 CALL MSGP, 0: RETURN

799 GOSUB 35: PRINT: PRINT CHR$ (4); "BLOAD IC2.ASM": TTABLE = LTABLE

800 GOSUB 180: GOSUB 195: A = FRE(0): GOTO 990

805 T$ = Pi + "4": CALL MSGP, PSTR, T$, 10, 1: TNUM = 0: ROW = 10: COL = 12: GOSUB 100

810 TNUM = 1: ROW = 48: COL = 2: GOSUB 100: GOSUB 20: GOSUB 855: CALL MSGP, 1, 0, 82, 167, 1, 38: TNUM = 3: GOSUB i00: GOSUB 855: CALL MSGP, 1, 0, 82, 167, 1, 38

815 TNUM = 4: COL = 4: GOSUB 100: GOSUB 55: GOSUB 190: RETURN


825 MNUM = 6: GOSUB 110: GOSUB 120: GOSUB 130

830 FOR PAUSE = 1 TO 1000: NEXT

835 STAFF = 1: COL = 22: RCOL = 36: NCOL = 26: S1 = 1: S2 = 1

840 GOSUB 110: MNUM = 7: GOSUB 120: GOSUB 130

845 TNUM = 2: ROW = 90: GOSUB 100: GOSUB 50: GOSUB 855: CALL MSGP, 1, 0, 82, 167, 1, 38: TNUM = 3: GOSUB 100: GOSUB 855: CALL MSGP, 1, 0, 82, 167, 1, 38

850 TNUM = 4: COL = 4: GOSUB 100: GOSUB 855: GOSUB 55: GOSUB 190: RETURN

855 GOSUB 60: IF S$ = "R" THEN MNUM = 6: GOSUB 130: FOR PAUSE = 1 TO 1000: NEXT: MNUM = 7: GOSUB 130: GOTO 855

856 RETURN

860 TNUM = 5: ROW = 20: COL = 2: GOSUB 100: CALL MSGP, 2, 27, 12, 22, 9: GOSUB 230

865 STAFF = 0: TLNE = 48: COL = 15: RCOL = 31: NCOL = 19: S1 = STAFF: S2 = STAFF: TMPD = 20

870 GOSUB 110: MNUM = 10: GOSUB 120: FOR PA = 1 TO 1000: NEXT: GOSUB 130: FOR PAUSE = 1 TO 1000: NEXT

880 TNUM = 6: ROW = 90: GOSUB 100: CALL MSGP, 2, 25, 98, 2, 0, 0: CALL MSGP, 2, 26, 98, 23, 0: GOSUB 230

885 STAFF = 1: TLNE = 13: GOSUB 110: MNUM = 8: GOSUB 120: FOR PA = 1 TO 1000: NEXT: GOSUB 130
193

890 GOSUB 50: GOSUB 50: IF S$ = "R" THEN MNUM = 10: GOSUB 130: FOR PAUSE = 1 TO 1000: NEXT: MNUM = 8: GOSUB 130: GOTO 890
895 GOSUB 55: GOSUB 190: RETURN
900 TNUM = 7: ROW = 70: GOSUB 100: GOSUB 220: RETURN
910 TNUM = 8: ROW = 20: GOSUB 100: CALL MSGP,2,27,28,1,4,0: CALL MSGP,2,13,36,16,0: CALL MSGP,2,15,36,2,0,0: CALL MSGP,2,26,28,23,0: CALL MSGP,2,29,108,8,0: GOSUB 220: RETURN
920 TLINE = 10: LCOL = 12: RCOL = 29: NCOL = 16: TMP0 = 40
925 MNUM = 9: GOSUB 110: GOSUB 120: GOSUB 130
930 FOR PAUSE = 1 TO 1000: NEXT
935 TNUM = 9: ROW = 47: GOSUB 100
940 FOR PAUSE = 1 TO 1000: NEXT
949 CALL MSGP,1,0,60,93,18,20: CALL MSGP,1,0,60,93,27,29
950 T$ = "m3rd d8ve m6th": CALL MSGP,PSTR,T$: 100,13: GOSUB 130
955 DI = 9: TNUM = 10: ROW = 116: GOSUB 100: GOSUB 230
960 DI = 10: TNUM = 11: ROW = 140: GOSUB 100: GOSUB 230: CALL MSGP,1,0,140,170,1,38: TNUM = 12: GOSUB 100: DI = 16: GOSUB 50
965 GOSUB 60: IF S$ = "R" THEN MNUM = 9: GOSUB 130: FOR PAUSE = 1 TO 1000: NEXT: MNUM = 13: GOSUB 130: GOTO 965
970 GOSUB 55: GOSUB 190: RETURN
980 TNUM = 13: ROW = 12: GOSUB 100: GOSUB 230: RETURN
990 FOR PG = 1 TO 7: ON PG GOSUB 810,820,860,900,910,920,980: NEXT PG
992 GOSUB 45: ROW = 145: GOSUB 40: IF R$ = "Y" GOTO 96
995 IF SCT > 3 THEN RV = RV + 1
996 IF SCT < 4 THEN SCT = 4
997 CALL MSGP,0: RETURN
1006 :
1010 GOSUB 35: PRINT : PRINT CHR$(4):"BLOAD IE.ASM":TTABLE = LTABLE
1015 GOSUB 180: GOSUB 185: A = FRE (0): GOTO 1290
1020 T$ = P$ + "5": CALL MSGP,PSTR,T$: 10,3: TNUM = 0: ROW = 10: COL = 14: GOSUB 100
1025 TNUM = 1: ROW = 50: COL = 5: GOSUB 100: GOSUB 230: CALL MSGP,1,0,48,160,1,38
1027 TNUM = 2: COL = 3: GOSUB 100: GOSUB 20: GOSUB 180: RETURN
1030 TNUM = 3: ROW = 20: COL = 2: GOSUB 100: CALL MSGP,2,27,12,24,0: GOSUB 230
1038 MNUM = 14: GOSUB 110: GOSUB 120
1043 T$ = "m2 m3 m2 m3": CALL MSGP, PSTR, T$ , 147, 10: FOR PAUSE = 1 TO 1000: NEXT: GOSUB 10 49
1044 GOSUB 50: GOSUB 60: IF S$ = "R" THEN GOSUB 104 9: GOTO 1044
1046 CALL MSGP, 1, 0, 3, 100, 1, 38: TNUM = 4: ROW = 36: COL = 4: GOSUB 100: CALL MSGP, 2, 25, 28, 16, 0: CALL MSGP, 2, 27, 44, 11, 0
1047 GOSUB 60: IF S$ = "R" THEN GOSUB 1049: GOTO 10 47
1048 GOSUB 55: GOSUB 190: RETURN
1049 MNUM = 14: GOSUB 130: FOR PAUSE = 1 TO 1000: NEXT: MNUM = 15: GOSUB 130: RETURN
1060 TNUM = 7: ROW = 20: GOSUB 100: GOSUB 220
1061 TNUM = 8: ROW = 10: GOSUB 100: HCOLOR = 7: HPL oT 7 .24 TO 271, 24: TNUM = 9: ROW = 32: GOSUB 100: CALL MSGP, 2, 25, 40, 18, 0: FOR PAUSE = 1 TO 1000: NEXT
1065 STAFF = 0: TLNE = 64: LCOL = 8: RCOL = 34: NCOL = 11 1: MUP = 2: MLO = 32: FDUR = 32: MNUM = 16: GOSUB 110 2: GOSUB 120
1068 CALL MSGP, 1, 0, 64, 94, 17, 19: CALL MSGP, 1, 0, 64, 94, 26, 28
1070 DI = 9: TNUM = 10: ROW = 102: GOSUB 100: FOR PAUSE = 1 TO 1000: NEXT: GOSUB 130: GOSUB 50: GOSUB 200
1090 TNUM = 12: ROW = 20: GOSUB 100: GOSUB 220: RETURN
1100 TLNE = 10: LCOL = 4: RCOL = 18: NCOL = 8: MLO = 64: M NUM = 14: FDUR = 64: GOSUB 110: GOSUB 120
1110 T$ = "Original Inversion": CALL MSGP, PST R, T$, 142, 8
1115 STAFF = 2: LCOL = 4: TLNE = 58: NCOL = 8: S1 = STAFF: S2 = STAFF: MNUM = 17: GOSUB 110: GOSUB 120
1120 T$ = "Transposed Inversions": CALL MSGP, PST R, T$, 90, 10
1125 GOSUB 1230
1129  GOSUB 50: GOSUB 60: IF S$ = "R" THEN GOSUB 123
   0: GOTO 1129
1130  DI = 12: TNUM = 13: ROW = 114: GOSUB 100: DI = 16
1135  GOSUB 60: IF S$ = "R" THEN GOSUB 1230: GOTO 11
   33
1140  GOSUB 55: GOSUB 190: RETURN
1200  CALL MSGP, 1, 1, 41, 51, 7, 16: RETURN
1210  CALL MSGP, 1, 1, 41, 51, 25, 35: RETURN
1220  CALL MSGP, 1, 1, 89, 99, 9, 31: RETURN
1230  GOSUB 1200: MNUM = 14: GOSUB 130: GOSUB 1200: FOR
   PAUSE = 1 TO 1000: NEXT: GOSUB 1210: MNUM = 15: GOSUB
   130: GOSUB 1210: FOR PAUSE = 1 TO 1000: NEXT
1240  GOSUB 1220: MNUM = 17: GOSUB 150: GOSUB 1220: RETURN
1250  TNUM = 14: ROW = 20: GOSUB 100: GOSUB 220: RETURN
1260  TNUM = 15: ROW = 12: GOSUB 100: GOSUB 230: TNUM =
   16: ROW = 82: GOSUB 100: GOSUB 250: RETURN
1290  FOR PG = 1 TO 8: ON PG GOSUB 1020, 1030, 1050, 1060,
   1090, 1100, 1250, 1260: NEXT PG
1292  GOSUB 45: ROW = 145: GOSUB 40: IF R$ = "Y" GOTO
   1015
1295  IF SCT > 4 THEN RV = RV + 1
1296  IF SCT < 5 THEN SCT = 5
1298  CALL MSGP, 0: RETURN
1310  GOSUB 35: PRINT: PRINT CHR$ (4): "LOAD SUMM.A
   SM": TBLE = LTABLE: GOSUB 180: GOSUB 185: GOTO 1
   360
1320  TNUM = 0: ROW = 10: COL = 15: GOSUB 100
1325  TNUM = 1: ROW = 48: COL = 2: GOSUB 100: GOSUB 20: GOSUB
   180: RETURN
1330  TNUM = 2: ROW = 20: GOSUB 100: GOSUB 230: TNUM = 3
   ROW = 90: GOSUB 100: GOSUB 220: RETURN
1340  TNUM = 4: ROW = 20: GOSUB 100: GOSUB 230: TNUM = 5
   ROW = 102: GOSUB 100: GOSUB 220: RETURN
1350  TNUM = 8: ROW = 40: GOSUB 100: GOSUB 58: GOSUB 70:
   RETURN
1360  FOR PG = 1 TO 4: ON PG GOSUB 1320, 1330, 1340, 1350:
   NEXT PG
1370  GOSUB 190: IF R$ = "Y" THEN GOSUB 180: GOSUB 1
   95: GOTO 1360
1375  IF SCT > 6 THEN RTAKE = 1: GOTO 1398
1380  TNUM = 6: ROW = 36: GOSUB 100: GOSUB 182: GOSUB 2
   20: TNUM = 7: ROW = 40: GOSUB 100: GOSUB 58: GOSUB
   90
1385  IF SCT < 6 THEN SCT = 6
1398  CALL MSGP, 0: RETURN
1998:
3000  GOSUB 160: TBLE = 33024: CALL MSGP, TXT, TBLE, 1,
   24, 2, DI
3010 POKE -16368,0:GET R$: IF ASC (R$) < > 27 AND (ASC (R$) < 49 OR ASC (R$) > 53) THEN GOTO 30
10
3020 R = VAL (R$): CALL MSGP,0:IF ASC (R$) = 27 THEN GOTO 3050
3030 ON Rgosub 250,410,603,805,1010
3040 GOTO 3000
3050 RETURN
3998
10001:
10010gosub 60000
10012 IF (SCT > 0 AND Sct < 6) THEN GOSUB 20010:REM PICKUP MENU
10015 IF PICKUP > 0 THEN PICKUP = SCT + 1: ON PICKUP
10020 IF REVIEW = 1 THEN GOSUB 3000:GOTO 19999
10060gosub 250
10070gosub 410
10080gosub 603
10090gosub 805
10100gosub 1010
10110gosub 1310
10115 IF RTAKE = 1 GOTO 19999
10120 IF R$ ="Y" THEN REVIEW = 1:GOSUB 3000
10130gosub 180:CALL MSGP,TXT,LTABLE,9,40,2,16:CALL
MSGP,1,1,103,111,14,14:gosub 230
19999 CALL MSGP,0:gosub 35:POKE 769,scT:POKE 770,
0:POKE 771,RV:PRINT:PRINT CHR$ (4);"RUN MENU U"
20000 END
20010 CALL MSGP,0:gosub 160;HEL$ = "HELLO " + F$ + ",":CALL MSGP;PSTR,HEL$,35,2:CALL MSGP,TXT,TTB
LE,2,60,2,DI
20020 POKE -16368,0:GET S$:IF ASC (S$) < 49 OR
ASC (S$) > 50 THEN 20020
20030 IF VAL (S$) = 1 THEN PICKUP = 1
20040 RETURN
20040 POKE -16368,0:GET R$:IF ASC (R$) < > 32 THEN
20400
20410 RETURN
20500 VTAB 22:PRINT "PRESS <SPACE BAR> TO CONTINUE"
:gosub 20400:RETURN
60000 PRINT :PRINT CHR$ (4);"BLOAD TUTMUSIC.ASM"
60010 MSGP = 24576;TTABLE = 33024;LTABLE = 34048;TXT = 
4;PSTR = 3;DI = 16;SETUP = 5;PLAY = 12;DR = 8;DP
LAY = 11;MODE = 0;MTABLE = 37120;WAVTABLE = 128
60015 KEY = 17;SROFF = 0;PBARS = 0;SHEET = 1;MOM$ = "0
one moment please...":F$ = "SECTION ",
60020 RNRD = PEEK (768):SCT = PEEK (769):REVIEW = PEEK
(770):RV = PEEK (771)
60030 TEMP = PEEK (777):F$ = ": FOR LOOP = 1 TO TEM
P:F$ = F$ + CHR$(PEEK (778 + LOOP)): NEXT LOO
P
60040 FOR I = 1 TO 6: READ IVCOL(I): NEXT
60050 DATA 14,16,20,16,22,24
60060 DATA 32,234,3,162,2,173,0,224,201,76,240,7,202
,157,128,192,16,243,2,162,20,76,18,212
60070 FOR L100P = 952 TO 975: READ TEMP: POKE L100P,
TEMP: NEXT L100P
60080 TEMP = INT (952 / 256): POKE 1010,952 - TEMP * 256:
POKE 1011,TEMP: IF PEEK ( - 3) = 250 THEN
CALL - 1169
60099 RETURN
63000 HOME : TEXT :ER = PEEK (222): VTAB 10: CALL 5
4915
63010 IF ER = 20 THEN PRINT "PLEASE DON'T PRESS THE
RESET BUTTON!": GOTO 63700
63020 IF ER = 8 THEN PRINT "IS THE DISK DOOR CLOSED
?"
63700 GOSUB 20500: POKE 216,0: GOTO 10012

Practice

1 REM *** PRACTICE... 1/25/84 ***
3 ONERR GOTO 63000
5 DATA 32,234,3,162,2,173,0,224,201,76,240,7,202,15
,128,192,16,243,2,162,20,76,18,212
7 FOR L100P = 952 TO 975: READ TEMP: POKE L100P,TEMP :
NEXT L100P
9 TEMP = INT (952 / 256): POKE 1010,952 - TEMP * 256:
POKE 1011,TEMP: IF PEEK (- 3) = 250 THEN CALL
- 1169
10 HIMEM: 16384: GOTO 10000
14 REM * One moment please *
15 HGR2 : CALL MSGP,0: CALL MSGP,PSTR,MOM$90,11: RETURN
19 REM * GET Y OR N *
20 POKE - 16368,0: GET R$: IF ASC (R$) < > 78 AND
ASC (R$) < > 89 GOTO 20
22 RETURN
24 CALL MSGP,1,0,127,137,1,38: CALL MSGP,PSTR,"Quit
this level (Y/N)?",128,9: GOSUB 40: IF R$ = "Y" THEN
QUIT = 1
26 RETURN
28 VTAB 22: PRINT "PRESS <SPACE BAR> TO CONTINUE": GOSUB
4130: RETURN
30 VTAB 20: PRINT "TO THE LAB MONITOR ONLY": PRINT
: PRINT "PRESS <SPACE BAR> FOR INSTRUCTIONS": GOSUB
4130: RETURN
159 REM *** PLAIN BORDER SUBROUTINE ***
160 CALL MSGF,0: HGR2: HCOLOR=7: HPLT 1,1 TO 1,19
.0 TO 278,190 TO 278,1 TO 1,1: RETURN
310 CALL MSGP,2,13,ROW,COL,0: RETURN
1000 IF SC > P1 THEN P1 = SC
1005 RETURN
1010 IF SC > P2 THEN P2 = SC
1015 RETURN
1020 IF SC > P3 THEN P3 = SC
1025 RETURN
4004 REM * PRACTICE TEXT *
4005 CALL MSGP,TXT,PTABLE,PNUM,ROW,COL,DI: GOSUB 413
0: GOSUB 4210: RETURN
4009 REM * INSTRUCTIONS *
410 T$ = STR$ (LEVEL)
415 GOSUB 4240: HPLOT 1,24 TO 278,24: CALL MSGP,TXT
,PTABLE,10,10,4,DI: HPLOT 1,172 TO 278,172: CALL
MSGP,PSTR,"Press <SPACE BAR> to go on",179,7: CALL
MSGP,PSTR,T$,10,33
418 CALL MSGP,TXT,PTABLE,25,36,2,DI: GOSUB 4130
420 IF LEVEL < 2 THEN PNUM = 11: ROW = 114: COL = 2: GOSUB
4005: CALL MSGP,TXT,PTABLE,12,40,2,DI: GOTO 4040
4209 GOSUB 4210
430 PNUM = 13: ROW = 45: COL = 2: GOSUB 4005: IF LEVEL
 = 3 THEN PNUM = 17: GOSUB 4005
435 PNUM = 14: GOSUB 4005: CALL MSGP,TXT,PTABLE,15,44
,2,DI
440 PNUM = 16: ROW = 100: GOSUB 4005
450 PNUM = 20: ROW = 44: COL = 2: GOSUB 4005: PNUM = 21
: GOSUB 4005: CALL MSGP,TXT,PTABLE,22,44,10,8: CALL
MSGP,TXT,PTABLE,23,90,2,DI: GOSUB 4130
460 CALL MSGP,1,0,90,160,1,38: PNUM = 24: ROW = 90: DI
 = 12: GOSUB 4005: DI = 16
480 GOSUB 160: CALL MSGP,TXT,PTABLE,18,44,3,DI: GOSUB
40: IF R$: = "Y" GOTO 4010
490 GOSUB 4210: CALL MSGP,TXT,PTABLE,19,70,4,DI: GOSUB
40: IF R$: = "Y" THEN MENU = 1
495 RETURN
499 REM * CONTINUE CUE FOR LEVEL 1 *
500 CALL MSGP,1,0,146,188,1,38: CALL MSGP,TXT,PTABLE
,2,164,7,DI: GOSUB 4130: RETURN
510 GOSUB 160: HPLOT 1,24 TO 278,24: HPLOT 1,144 TO
278,144: RETURN
520 T$ = "LEVEL " + STR$ (LEVEL) + " QUESTION ": CALL
MSGP,PSTR,T$,10,10: CALL MSGP,TXT,PTABLE,7,34,9,D
I: RETURN
529 REM * WAIT FOR SPACEBAR *
530 POKE -16368,0: GET R$: IF ASC (R$) < > 32 THEN
530 GOSUB 4130
532 RETURN
4135 REM * DISPLAY & PLAY MUSIC *
4140 CALL MSGP, SETUP, STAFF, TLNE, LCOL, RCOL, CLEF, KEY, MODE
4142 CALL MSGP, DR, STAFF, LCOL + 1, LCOL + 3
4144 CALL MSGP, DPLAY, QTABLE, QNUM, NVOICES, FWIDTH, FDIR
, LCOL + 4, SOFF, S1, S2, MUP, MLO, SBEET, PBARS, ACTIVC:
4145 IF NOPLAY = 1 GOTO 4148
4147 FOR PAUSE = 1 TO 500: NEXT
4148 RETURN
4150 GOSUB 160: HPLOT 1, 14 TO 278, 14: HPLOT 1, 130 TO
278, 130: T$ = "LEVEL " + STR$(LEVEL) + " QUESTION": CALL MSGP, PSTR, T$, 4, 10: HPLOT 1, 162 TO 2
78, 162: RETURN
4155 CALL MSGP, TXT, PTABLE, 19, 134, 2, 8: CALL MSGP, 2, 12,
142, 17, 0: CALL MSGP, 2, 14, 142, 22, 0: CALL MSGP, TXT
, PTABLE, 20, 176, 9, 8: ROW = 168: COL = 2: GOSUB 310:
4158 :
4159 REM * GET & CHECK STUDENT ANSWER & PREPARE RES
PONSE *
4160 IF Q < 6 THEN C$ = "E": ANAL$ = "EQUIVALENT."
4165 IF Q > 5 THEN C$ = "N": ANAL$ = "NOT EQUIVALENT.
"
4175 IF A$ = C$ THEN MESS$ = "Correct. They are " +
ANAL$: SC = SC + 1
4180 IF A$ < > C$ THEN MESS$ = "Sorry. They are " +
ANAL$
4188 RETURN
4189 :
4190 TB = INT (21.5 - (LEN (MESS$) / 2))
4191 CALL MSGP, PSTR, MESS$, 128, TB: RETURN
4192 :
4194 REM * CONTINUE CUE FOR LEVELS 2 & 3 *
4195 CALL MSGP, 1, 0, 146, 188, 1, 38: CALL MSGP, TXT, PTABLE
, 1, 156, 7, DI: CALL MSGP, TXT, PTABLE, 2, 172, 7, DI
4196 POKE -16368, 0: GET S$: IF ASC (S$) < > 32 AND
ASC (S$) < > 82 AND ASC (S$) < > 27 GOTO 419
6
4197 IF ASC (S$) = 27 THEN GOSUB 50: IF QUIT = 0 THEN
CALL MSGP, 1, 0, 127, 137, 1, 38: GOTO 4196
419B RETURN
4199 REM * CLEAR CUE & QUESTION FIELDS *
4200 CALL MSGP, 1, 0, 146, 188, 1, 38: CALL MSGP, 1, 0, 44, 14
3, 1, 38: RETURN
4209 REM * CLEAR INSTRUCTION FIELD *
4210 CALL MSGP, 1, 0, 25, 170, 1, 38: RETURN
4219 REM * CLEAR CUE & PRINT LISTEN MESS *
4220 CALL MSGP, 1, 0, 146, 188, 1, 38: IF LEVEL = 1 THEN CALL
MSGP, TXT, PTABLE, 9, 166, 9, DI: GOTO 4225
CALL MSGP, TXT, PTBLE, 3, 160, 9, DI: CALL MSGP, TXT, PTBLE, 4, 172, 9, DI
4225 RETURN
4229 REM * CLEAR QUESTION FIELD *
4230 FOR PAUSE = 1 TO 200: NEXT: CALL MSGP, 1, 0, 44, 1
431, 38: RETURN
4235 RETURN
4239 REM * CLEAR ALL BUT PLAIN BORDER *
4240 CALL MSGP, 1, 0, 2, 189, 1, 38: RETURN
4249 REM * RANDOMIZER *
4250 LAST = MAX: FIRST = 1
4255 FOR I = 1 TO MAX: NUMO(I) = I: NEXT
4260 FOR I = 1 TO MAX
4265 LOC = INT (RND (1) * LAST) + 1: TEMP = NUMQ(LOC): NUMQ(LAST) = NUMQ(LOC): NUMQ(LAST) = TEMP: LAST = (LAST - 1) + MAX * (LAST = 1)
4270 NEXT I
4275 RETURN
4280 MAX = 5: GOSUB 4250: FOR I = 1 TO 5: X(I) = NUMO(I): NEXT I: RETURN
4290 Y = INT (RND (1) * 6) + 1: IF Y = Y THEN GOTO 4290
4292 RETURN
4299 REM * PRACTICE MENU *
4300 GOSUB 160: CALL MSGP, TXT, PTBLE, 5, 24, 6, DI: HPLOT 7, 136 TO 272, 136: CALL MSGP, TXT, PTBLE, 6, 152, 3, DI
4310 GET M$: IF (ASC(M$) < 49 OR ASC(M$) > 51) AND ASC(M$) < 27 GOTO 4310
4320 IF ASC(M$) = 27 THEN EXIT = 1: GOTO 4335
4330 LEVEL = VAL(M$)
4335 RETURN
4340 REM * SET PARAMETERS & CALL MUSIC A *
4350 STAFF = 1: LCOL = 4: RCOL = 18: S1 = 0: S2 = 0: QNUM = QNUM(Q * 2 - 1): GOSUB 4140: RETURN
4359 REM * SET PARAMETERS & CALL MUSIC B *
4360 STAFF = 0: LCOL = 22: RCOL = 36: S1 = 0: S2 = 0: QNUM = QNUM(Q * 2): GOSUB 4140: RETURN
4399 REM * QWRITER *
4400 GOSUB 4280: FOR I = 1 TO 5: TYPE(I) = X(I): NEXT I
4410 INDEX = 1; FOR ELOOP = 1 TO 5
4412 Y1 = 0: GOSUB 4290: Y1 = Y: QNUM(INDEX) = QMTRIX(X(ELOOP), Y): IF INDEX = 1 GOTO 4420
4415 FOUND = 0: FOR I = 1 TO (INDEX - 1): IF QNUM(INDEX) = QNUM(I) THEN FOUND = 1: I = (INDEX - 1)
4418 NEXT I: IF FOUND = 1 GOTO 4412
4420 GOSUB 4290: QNUM(INDEX + 1) = QMTRIX(X(ELOOP), Y)
4430 INDEX = INDEX + 2: NEXT ELOOP
INDEX = 11: GOSUB 4280: FOR I = 1 TO 5: XX(I) = N
Umo(I): NEXT I: GOSUB 4230: FOR I = 1 TO 5: T2YPE
(I) = X(I): NEXT I
4450 FOR NLOOP = 1 TO 5
4452 GOSUB 4290: QNUM(INDEX) = OMTRIX(X(NLOOP), Y)
4455 FOUND = 0: FOR I = 1 TO (INDEX - 1): IF QNUM(INDEX) = QNUM(I) THEN FOUND = 1: I = INDEX - 1
4457 NEXT I: IF FOUND = 1 GOTO 4452
4458 GOSUB 4290: INDEX = 11: GOSUB 4280: FOR I = 1 TO 5: XX(I) = X(NLOOP) THEN CNTR = 5: GOTO 4490
4460 C = 1: GOTO 4490
4462 NEXT NLOOP
4522 IF ASC (S$) = 27 THEN GOSUB 50: IF QUIT = 0 THEN CALL MSGP,1,0,127,137,1,38: GOTO 4520
4525 RETURN
4529 REM * VECTOR ANALYSIS *
4530 V$ = "<111000>": RETURN
4532 V$ = "<101100>": RETURN
4534 V$ = "<100110>": RETURN
4536 V$ = "<100011>": RETURN
4538 V$ = "<011010>": RETURN
4550 ON T2YPE(Q) GOSUB 4530,4532,4534,4536,4538: CALL MSGP,PSTR,V$,106,6: CALL MSGP,PSTR,V$,106,24: RETURN
4560 ON T2YPE(Q - 5) GOSUB 4530,4532,4534,4536,4538: CALL MSGP,PSTR,V$,106,6: ON T2YPE(Q - 5) GOSUB 4530,4532,4534,4536,4538: CALL MSGP,PSTR,V$,106,24: RETURN
4599 REM * QUESTION DRIVER *
4600 GOSUB 4110: REM DRAW BORDER
4605 GOSUB 4120: REM CALL HEADING
4610 MOPLAY = 0: QUIT = 0: SC = 0
4635 IF 0LOOP = 10 THEN CALL MSGP,PSTR,"10",10,29: GOTO 4650
4636 CALL MSGP,2,0LOOP + 48,10,29,0
4650 Q = 0 (0LOOP)
4660 GOSUB 4220: REM CLEAR CUE & PRINT LISTEN MES
4662  IF LEVEL = 1 THEN NOPLAY = 1: GOSUB 4350: GOSUB 4360: GOSUB 4520: IF QUIT = 1 THEN QLOOP = 10: GOTO 4745
4663  IF LEVEL = 1 GOTO 4715
4664  REM * PLAY SET 1 OR 2 OR GOTO ANSWER *
4665  FST = 0: SND = 0
4667  POKE -16368,0: GET S$: S = ASC (S$): IF S < 2
4668  7 OR (S > 27 AND S < 49) OR (S > 50 AND S < 69) OR
4669  (S > 69 AND S < 78) OR S > 78 THEN 4670
4670  CALL MSGP,1,0,127,137,1,38: REM CLEARS MESSAGE AREA
4671  IF S = 27 THEN GOSUB 50: IF QUIT = 0 THEN CALL
4672  MSGP,1,0,127,137,1,38: GOTO 4670
4673  IF QUIT = 1 THEN QLOOP = 10: GOTO 4745
4674  IF S$ = "1" THEN FST = FST + 1
4675  IF S$ = "2" THEN SND = SND + 1
4676  IF (S$ = "E" OR S$ = "N") AND (FST = 0 OR SND = 0) THEN CALL MSGP,FSTR,"Listen to BOTH sets before answering",128,2: GOTO 4670
4677  IF S$ = "E" OR S$ = "N" THEN GOTO 4715
4678  ON VAL (S$) GOSUB 4350,4360
4679  IF LEVEL = 3 THEN GOSUB 4250
4680  GOTO 4670
4681  A$ = S$: GOSUB 4160
4682  CALL POS/NEG MESSAGE
4683  GOSUB 4190: REM CALL POS/NEG MESSAGE
4684  IF LEVEL = 3 THEN NOPLAY = 1: GOSUB 4350: GOSUB 4360: NOPLAY = 0
4685  IF S < 6 THEN GOSUB 4550: GOTO 4728
4686  GOSUB 4560
4687  IF LEVEL = 1 THEN GOSUB 4100: GOTO 4740
4688  GOSUB 4195: REM CLEAR BOTTOM & WAIT
4689  IF QUIT = 1 THEN QLOOP = 10: GOTO 4745
4690  IF S$ = "R" THEN GOSUB 4350: FOR I = 1 TO 500:
4691  NEXT : GOSUB 4360: GOTO 4730
4692  NEXT QLOOP
4693  GOTO QLOOP
4694  IF QUIT = 1 THEN SC = 0
4695  ON LEVEL GOSUB 1000,1010,1020
4696  RETURN
4697  10000 GOSUB 60000
4698  10010 EXIT = 0: GOSUB 4300: IF EXIT = 1 GOTO 10090
4699  10020 GOSUB 4240: CALL MSGP,TXT,PTABLE,9,90,3,DI: GOSUB 4190: IF R$ = "Y" THEN MENU = 0: GOSUB 4010: IF MENU = 1 GOTO 10010: REM INSTRUCTIONS
4700  10030 GOSUB 4210: CALL MSGP,FSTR,"One moment please, while I write",90,4: CALL MSGP,FSTR,"your questions...",92,11
4701  10040 GOSUB 4400: GOSUB 4600: PR = PR + 1: GOTO 10010
10090 POKE 772,PR: POKE 773,P1: POKE 774,P2: POKE 775,P3: CALL MSGP,0: GOSUB 35: PRINT: PRINT CHR$(4);"RUN MENU"
10099 END

60000 PRINT: PRINT CHR$(4);"BLOAD PRACTEXT4.ASM": PRINT: PRINT CHR$(4);"BLOAD PRMUS2.ASM"
D§ = CHR$(13) + CHR$(4)
60025 P1 = PEEK (773):P2 = PEEK (774):P3 = PEEK (775)
60030 TLNE = 64:CLEF = 0:MODE = 0:KEY = 17:NVOICES = 1:FWIDTH = 3:FDUR = 64:SOFF = 0:MUP = 3:MLO = 64
SBEET = 1:PBARS = 0:TEMPO = 50:ACTIVC = 1
60040 DIM QNUM(20):C = 1: FOR X = 1 TO 5: FOR Y = 1 TO 6:QMTRIX(X,Y) = C:C = C + 1: NEXT Y: NEXT X: RETURN

63000 HOME: TEXT:ER = PEEK (222): VTAB 10: CALL 5
4915
63010 IF ER = 20 THEN PRINT "PLEASE DON'T PRESS THE RESET BUTTON!": GOTO 63700
63020 IF ER = 8 THEN PRINT "IS THE DISK DRIVE DOOR CLOSED?"
63700 GOSUB 60: POKE 216,0: GOTO 10010
APPENDIX F

PET TRIALS

Standard Target SC Lure PI Lure

Set Type 3-2

1.1

1.2

1.3

1.4

1.5

The numbers to the left of the examples indicate the set-type number and the target-type number.
Set Type 3-3

2.1

2.2

2.3

2.4

2.5

Set Type 3-4

3.1

3.2

3.3
Set Type 3-5

4.1

4.2

4.3

4.4

4.5

Set Type 3-7

5.1
APPENDIX G

PET2 TRIALS

Standard  Target  II Lure  PI Lure

Set Type 3-2

1.1

1.2

1.3

1.4

1.5

Set Type 3-3

2.1

208
Set Type 3-4
Set Type 3-5

4.1

4.2

4.3

4.4

4.5

Set Type 3-7

5.1

5.2

5.3
5.4
\[ \text{Diagram} \]

5.5
\[ \text{Diagram} \]
APPENDIX H

PROGRAM LISTING FOR PERCEPTION OF EQUIVALENCE TEST

1 REM *** PET2.1 ***
3 ONERR GOTO 63000
6 DATA 32,234,3,162,2,173,9,224,201,76,240,7,202,15
7,128,192,16,243,2,162,20,76,18,212
7 FOR L100P = 952 TO 975: READ TEMP: POKE L100P,TEMP
8 NEXT L100P
8 TEMP = INT (952 / 256): POKE 1010,952 - TEMP * 256
9: POKE 1011,TEMP; IF PEEK (-3) = 250 THEN CALL
10 HIMEM: 16384: GOTO 10010
34 REM * ONE MOMENT PLEASE *
35 CALL MSGF',0: CALL MSGP,PSTR,MOM*,90,11: RETURN
39 REM * GET "Y" OR "N" *
40 POKE -16368,0: GET R$: IF ASC (R$) < > 78 AND
41 ASC (R$) < > 89 THEN 40
45 RETURN
50 POKE -16368,0: GET S$: IF ASC (S$) < > 21 GOTO
55 50
52 RETURN
60 VTAB 22: PRINT "PRESS <SPACE BAR> TO CONTINUE": GOSUB
61 230: RETURN
70 VTAB 20: PRINT "TO THE LAB MONITOR ONLY:"; PRINT
80 : PRINT "PRESS <SPACE BAR> FOR INSTRUCTIONS": GOSUB
81 230: RETURN
99 REM * DISPLAY TEXT *
100 CALL MSGP,TXT,TTBLE,TNUM,ROW,COL,DI: RETURN
119 REM * CLEAR QUESTION NO. AREA *
120 CALL MSGP,1,0,25,50,2,37: RETURN
129 REM * CLEAR CUE AREA *
130 CALL MSGP,1,0,153,189,1,38: RETURN
139 REM * TITLE BORDER & TITLE *
140 HPLLOT 1,24 TO 278,24: GOSUB 100: RETURN
149 REM * QUESTION BORDER *
150 GOSUB 290: HPLLOT 1,152 TO 278,152: RETURN
160 TNUM = 8:ROW = 167:COL = 2: GOSUB 100: RETURN : REM
170 GOSUB 150:T$ = "Use " + CHR$ (12) + " or " + CHR$ (14) + " to move the arrow (" + CHR$ (13) + ")"
180 : CALL MSGP,PSTR,T$,161,3: CALL MSGP,PSTR,"over
190 the answer & press <SPACE BAR>",173,3

212
172 ROW = 90: COL = 2: GOSUB 310: RETURN : REM QCUE2 & ARROW
179 REM * PAGE BORDER WITH CUE LINE *
180 CALL MSGP,0: HGR2: HCOLOR = 7: HPLT 1,1 TO 1,19
   0 TO 278,190 TO 278,1 TO 1,1: HPLT 1,172 TO 278,
   172:TNUM = 0: ROW = 178: COL = 7: GOSUB 100: RETURN
189 REM * SETUP & PLAY *
190 CALL MSGP,SETUP,STAFF,TLNE,LCOL,RCOL,CLEF,KEY,MODE:
   CALL MSGP,PLAY,QTBLE,SNUM,NVOCIES,TMPO,WAVTB
   LE,SOFF,ACTIVC
192 RETURN
199 REM * CHECK ANSWER CHOICE *
200 FOR L300P = 1 TO C
202 IF S$ = AC$(L300P) THEN FOUND = 1: L300P = C
205 NEXT L300P: RETURN
209 REM * GET 1,2 OR 3 *
210 POKE -16368,0: GET S$: IF ASC(S$) < 49 OR ASC
   (S$) > 51 THEN GOTO 210
215 RETURN
219 REM * WAIT FOR <SPACE> THEN CLEAR PAGE SPACE *
220 GOSUB 230
225 CALL MSGP,1,0,30,170,1,38: RETURN
229 REM *** WAIT FOR <SPACE BAR> THEN RETURN ***
230 POKE -16368,0: GET S$: IF ASC(S$) < > 32 THEN
235 RETURN
239 REM * CLEAR PAGE SPACE *
240 CALL MSGP,1,0,30,170,1,38: RETURN
249 REM * CLEAR QUESTION INSTRUCTION SPACE *
250 CALL MSGP,1,0,120,150,1,38: RETURN
259 REM * NEXT QUESTION *
260 CALL MSGP,TXT,TTBLE,10,168,2,DI: RETURN
289 REM * PLAIN BORDER *
290 CALL MSGP,0: HPLT 1,1 TO 1,190 TO 278,190 TO 278,
   1,1 TO 1,1: RETURN
299 REM * GET ARROW POSITION *
300 GOTO 370
310 CALL MSGP,2,13,ROW,COL,0: RETURN
320 CALL MSGP,2,13,ROW,COL,1: RETURN
330 GOSUB 320:N = N + 1: IF N > MAX THEN N = MAX
340 COL = (N - 1) * 10 + 9: GOSUB 310: RETURN
350 GOSUB 320:N = N - 1: IF N < 1 THEN N = 1
360 COL = (N - 1) * 10 + 9: GOSUB 310: RETURN
370 N = 1: COL = (N - 1) * 10 + 9: GOSUB 310
375 POKE -16368,0: GET R$
380 R = ASC(R$): IF R < > 32 AND R < > 21 AND R <
   > 8 THEN GOTO 375
385 IF R = 21 THEN GOSUB 330
390 IF R = 8 THEN GOSUB 350
395 IF R = 32 THEN GOSUB 320: RETURN
397 GOTO 375
399 REM * QUESTION PAGE LAYOUT *
400 CALL MSGP,PSTR,"Original",70,16: RETURN
405 CALL MSGP,TXT,TTBLE,7,110,7,DI: RETURN
410 CALL MSGP,1,1,108,118,6,12: RETURN
420 CALL MSGP,1,1,108,118,16,22: RETURN
430 CALL MSGP,1,1,108,118,26,32: RETURN
499 REM * PLAY ROUTINES *
500 CALL MSGP,1,1,68,78,15,24:SNUM = OSET: GOSUB 190
510 GOSUB 410: GOSUB 190: GOSUB 410: RETURN
520 GOSUB 420: GOSUB 190: GOSUB 420: RETURN
530 GOSUB 430: GOSUB 190: GOSUB 430: RETURN
699 REM * RANDOMIZER *
700 LAST = MAX:FIRST = 1
710 FOR I = 1 TO MAX:NUMQ(I) = I: NEXT
720 FOR I = 1 TO MAX
730 LOC = INT ((RND (1) * LAST) + 1):TEMP = NUMQ(LOC)
735 NUMQ(LOC) = NUMQ(LAST):NUMQ(LAST) = Temp:LAST = 
740 NEXT I: RETURN
750 LAST = MAX:FIRST = 1
760 FOR I = 1 TO 13:NUMARRAY(I) = I: NEXT
770 FOR I = 1 TO 13
780 LOC = INT (RND (1) * LAST) + 1:KNUM = NUMARRAY( 
785 LOC):Temp = NUMARRAY(LOC):NUMARRAY(LOC) = NUMARR
790 NEXT I: RETURN
999 REM *** QUESTION LOOP ***
1000 GOSUB 150:TNUM = 5:ROW = 10:COL = 5: GOSUB 140
1002 GOSUB 400: GOSUB 405
1010 FOR QLOOP = BEG TO 25
1015 GOSUB 160
1020 OSET = (TYPE(QLOOP) - 1) * 16 + 1:TARG = OSET + 2 + TARG(QLOOP):KEY = KEY(TYPE(QLOOP),TARG(QLOOP) )
1030 CLEF = 0
1035 CH$ = "QUESTION " + STR$(QLOOP): CALL MSGP,PSTR
1040 FOR CHOICE = 1 TO 3
1050 GOSUB 230: GOSUB 500: REM PLAY ORIGINAL
1060 CH$ = AMTRIX*(QLOOP,CHOICE): IF CH$ = "T" THEN S
1070 NUM = TARG
1075 IF CH$ = "I" THEN SNUM = OSET + 1
1080 IF CH$ = "P" THEN SNUM = OSET + 2
1085 GOSUB 230: ON CHOICE GOSUB 510,520,530
1090 NEXT CHOICE
1095 GOSUB 170
1100 GOSUB 320:MAX = 3: GOSUB 300
215

IF AMTRIX#(QLOOP,N) = "T" THEN TSC = TSC + 1
IF AMTRIX#(QLOOP,N) = "I" THEN ISC = ISC + 1
IF AMTRIX#(QLOOP,N) = "P" THEN PISC = PISC + 1
GOSUB 130
IF QLOOP = 25 THEN CALL MSGP,PSTR,"Press <SPACE> to see your scores",160,2: GOTO 1140
GOSUB 260
GOSUB 230: GOSUB 120: GOSUB 130
NEXT QLOOP
1999 RETURN

REM *** MAIN DRIVER ***
GOSUB 60010
HGR2 : HCOLOR = 7
GOSUB 290: CALL MSGP,PSTR,"One moment please",80,11: CALL MSGP,PSTR,"while I write your questions...",92,5: GOSUB 55000: THRU = 1
BEG = 1
GOSUB 1000: THRU = 2: REM QUESTION LOOP
GOSUB 35
GOSUB 20010: THRU = 3: REM WRITE TO FILE
GOSUB 30000: REM CLOSING
T$ = "GOODBYE, " + F$ + "+!": CALL MSGP,PSTR,T$,154,2
19999 END

REM *** FILE WRITER ***
TEMP$ = "" N$ = F$ + " ": L$ = NAME$ = LEFT$ (N$ + TEMP$,26)
AN$ = "": FOR I = 1 TO 5: FOR J = 1 TO 5: AN$ = AN$ + SA$(I,J): NEXT J: NEXT I
TYPE$ = "": FOR I = 1 TO 25: TYPE$ = TYPE$ + STR$(TYPE(I)): NEXT I
TARG$ = "": FOR I = 1 TO 25: TARG$ = TARG$ + STR$(TARG(I)): NEXT I
FINAL$ = NAME$ + AN$ + TYPE$ + TARG$
D$ = CHR$(13) + CHR$(4)
PRINT D$;"OPEN PETFILE,L105"
PRINT D$;"READ PETFILE,RO"
INPUT REX
REX = REX + 1
PRINT D$;"WRITE PETFILE,R";REX
PRINT D$;"WRITE PETFILE,R";
PRINT CHR$(4): REM TERMINATE WRITE
PRINT D$;"CLOSE PETFILE"
20190 RETURN

REM * SCORES & CLOSING *
30000 \texttt{GOSUB 180: \texttt{TNUM = 11: ROW = 10: COL = 10: GOSUB 100: HPLLOT 1,24 TO 278,24: CALL MSGP,TXT,TTBLE,9,52,2,16: GOSUB 220}}
30005 \texttt{CALL MSGP,TXT,TTBLE,24,40,2,12: GOSUB 220}
30010 \texttt{HPLLOT 5,28 TO 5,168 TO 274,168 TO 274,28 TO 5,28: CALL MSGP,TXT,TTBLE,21,50,5,16: HPLLOT 5,79 TO 274,79}
30020 \texttt{CALL MSGP,PSTR, STR\# \texttt{(TSC \times 4) + \textasciitilde "\%",50,31}}
30030 \texttt{CALL MSGP,PSTR, STR\# \texttt{(IISC \times 4) + \textasciitilde "\%",114,31: CALL MSGP,PSTR, STR\# \texttt{(PISC \times 4) + \textasciitilde "\%",130,31: GOSUB 220}}
30050 \texttt{GOSUB 290: CALL MSGP,TXT,TTBLE,22,40,2,12}
39999 \texttt{RETURN}
49999 \texttt{REM * QUESTION RANDOMIZER *}
50000 \texttt{Y = 0: FOUND = 0: IF USED \neq 5 GOTO 50050}
50010 \texttt{FOR HUNT = \textasciitilde \texttt{(USED + 1)} TO 5}
50020 \texttt{IF TMTRIX \texttt{(R,NUMQ \texttt{(HUNT)}) < \textasciitilde 99 THEN Y = NUMQ \texttt{(HUNT): NUMQ \texttt{(HUNT)} = NUMQ \texttt{(USED): NUMQ \texttt{(USED)} = Y:HUNT = 5}}}
50030 \texttt{NEXT HUNT}
50040 \texttt{IF Y \neq 0 \texttt{THEN GOTO 50290}
50049 \texttt{REM * 2-WAY SWITCH *}
50050 \texttt{KOUNT = 0: FOR HUNT = 1 TO 5: IF TMTRIX \texttt{(R,HUNT)} \neq 99 THEN KOUNT = KOUNT + 1:Y \texttt{(KOUNT) = HUNT}}
50060 \texttt{NEXT HUNT}
50070 \texttt{FOR L200P = 1 TO KOUNT}
50080 \texttt{FOR L100P = (P + 1) TO (P + USED - 1): IF TARG \texttt{(L100P)} = Y \texttt{(L200P) THEN INDEX \texttt{(L200P)} = L100P:L100P = P + USED - 1}}
50090 \texttt{IF TMTRIX \texttt{(R,L200P),C} = 99 GOTO 50110}
50095 \texttt{IF TMTRIX \texttt{(X(L200P),C) = 99 GOTO 50110}
50100 \texttt{TARG \texttt{(INDEX \texttt{(L200P)}) = C: NUMQ \texttt{(USED)} = Y \texttt{(L200P)}: NUMQ \texttt{(INDEX \texttt{(L200P)} - P) = C: TMTRIX \texttt{(X(L200P),Y \texttt{(L200P)}) = Y \texttt{(L200P)}}: TMTRIX \texttt{(X(L200P),C} = 99: TMTRIX \texttt{(R,Y \texttt{(L200P)}) = 99: TARG \texttt{(P + USED)} = Y \texttt{(L200P)}: L200P = \texttt{KOUNT: FOUND = 1}}}
50110 \texttt{NEXT L200P: IF FOUND = 1 GOTO 50290}
50120 \texttt{REM * 3-WAY SWITCH *}
50130 \texttt{FOR L400P = 1 TO KOUNT:X = X \texttt{(L400P)}: Y = Y \texttt{(L400P)}: INDEX = INDEX \texttt{(L400P): FULL = 0: OK = 0}}
50140 \texttt{FOR L500P = 1 TO (5 - (P / 5 + 1))}
50150 \texttt{IF HUNT = 1 TO 5: IF TMTRIX \texttt{(X,HUNT)} \neq 99 THEN YY \texttt{(L500P) = HUNT}}
50160 \texttt{NEXT HUNT}
50170 \texttt{FOR HUNT = \textasciitilde \texttt{(P + 1)} TO (P + USED - 1): IF TARG \texttt{(HUNT)} = YY \texttt{(L500P) THEN FULL = 1}}
50180 \texttt{NEXT HUNT}
50190 \texttt{IF FULL \neq 0 GOTO 50240}
50200 TARG(P + USED) = Y: TMTRIX(R, Y) = 99: NUMQ(USED) =
Y: TARG(INDEX) = YY(L50OP): NUMQ(INDEX - P) = YY(L
500P): TMTRIX(X, Y) = Y: TMTRIX(X, YY(L50OP)) = 99
50210 FOR HUNT = 1 TO 5: IF NUMQ(HUNT) = YY(L50OP) THEN
NUMQ(HUNT) = C
50220 NEXT HUNT
50230 L50OP = S - (P / 5 + 1): L400P = KOUNT: OK = 1
50240 NEXT L500P
50250 NEXT L400P
50260 IF OK = 1 GOTO 50290
50270 REM * LAST RESORT *
50280 LR = 1: FOR L600P = (P + 1) TO (P + USED - 1): T
MTRIX(TYPE(L600P), TARG(L600P)) = TARG(L600P): NEXT
L600P
50290 RETURN
55000 MAX = 5
55010 FOR RLOOP = 1 TO 5
55020 GOSUB 700
55030 IF RLOOP < 2 GOTO 55050
55040 IF NUMQ(1) = TYPE((RLOOP - 1) * 5) GOTO 55020
55050 FOR I = 1 TO 5: TYPE((RLOOP - 1) * 5 + I) = NUMQ(I): NEXT I
55060 NEXT RLOOP
55070 MAX = 5: GOSUB 700: FOR I = 1 TO 5: TARG(I) = NUMQ(I): TMTRIX(TYPE(I), TARG(I)) = 99: NEXT I
55080 FOR RLOOP = 1 TO 3: MAX = 5: GOSUB 700
55090 FOR I = 1 TO 5
55100 USED = 0: FOUND = 0: LR = 0: IF TMTRIX(TYPE(RLOOP * 5 + I), NUMQ(I)) = 99 THEN USED = I: P = RLOOP *
5
55110 IF FOUND = 1 GOTO 55140
55120 IF LR = 1 THEN I = 5: RLOOP = RLOOP - 1: GOTO 5
5140
55130 TARG(RLOOP * 5 + I) = NUMQ(I): TMTRIX(TYPE(RLOOP * 5 + I), NUMQ(I)) = 99
55140 NEXT I: NEXT RLOOP
55150 FOR I = 1 TO 5: FOR J = 1 TO 5: IF TMTRIX(TYPE(20 + I), J) < > 99 THEN TARG(20 + I) = TMTRIX(TYPE(20 + I), J): J = 5
55160 NEXT J: NEXT I
55170 RETURN
60000 REM *** BINARY FILES & CONSTANTS ***
60010 MSGP = 24576: PSTR = 3: TXT = 4: MOM$ = "One momen
t please...": TTABLE = 33024: QTABLE = 36864: DI = 16
: SETUP = 5: PLAY = 12: WAVTABLE = 128: GFIX = 2
60015 STAFF = 0: TLNE = 20: LCOL = 2: RCOL = 36: KEY = 17
: MODE = 0: NVOCIES = 1: ACTIVC = 1: TMPD = 50: SOFF =
0: TSC = 0: IISC = 0: PISC = 0
218

60020 TEMP = PEEK (768): F$ = "": FOR LOOP = 1 TO TEM
   P:F$ = F$ + CHR$ ( PEEK (769 + LOOP)): NEXT LOOP
   P:TEMP = PEEK (769): L$ = "": FOR LOOP = 1 TO TE
   MP:L$ = L$ + CHR$ ( PEEK (769 + LEN (F$) + LOOP)
   P): NEXT LOOP

   KEY(5,5)
60030 DIM AMTRIX$(25,3): DIM SAs(5,5)
60040 FOR J = 1 TO 5
60050 FOR J = 1 TO 5
60060 TMTRIX(I,J) = J
60070 NEXT J
60080 NEXT I
60090 FOR I = 1 TO 5
60100 FOR J = 1 TO 3
60110 READ AMTRIX$(I,J)
60120 NEXT J
60130 NEXT I
60140 REM * ANSWER CHOICE INFO *
60200 DATA P,I,T
60210 DATA T,P,I
60220 DATA T,I,P
60230 DATA P,T,I
60240 DATA I,P,T
60250 DATA P,T,I
60260 DATA T,I,P
60270 DATA I,P,T
60280 DATA I,T,P
60290 DATA P,I,T
60300 FOR I = 1 TO 5: FOR J = 1 TO 5: READ KEY(I,J): NEXT J: NEXT I
60310 DATA 18,24,16,21,13
60320 DATA 16,10,18,12,20
60330 DATA 12,18,10,16,21
60340 DATA 19,11,16,21,13
60350 DATA 21,16,10,18,13
REM DOS & SYSTEM ERRORS
IF ER = 255 THEN PRINT "PLEASE DON'T TYPE <CONTROL> C AGAIN!": GOTO 63700
IF ER = 4 THEN PRINT "I AM UNABLE TO RECORD YOUR VISIT TODAY."
PRINT "PLEASE TELL THE LAB MONITOR THAT THIS";
PRINT "DISKETTE IS 'WRITE-PROTECTED.'": GOSUB 70

IF ER = 4 THEN HOME: VTAB 10: PRINT "1. REMOVE DISK FROM DRIVE"
PRINT "2. TAKE OFF WRITE-PROTECTION STICKER"
PRINT "3. PLACE DISK BACK IN DRIVE": GOTO 63700

IF ER = 5 THEN PRINT "THERE IS SOMETHING WRONG WITH MY FILE."
PRINT "PLEASE TELL THE LAB MONITOR."; GOTO 63700

IF ER = 9 THEN PRINT "MY FILE IS FULL.";
PRINT "PLEASE ASK THE LAB MONITOR FOR HELP."
GOSUB 70

IF ER = 9 THEN HOME: VTAB 10: PRINT "1. REMOVE DISK FROM DRIVE"
PRINT "2. PUT IN A DIFFERENT COPY OF PAT DISK": GOTO 63700

IF ER = 8 THEN PRINT "IS THE DISK DOOR CLOSED ?": GOTO 63700

IF ER = 20 THEN PRINT "PLEASE DON'T PRESS THE RESET BUTTON!": GOTO 63700

GOSUB 60: HGR2: POKE 216,0: IF THRU = 1 THEN
BEG = TSC + PISC + SCSC + 1: IF BEG = 26 THEN BEG = 25

IF THRU = 0 THEN GOTO 10050
ON THRU GOTO 10060,10125,19999
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