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ABSTRACT

For this study, five hypotheses were formulated stating that ability to identify melodic intervals during music dictation is not affected by (1) the differences in timbre, (2) the use of familiar or unfamiliar timbres (MAJOR), (3) formal ear training experience (FETE), or (4) playing/performing experience on an instrument (PPEM), and (5) that there is no significant interaction between PPEM and FETE. Two hundred and twenty college and university subjects were tested, using an author written test of melodic interval identification. Melodic intervals were presented in random order by six instruments: clarinet, trumpet, piano, violin, xylophone, and synthesizer (sine waveform). Each instrument played 12 randomly assorted melodic intervals, based on C4 and not exceeding one octave. Results showed that FETE, PPEM, and MAJOR all affected subjects' scores on intervals presented with different timbres. There was no significant interaction between PPEM and FETE. (Author/RM)

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THE EFFECT OF DIFFERENT MUSICAL TIMBRES ON STUDENTS' IDENTIFICATION OF MELODIC INTERVALS

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REPORTS

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THE EFFECT OF DIFFERENT MUSICAL TIMBRES ON STUDENTS' IDENTIFICATION OF MELODIC INTERVALS

by

DALLAS EDWARD HINTON

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

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Department of Visual and Performing Arts in Education
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We accept this thesis as conforming

to the required standard

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ABSTRACT

Musical timbre, an attribute of musical tone, is seldom considered to play an important part in pitch identification. College/university music students routinely are given ear training, i.e., are taught to identify intervals and chords from dictation, as part of their regular harmony or theory classes.

For this exploratory study five hypotheses were formulated, stating that ability to identify melodic intervals during music dictation is not affected by differences in timbre, the use of familiar or unfamiliar timbres (MAJOR), formal ear training experience (FETE), or playing/performing experience on an instrument (PPEM), and that there is no significant interaction between PPEM and FETE.

Melodic intervals were presented in random order by six instruments: clarinet, trumpet, piano, violin, xylophone, and synthesizer (sine waveform). Each instrument played twelve randomly assorted melodic intervals, based on C4 and not exceeding one octave.

The independent variables were MAJOR instrument, FETE, and PPEM. The dependent measures were the scores achieved on an author-written melodic interval dictation test closely resembling the "typical" ear training quiz used in many college/university music theory classes. A multivariate analysis of variance (MANOVA) was used for an analysis of PPEM (three

levels) compared with FETE (three levels). A second MANOVA analysis was used for MAJOR. Appropriate Scheffé post hoc analyses were carried out.

It was found that the amount of playing/performing experience affected subjects' scores on the dependent variables, but only for those subjects with more than ten years of PPEM. The amount of formal ear training experience also significantly affected subjects' scores, but there was no clear pattern discernible. Both PPEM and FETE interacted with the dependent variables to produce pairwise differences at various levels of each independent variable. No significant interaction between PPEM and FETE was found. There were statistically significant differences among the various levels of the declared MAJOR instruments, but no clear pattern was found. It was concluded that FETE, PPEM, and MAJOR all affected subjects' scores on intervals presented with different timbres.

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Chapter 1

DESCRIPTION OF THE STUDY AREA

Introduction to the Problem

Ear training has long been a part of traditional college music theory instruction. In 1942, Hindemith declared that the interval is ". . . the basic unit of musical instruction."[1] In 1949, he commented that

> The ability to follow musical dictation is not necessarily an index of the degree or quality of musical talent. . . .
> On the other hand it cannot be denied that the complete absence of such ability is at least an unfavorable indication of the state of a musician's knowledge. It is therefore necessary to develop it--whatever its amount or quality may be--to the utmost, just as all other parts of his gift must be developed.[2]

Some institutions include ear training in the music theory classes; others, however, teach these skills in separate classes on an intensive basis.[3] Ear training skills are often divided

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[1] Paul Hindemith, The Craft of Musical Composition, trans. Arthur Mendel (New York: Associated Music Publishers, 1942), Book I, p. 57.

[2] Paul Hindemith, Elementary Training for Musicians, 2nd ed. (New York: Associated Music Publishers, 1949), p. 181.

[3] For example, Berklee College of Music, Boston, Mass.; Northeastern University, Boston, Mass.; and Julliard School of Music, New York.

into two distinct aspects: visual (active), i. e. sight-singing from a written stimulus, and auditory (passive), i. e. attaching a label or designator to a heard stimulus.[4] During the early stages of "passive" training, students are required to listen to auditory stimuli and attach appropriate labels, e.g. minor triad, perfect fifth. In more advanced classes, students may be required to attach several labels involving musical notation of pitch, rhythm, and/or duration. Material may be presented melodically ascending, melodically descending, harmonically, or by a combination of these methods.[5]

At many institutions, ear training traditionally has meant listening to and singing with the piano as a means to learning identification of melodic and harmonic intervals. Gephardt, however, observed that:

> Nonpianist students often verbalize their belief that their dictation abilities might improve if the musical material were presented in a more familiar timbre--that of the instrument on which they themselves perform. In the course of presenting heard material, students are often observed "fingering," on a make-believe instrument, the notes of an interval or

[4] Paul J. Vander Gheynst, "The Effect of Timbre on Auditory-Visual Discrimination" (Ed. D. dissertation, University of Illinois, 1978); Donald L. Gephardt, "The Effects of Different Familiar and Unfamiliar Musical Timbres on Musical Melodic Dictation" (Ed.D. dissertation, Washington University, Missouri, 1978).

[5] A melodic interval is one in which the notes are played consecutively; an harmonic interval is one in which the notes are played simultaneously.

> melodic passage that they are asked to identify. . . . One can speculate that perhaps the student is trying to get the "feel" kinesthetically of performing the pitches that he/she is hearing.[6]

Another factor which may be operating is that of the student's experience of timbre changes within the range of a particular instrument. The clarinet, for example, has a particularly characteristic change of timbre in the throat register. A clarinetist may possibly be more sensitive to such timbre differences than are other musicians. Beyer found that performers are more sensitive to pitch variations produced by their own instruments, and has theorized that these subjects might be able to use timbre as a guide to pitch and interval identification.[7]

Many textbooks on ear training ignore the effect of timbre with statements such as:

> Any melody possesses at least three basic characteristics: . . . time, . . . pitch, . . . [and] timbre. Since this third characteristic of melody varies with the instrument on which a melody is performed, we shall ignore it and concern ourselves exclusively with rhythm and pitch.[8]

In the opinion of the author, and of many other music educators, insufficient attention has been paid to the effects of timbre on the perception of pitch.

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[6] Gephardt, p. 6.

[7] George Heydrick Beyer, "The Determination of Pitch Discrimination in High School Students with Musical Training" (M.A. thesis, California State University, 1977).

[8] William E. Thomson and Richard P. Delone, Introduction to Ear Training (California: Wadsworth Publishing, 1968), p.1.

As recently as 1978, Gephardt stated that:

> Although some current music educators, such as Spohn and Trythall, discount the importance of the connection between timbre and pitch perception, other psychophysicists and musicians have pointed out that there may be an important relation between the attributes.[9]

Gephardt's statement reinforces the opinion of Roederer:

> Whereas considerable research has been done on the perception of pitch and loudness of pure tones. . . much remains to be done in the study of the perception of quality or timbre of complex tones.[10]

The Problem

In this study, the main area of interest was the effect of instrumental timbre upon students' ability to perceive and describe melodic intervals.

This study attempted to explore possible answers to the following questions:

1) Do differences in timbre affect students' ability to identify melodic intervals during dictation?

2) Does the length of time that students have been training to identify melodic intervals have a relationship with a possible effect of familiarity of timbre, as measured by ability to identify melodic intervals?

3) Does the length of time that students have been playing their declared major instrument have a relationship with a possible effect of

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[9] Gephardt, p.86.

[10] Juan G. Roederer, Introduction to the Physics and Psychophysics of Music (London: The English Universities Press, 1973), p. 127.

familiarity of timbre, as measured by ability to identify melodic intervals?[11]

4) Does the use of familiar or unfamiliar timbre sources affect students' ability to identify melodic intervals?

Definition of Terms

Ear training. For the purposes of this study, the definition of ear training used by Shaw is accepted:

> . . . that branch of musical education which attempts to develop a positive awareness in the mind of the various phenomena which constitute the mere material of music, the chief of which are time and rhythmic relationships; pitch relationships, whether simultaneous or in succession; tonality and modulation. It is concerned with the mind rather than the fingers, and with terminology and the symbols of notation only so far as these relate to mental conceptions of musical sound.[12]

Formal Ear Training Experience (FETE). For the purposes of this study, FETE is defined as the number of months a subject has spent enrolled in a university level theory/harmony course. It was assumed that, at the institutions being used for this study, an average amount of ear training is done during routine classroom instruction.

Music dictation. For the purposes of this study, the

[11] In this study, the term "instrument" includes the voice.

[12] Grove's Dictionary of Music and Musicians, 5th ed. (1954), s.v. "Ear-training," by Harold Watkins Shaw.

definition of music dictation used by Gephardt and others is accepted:

> . . . music dictation is [a task] which requires the subject to reproduce, in exact musical notation using the commonly accepted symbols which designate musical pitch, . . . the heard musical material which is presented to the subject. . . . The term dictation refers to its common denotation by music theory instructors.[13]

Frequency. The physical property, frequency, is defined by Seashore and others as cycles per second (cps) and is perceived as pitch.[14]

Pitch. A musical pitch is defined for purposes of this study as being any of the frequencies normally used in the equal tempered scale using a standard tuning reference of A = 440 Hz. Pitches used in this study cover a one octave range from C4 to C5.[15]

Pure Tone. For purposes of this study, a pure tone is considered to be a tone that has no harmonics present.

Complex Tone. For purposes of this study, a complex tone is considered to be one that is produced by a sinusoidal wave, and

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[13] Gephardt, p. 18.

[14] After Carl E. Seashore, The Psychology of Musical Talent (Boston: Silver Burdett, 1919).

[15] The pitch notation used in this study is that adopted by the American Standards Association in 1960, as altered and used by The Instrumentalist and other journals. In this notation, C0 is 16.352 Hz, and is located four octaves below piano "middle C", designated as C4.

has several partials or harmonics forming an integral part of the sound.

Partial. For purposes of this study, a partial is considered to be one of the frequencies, other than the fundamental, present in a tone. A partial may or may not have a whole-number relationship to the fundamental; i.e. it may or may not be a multiple of the fundamental.[16]

Harmonics. For the purposes of this study, the definition used by Backus will be used:

> . . . the constituent partials must be related in a very simple way; their frequencies must be integral multiples . . . times the fundamental frequency of the vibration. . . . Partials related in this simple way are given a special name: they are called harmonics.[17]

Hertz (Hz). The term "Hertz" is an internationally used term meaning cycles per second, and is used as a measure of the frequency of a sound.

Cent. The term "cent" is a measure of pitch used for alterations of less than a semitone. There are 100 cents in each semitone.

Decibel (dB). A decibel is a measure of sound pressure level (SPL), and is calculated with the following formula:

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[16] After Arthur Benade, Fundamentals of Musical Acoustics (New York: Oxford University Press, 1976), p. 63.

[17] John Backus, The Acoustical Foundations of Music (New York: W. W. Norton, 1969), pp. 108-109.

$$L = 10 \text{ Log } I/I_o \qquad \text{(Equation 1)}$$

where I_o is the threshold of human hearing,
I is the sound intensity, and
L is the intensity level, measured in decibels (dB).[18]

> . . . the intensity level is a purely physical quantity. . . . In practice, direct measurement of the intensity of a sound wave is difficult. It is much easier to obtain the pressure amplitude of the sound. . . . The intensity of a sound wave progressing in one direction is proportional to the square of the sound pressure.[19]

Backus goes on to demonstrate that, from Equation 1:

$$L_p = 20 \text{ Log } P/P_o$$

where L_p is the sound pressure level, and
P is the Root Mean Square (RMS) sound pressure.

> The reference pressure P_o is the RMS sound pressure corresponding to the threshold intensity and has the value 2×10^{-5} Newtons/M^2.[20]

0 dB is, therefore, the threshold of human hearing.

dBA. Sound level meters typically have three scales: A, B, and C. Each of these scales is designed to reduce the sound pressure reading at certain frequencies, in order to reflect more accurately the response of the human ear. This study used the A weighted scale because:

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[18] Ibid., p. 92.

[19] Ibid., p. 93-94.

[20] Ibid.

> . . . with [the A weighting] inserted, the meter is less sensitive to low frequencies. . . . This designation [dBA] is seen frequently in sound level measurements, since it has been found that readings with . . . [A weighting] correspond well to the subjective impression of the listener to the sound presented.[21]

Timbre. "Timbre" is a term with a number of definitions. The definition given in American Standard Acoustical Terminology is:

> Timbre (Musical Quality). Timbre is that attribute of auditory sensation in terms of which a listener can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar.
>
> Note: Timbre depends primarily upon the spectrum of the stimulus, but it also depends upon the wave form, the sound pressure, and the frequency location of the spectrum of the stimulus.[22]

For the purposes of this study, the term "timbre" will refer to:

> . . . the differences perceived by observers in the tones produced by various conventional and electronic musical instruments of the same pitch and loudness.[23]

Characteristic Timbre. Characteristic timbre is defined for purposes of this study as being that timbre which professional musicians and music teachers can agree upon as being a "good tone" for a particular instrument.

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[21] Ibid., pp. 97-98.

[22] American Standards Association, American Standard Acoustical Terminology (New York: American Standards Association, Inc., 1951), p. 25.

[23] Gephardt, p. 16.

<u>Familiar timbre</u>. A familiar timbre is defined for purposes of this study as a timbre produced by an instrument which is the same as the subject's declared major instrument. The exact amount of familiarity is described by the measure of PPEM which was gathered in the preliminary questionnaire.

Statistical Hypotheses

There were five hypotheses arising from the general research question:[24]

<u>Hypothesis I</u>:

> There will be no statistically significant interaction between formal ear training experience (FETE) and playing/performing experience (PPEM) as measured by scores attained on an author-produced test of melodic interval identification.

<u>Hypothesis II</u>:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals, as measured by scores attained on an author-produced test of melodic interval identification, regardless of the amount of PPEM each has had.

<u>Hypothesis III</u>:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals, as measured by scores attained on an author-produced test of melodic interval identification, regardless of the amount of FETE each has had.

[24] The .05 level of statistical significance was used in this exploratory study.

Hypothesis IV:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals presented using different timbres, as measured by scores attained on an author-produced test of melodic interval identification.

Hypothesis V:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals presented using timbres that differ in familiarity, as measured by scores attained on an author produced test of melodic interval identification.

Assumptions, Scope, and Limitations

This study was done with students enrolled either in junior college or in university who had completed or who were then taking at least one first year theory/harmony course. It was assumed that the subjects involved, as a result of the population definition, were familiar with the conventions of musical notation and procedures commonly used in melodic dictation. It was not assumed that the population under investigation was representative of all music students, since it is possible that students from other institutions might be significantly different from the selected population in terms of musical ability, aptitude, training, etc. No attempt was made to deal with intervals, instruments or timbres other than those specified.

Chapter 2

REVIEW OF THE LITERATURE

There appears to be a relatively large body of work discussing the attributes of pitch, loudness, and duration, but relatively little published or unpublished material investigating the effect of timbre upon pitch perception.

Seashore examined timbre only briefly, claiming that:

> The hearing of timbre. . . gives no new attribute of sound; a tone of a given timbre is merely a complex of a given number of pitches in their respective intensities, usually blending into the experience of a single tone.[1]

Farnsworth seemed to disagree with Seashore, saying that:

> . . . it is unfortunate that authorities write at times as though a perfect fifth, a minor chord, or a melody will have identical characteristics whether sung or played on a marimba, a harmonica, a tuba, or an old Cremona violin. They are neglecting the differences in timbre.[2]

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[1] Carl E. Seashore, The Psychology of Musical Talent (Boston: Silver Burdett, 1919), pp. 1389.

[2] Paul R. Farnsworth, The Social Psychology of Music (New York: The Dryden Press, 1958), p. 56.

In 1919, Carl Seashore stated that:

> . . . Pure tones are rarely used in music, partly because they cannot be produced by the voice or the ordinary musical instruments, and partly because they are thin, and lack richness and flexibility.[3]

More recently, Backus wrote that:

> . . . In our everyday experience, pure tones are very seldom heard, even in music. With the exception of the tuning fork, most sound sources, including musical instruments, produce complex tones that are mixtures of simple tones of various amplitudes and frequencies.[4]

Zeitlin found that among his test subjects there was significantly better pitch discrimination for complex tones than for pure tones, in the frequency range from 190 Hz to 6000 Hz (approximately G2 to G7).[5] The research of Henning and Grosberg confirmed these results, suggesting that greater exposure to complex tones might facilitate learning;

> . . . complex tones . . . [presumably] evoke a better response on the basilar membrane from which more comprehensive frequency information can be obtained.[6]

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[3] Seashore, pp. 128-129.

[4] John Backus, The Acoustical Foundations of Music (New York: W. W. Norton, 1969), pp. 107-108.

[5] L. R. Zeitlin, "Frequency Discrimination of Pure and Complex Tones," Journal of the Acoustical Society of America, 36(1964), pp. 1207-1219.

[6] G. B. Henning and S. L. Grosberg, "Effects of Harmonic Components of Frequency Discrimination," Journal of the Acoustical Society of America, 44(1968), pp. 1386-1389.

Stevens commented that:

> The pitch of a sound of given frequency depends to some extent on its intensity. If the loudness of a pure tone is increased, a change in pitch may occur. . . . A number of studies have been made of this effect, but with rather little agreement among them. . . .[7]

Cohen found rather less effect, as did Verschure and von Meerten.[8] Snow concluded that:

> The effect apparently exists only for pure tones; it seems generally agreed that complex tones show no change in pitch with intensity.[9]

Chapin and Firestone experimented with shifting the phase of a lower harmonic of a 108 Hz tone (at 104 dB), with somewhat inconclusive results,[10] while Fletcher claimed that:

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7 S. S. Stevens, "The Relation of Pitch to Intensity," Journal of the Acoustical Society of America, 6(1935), p. 153.

8 A. Cohen, "Further Investigations of the Effects of Intensity upon the Pitch of Pure Tones," Journal of the Acoustical Society of America, 33(1961), pp. 1363-1376; J. Verschure and A. A. von Meerten, "The Effect of Intensity on Pitch," Acoustica, 32(1975), pp. 33-44.

[illegible] W. B. Snow, "Change of Pitch with Loudness at Low F[illegible]cies," Journal of the Acoustical Society of America, 8(1936), pp. 18-19; see also D. Lewis and M. Cowan, "The Influence of Intensity on the Pitch of Violin and Cello Tones," Journal of the Acoustical Society of America, 8(1936), pp. 20-22; and E. Terhardt, "The Influence of Intensity on the Pitch of Complex Tones," Acoustica, 33(1975), pp. 344-48.

10 E. K. Chapin and F. A. Firestone, "The Influence of Phase on Tone Quality and Loudness; The Interference of Subjective Harmonics," Journal of the Acoustical Society of America, 5(1934), pp. 173-180.

> The fact that considerable timbre distortions in amplifiers and electroacoustic transducers could be tolerated without any noticeable effect on the quality of reproduced music and speech, supported the [then] generally accepted opinion that ~~the~~ ear had a limited sensitivity in the discrimination of timbre under varying phase conditions.[11]

Plomp's work in part confirmed this finding, concluding that for the usual musical instruments:

> . . . harmonics beyond about the seventh cannot be heard out.[12]

This finding has interesting implications regarding the minimum frequency range requirements of audio equipment; for a given tone with a fundamental frequency of, for example, 520 Hz, harmonics above a frequency of about 5500 Hz (the seventh partial) may be of little or no importance.

C. A. Taylor states that there are three major factors contributing to differences in tone quality:

> 1) Simultaneous vibration in several modes of resonance; 2) amplification systems with resulting transient effects; and 3) transients caused specifically by the method of initiation of the sound.[13]

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[11] Harvey Fletcher, "Loudness, Pitch and the Timbre of Musical Tones, and Their Relation to the Intensity, the Frequency and the Overtone Structure," Journal of the Acoustical Society of America, 6(1934), pp. 59-69.

[12] R. Plomp, "Pitch, Timbre, and Hearing Theory," International Audiology, 7(1967), pp. 322-344.

[13] C. A. Taylor, The Physics of Musical Sound (New York: American Elsevier Publishing, 1965), p. 106.

Taylor cites two other areas as having some additional effect upon tone quality: the formants of a tone, and the terminal transient effect.[14]

Ward does not appear to consider that the term "timbre" is used correctly, saying that:

> Timbre, which is a function of the harmonic content of the sound . . . is often used as a waste basket category; if two sounds are 'different' though having the same pitch and loudness, then they must differ in timbre.[15]

During a conference in Stockholm, Risset declared that:

> Ever since Helmholtz, acoustics textbooks explain that timbre--the distinctive quality of a musical instrument--is associated with harmonic spectra; the configuration of a spectrum would therefore determine the timbre of the instrument. The research work carried out by Schaeffer's group [P. Schaeffer, Traité des objects Musicaux, Seuil, Paris (1966)] pointed out the total inadequacy of such a simple conception, as did the studies [of] . . . E. Leipp [Bulletins du Groupe d'Acoustique Musicale (1963-1970), Acoustics Laboratory of the Faculty of Science, 9, quai Saint-Bernard, Paris] and . . . M. Clark [J. M. Clark, Several Problems in Musical Acoustics, J. Audio Engineering Sty, 7(1959) p. 2].[16]

Although Risset does not go into further detail, Backus explains that:

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[14] Ibid., pp. 106-110.

[15] W. Dixon Ward, "Musical Perception," in Foundations of Modern Auditory Theory, ed. Jerry V. Tobias (New York: Academic Press, 1970), Vol. I, p. 409.

[16] Ibid., pp. 125-126.

> For a particular instrument, the structure of a given single tone will depend on a number of factors. It changes with loudness. . . . the harmonics in the sound radiate differently in different directions from the instrument, due to interference and diffraction effects, so that the harmonic structure of a tone will depend on where it is heard. The spectrum of a tone will also depend on how the player produces it. It will also depend on the characteristics of the room in which it is played.
>
> An alternative theory suggests that an instrument has a certain fixed frequency region or regions in which harmonics of a tone are emphasized, regardless of the frequency of the fundamental. A fixed frequency region of this kind is called a formant, and it is the location of these formant regions that characterizes the instrument. . . .
>
> . . . there are other aspects of tone that are important in identifying the instrument producing it. For example, the initial transient . . . is rather important. . . . The decay transient can also be important.[17]

The first controlled experiments dealing with the auditory perception of timbre and wave patterns in complex tones were reported in 1862 by Helmholtz.[18] Although some of his findings are now in question, he is given credit for beginning the exploration of the field of timbre. As recently as 1980, Jameson commented that:

> The least amount of research, and also the most recent, has focused on the effect timbre has upon pitch perception and pitch matching ability in a musically relevant setting.[19]

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[17] Backus, pp. 117-118.

[18] Hermann L. F. Helmholtz, <u>On the Sensations of Tone as a Physiological Basis for the Theory of Music</u>, trans. and ed. Alexander J. Ellis. 2nd ed. (New York: Dover, 1954).

[19] Jameson, p. 11.

Whybrew, commenting on the timbre test portion of Seashore's Measures of Musical Talents, said:

> Timbre was varied by altering the balance in the overtone structure of the tones used. The authors point out . . . that they had certain doubts about the inclusion of such a measure, due to difficulties occasioned by phonograph function and room acoustics. They expressed the belief that reasonably constant results might be expected but that further investigation was needed.[20]

Cuddy's findings tend to support the premise that a subject who studies a particular instrument for a number of years develops a sense of pitch judgement which is better for tones produced by that instrument than it is for tones produced for other instruments. Cuddy found that:

> Musically trained subjects who were studying the piano as a major instrument named piano tones more accurately than pure tones. In general, the accuracy of pitch judgement was related to familiarity with musical tones.[21]

Leonard, examining this premise from a different viewpoint, concluded that students who had not studied instruments in depth would not be affected by the timbre used. He tested the effect of six factors on the pitch discrimination skill of subjects who were non-music majors. The experimental variables were

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[20] W. E. Whybrew, Measurement and Evaluation in Music, 2nd ed. (Iowa: Wm. C. Brown, 1971), pp. 116-117.

[21] Lola Lane Cuddy, "Practice Effects in Pitch Perception" (D.M.A. dissertation, University of Toronto, 1965), p. 91.

intensity, timbre, register content, duration, and interstimulus time interval. All factors except timbre were found to affect pitch discrimination.[22]

In 1970, Greer tested the effect of timbre on the external intonation patterns of college age brass-wind music majors. He used four timbre conditions, and twelve pitch levels. It was found to be significantly more difficult for the brass-wind performers to match the pitch produced by a sine wave than to match the pitch of their own instrument, piano, or a flute stop on an organ.[23]

In a related experiment, Hermanson explored the effect of timbre on young children. Among Kindergarten and Grade Three students, he found significantly fewer degrees of intonation error when students matched pitches produced by a woman's voice than when they matched pitches produced by other children, piano, or a sine wave.[24]

Sergeant examined pitch discrimination of subjects exposed to both square waves and natural state piano tones. He theorized

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[22] Nels Leonard, Jr., "The Effect of Certain Intrinsic and Contextual Characteristics of the Tone Stimulus on Pitch Discrimination" (Ed. D. dissertation, West Virginia University, 1967).

[23] R. Douglas Greer, "The Effect of Timbre on Brass-Wind Intonation," in Experimental Research in the Psychology of Music, ed. Edwin Gordon (Idaho: University of Iowa Press, 1970), vol VI.

[24] L. W. Hermanson, "An Investigation of the Effects of Timbre on Simultaneous Vocal Pitch Acuity of Young Children" (Ed. D. dissertation, Columbia University Teachers' College, 1971).

that judgement of pitch changes would be better for the square wave pitches than for the natural state piano tones. Statistical testing, however, did not substantiate his hypothesis.[25]

Grey explored musical timbre using a computer, and suggested that further perceptual research of timbre should be conducted within the different families of instruments, e. g. using only woodwinds, or only brass-winds.[26]

Williams, using a triangle wave, a square wave, and a sine wave rather than timbres produced by musical instruments, found that timbre differences had a significant effect on the ability of Grade Two and Grade Five children to identify melodic motion.[27] Blatter, in a similar study, designed and constructed an instrument which was capable of producing a variety of frequencies with various wave forms. He then used this instrument to test subjects' abilities to match pitches. While Blatter, like Williams, found a significant timbre effect,

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[25] Desmond Sergeant, "Experimental Investigation of Absolute Pitch," Journal of Research in Music Education, 17(Spring, 1969), pp. 135-143.

[26] J. M. Grey, "An Exploration of Musical Timbre using Computer Based Techniques for Analysis, Synthesis and Perceptual Scaling" (Ph. D. dissertation, Stanford University, 1975).

[27] David B. Williams, "An Interim Report of a Programmatic Series of Music Inquiry Designed to Investigate Melodic Pattern Identification Ability in Children" (California: SWRJ Education Research and Development, 1976).

[28] Alfred Wayne Blatter, "The Effect of Timbre on Pitch-matching Judgements (with) 'Reflections for Chorus, Narrator, and Fourteen Instruments'" (D. M. A. dissertation, University of Illinois at Urbana-Champaign, 1974).

neither author made use of conventional musical instruments.[28]

Silber and Howell had contradictory findings in their research. Using undergraduates in second year or higher, Silber investigated the effect of familiarity with a musical medium (vocal, string, woodwind, and brass quartet, and piano) on the students' ability to analyze and identify four part musical chords. The length of time subjects had been studying their instruments was correlated with the chord recognition test scores. Significant differences were found only for vocal and string performers.[29] Howell also investigated the effect of timbre on the identification of harmonic intervals by instrumentalists. He tested first and second year post-secondary students using pitches produced by clarinet, trumpet, piano, "pure tone", and "mixed tone" (a combination of French horn and flute). The results showed that pianists attained the highest score, and that neither timbre nor familiarity caused a difference in scores.[30]

Meyer, in 1978, investigated pitch discrimination using paired sounds with identical fundamental frequency and differential spectra. He used a sawtooth ("normal overtone

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[29] John S. Silber, "Aural Analytic Ability in Harmonic Dictation in Various Musical Media" (Ph. D. dissertation, University of Indiana, 1955).

[30] Ronald Thomas Howell, "The Effect of Timbre on the Interval Perception and Identification Skill of Instrumentalists" (Ed. D. dissertation, The University of Oklahoma, 1976).

series") and a square wave ("altered partials"). A significant majority of the musicians tested perceived the sawtooth wave as being sharper in pitch than the square wave.[31]

In the same year, Gephardt examined first and second year music majors. Subjects were given the first note of a dictated melody of unspecified length, and asked to notate the remainder of the dictation. Melodies were dictated using seven different timbres: trumpet, alto saxophone, piano, guitar, synthesizer (sawtooth wave), "Mixed I", and "Mixed II". He found that timbre, envelope, melody length, and task experience significantly affected subjects' scores on the dictation test, and that familiarity with the timbre source was not a significant factor.[32]

Summary

From the foregoing examination of the literature dealing with timbre and pitch perception, it seems clear that tones produced by musical instruments are easier to identify and to discriminate than are tones produced by electronic sources. There is some evidence to suggest that previous performance experience on a musical instrument, and the amount of previous

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[31] J. Meyer, "The Dependence of Pitch on Harmonic Sound Spectra," Psychology of Music, 1978, 6(1), pp. 3-12.

[32] Donald L. Gephardt, "The Effects of Different Familiar and Unfamiliar Musical Timbres on Musical Melodic Dictation" (Ed. D. dissertation, Washington University, Missouri, 1978).

ear training experience, contribute to pitch identification tasks.

In general, there appears to be agreement among researchers that timbre does have an effect on pitch judgement; there is no clear consensus about this effect, however. Only Gephardt seems to have addressed the question of unfamiliar timbres, and their effect on pitch perception, as compared to the effect of familiar timbres. Many researchers seem to be agreed that there is much to be done in the field of timbre and its effect on the perception of pitch.

This study was perceived as an exploratory investigation into a field which has apparently been little examined. It was hoped that some broad guidelines might be discovered which might serve to offer direction to future researchers in this area. In this study, the main area of interest was the effect of instrumental timbre upon students' ability to perceive and describe melodic intervals. As discussed on page 4, this study attempted to answer the following four questions:

1) Do differences in timbre affect students' ability to identify melodic intervals during dictation?

2) Does the length of time that students have been training to identify melodic intervals have a relationship with a possible effect of familiarity of timbre, as measured by ability to identify melodic intervals?

3) Does the length of time that students have been playing their declared major instrument have a relationship with a possible effect of familiarity of timbre, as measured by ability to identify melodic intervals?

4) Does the use of familiar or unfamiliar timbre sources affect students' ability to identify melodic intervals?

Chapter 3

METHODOLOGY

Population and Sample

All subjects were volunteers from among those students enrolled in either the Music Education Department or the Music Department of the University of British Columbia, or in the Music Department of Douglas College.[1] Only those students who had taken or were taking at least one university level theory/harmony course were eligible for participation in the study. Subjects were categorized on the basis of their answers to a short questionnaire, administered immediately prior to the actual testing. At that time information was gathered as to the major instrument played by each subject, the length of time the subject had been playing that instrument, and other pertinent details (see Appendix 2).

In total, 220 subjects volunteered for this study: 91 males and 125 females. Of these, eight subjects were excluded. Two were faculty members, excluded only because of small numbers; the other six subjects were disqualified from the PPEM/FETE

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[1] A two-year regional college.

portion of the study because of incomplete response forms. Only the two faculty members were excluded from the MAJOR portion of the study. The ages of the subjects ranged from 17 to 47 years, with a mean age of 21.8 years. Sixty subjects were registered in Year One of university or college, 48 in each of Years Two and Three, 30 in Year Four, and 29 in Year Five. Seventy-four subjects were from the University of British Columbia Music Education Department, 43 from Douglas College, and 101 from the University of British Columbia Music Department.

The subjects were categorized into three different groups, on the basis of Formal Ear Training Experience (FETE):

Group 1, one to eight months formal ear training;
Group 2, nine to sixteen months formal ear training;
Group 3, seventeen months or more of formal ear training.

These groupings were chosen because the university/college academic year normally consists of eight months. Preliminary examination of the demographic data revealed that there were not sufficient subjects at the higher levels of FETE to permit analysis with both FETE and PPEM, if more than three levels of FETE were used. The lack of subjects at the upper levels of FETE may have been due in part to natural attrition of students throughout the academic process, lack of availability of advanced courses involving ear training, or to some other cause beyond the researcher's control.

Subjects were also categorized on the basis of Playing/Performing Experience (PPEM):

Group 1, less than six years PPEM;
Group 2, six to ten years PPEM;
Group 3, more than ten years PPEM.

The categories of PPEM were designated after the work of Cuddy, Leonard, Silber, and Howell. While the original intent was to use four levels of PPEM, examination of the demographic data revealed that, as was the case for levels of FETE, there were not sufficient subjects to permit analysis using four levels.

Subjects were further categorized by the declared major instrument (MAJOR), resulting in five groups:

MAJOR 1, Clarinet;
MAJOR 2, Trumpet;
MAJOR 3, Piano;
MAJOR 4, Voice;
MAJOR 5, Other (all those whose Major was not one of the above 4).

Selection of Intervals and Timbre Sources

The twelve melodic ascending intervals shown in Appendix 1 were chosen as being representative of conventional ear training tests. It was the opinion of the author and of several experienced music educators that the test would provide sufficient challenge to all subjects. The 13th interval, a perfect unison, was omitted because it was felt that it would not have sufficient variance to be a useful measure. The intervals chosen are situated in a range which allows each instrument to produce a characteristic timbre, and which falls well within the range of the majority of heard musical material. By avoiding the extreme ranges of each instrument it was hoped to control to a certain extent the nuisance variables of uncharacteristic timbre, inaccurate pitch, and embouchure or finger fatigue.

The six timbre sources used in this investigation were produced by the following instruments: clarinet, trumpet, piano, violin, xylophone, and synthesizer (pure sine wave). These instruments were selected for the following reasons:

Clarinet. The clarinet is representative of the woodwind family, and is a common instrument in school and community bands and orchestras.

Trumpet. The trumpet is representative of the brass family, and is also a common instrument in school and community bands and orchestras.

Piano. The basic instrument of ear training has traditionally been the piano, as discussed in Chapters One and Two.

Violin. The violin is representative of the string family, and is common in school and community orchestras.

Xylophone. The xylophone is representative of the tuned percussion family of instruments, and while not common in school bands and orchestras, is often found in elementary school general music classes and primary classrooms.

Synthesizer. The synthesizer was used as a convenient way to provide a pure sine wave. The instrument used is designed to produce notes of the equi-tempered scale without regard for the wave form (timbre), attack, or decay being produced. It was possible, therefore, to make use of an oscilloscope to ensure that a pure sine wave was being produced, and to be confident that notes other than those actually examined on the oscilloscope would be in tune. The sine wave was included in the study because of its frequent use in tests of perception by researchers such as Seashore, Bentley, and others.

Preparation of the Test Tape

The master tape was recorded at 15 inches per second (i.p.s.) using the facilities of Bullfrog Recording Company Limited. During the recording process, each tone was monitored for intensity and for equal temperament frequency level (see Appendix 3). The entire recording process was also monitored for possible harmonic distortion and each recorded tone was adjusted for intensity level so that the final recording contained only equal intensity signals. Each instrument was played by a professional performer, who was asked to play all intervals at a uniformly moderate volume level.

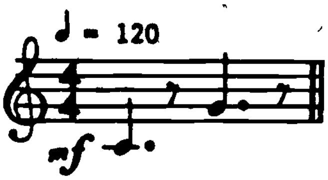

Figure 1. Rhythmic Pattern used for Melodic Intervals.

Each interval was played by the performer using the rhythmic pattern shown in Figure 1. An electronic metronome was used to ensure accurate and consistent performance of both pitch and rest durations. The chosen tempo was 2 beats per second (♩ =120), since:

> . . . in order to be heard clearly as of definite pitch, a tone at 128 [Hz] must have a duration of [at least] 0.09 sec; for 256, about 0.07 sec; for 384, about 0.04 sec; and for 512, about the same.[2]

After all seventy-two intervals (12 X 6 instruments) had been recorded, each interval was assigned a random number to eliminate any sequential effect that might influence scores. Intervals, sounded twice, were then transferred to a second master tape in their previously determined random order, together with a pitch reference tone (A = 440 Hz), instructions, and question identification numbers (see Appendix 4). The master

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[2] Carl E. Seashore, The Psychology of Musical Talent (Boston: Silver Burdett, 1919), p. 62.

tape was then re-recorded at 7.5 i.p.s., and leader tape was inserted to mark the various sections where pauses would occur during administration of the test.

Testing Procedure

The tests were conducted in various music classrooms in the University of British Columbia Scarfe and Music Buildings, and in the Douglas College Music facilities. The placement of the test equipment was kept as closely identical as feasible in each test location. Ambient background noise was measured prior to each administration of the test, and was found to be consistently less than 60 dBA in every instance. Similarly, tape speed was measured before each administration, and was found to be consistent to ±.5 Hz for the reference tone of A = 440 Hz. Playback levels were set to yield an SPL of 85 dBA at four feet in front of the speakers when playing the pitch reference tone. This setting produced an average SPL of 68 to 78 dBA throughout the room for the recorded intervals. The playback equipment consisted of a Sony TC-630 combined tape recorder, amplifier, and speakers.

The tests were made in a "free field", using loud speakers, since:

> It appears that scientific investigators can sometimes simplify the analysis of their experiments if sounds are sent from source to listener in an anechoic chamber. They can often further simplify their labors by working with electrically generated sound supplied directly to the ears by means of headphones. However, it is almost universally true that the human ear's ability to discriminate small changes of pitch, loudness, or tone color, or otherwise to 'make sense' out of a combination of signals, is immensely better in a room than it is under acoustically more sterile surroundings.[3]

It was felt that this free field procedure duplicated, more closely than might otherwise be the case, a realistic situation in which music might be heard. In every instance, the speakers were located at the front of the room, in a position approximately equivalent to that of the piano usually used for ear training in that room.

Subjects heard Part A of the test instructions, and then were given a short time to complete the Background Information Sheet. Subjects then heard Part B of the instructions followed by three "practice intervals" (P4, P5, and P8, played on piano) which were not scored. After being given an opportunity to ask questions, subjects then began the actual test, recording their answers in the appropriate boxes on the answer sheet (see Appendix 2). The test took approximately 20 minutes from start to finish. Test scores were not identified with individuals in any way, and subjects were assured of confidentiality.

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[3] Arthur H. Benade, Fundamentals of Musical Acoustics (New York: Oxford University Press, 1976), p. 197.

Statistical Design and Analysis

Subjects' answers were hand coded, transferred to a computer disk file, and then recoded from the original thirteen item code to a two item code. This process was necessary to make them suitable for machine scoring by the computer program LERTAP.[4] Details of this recoding procedure may be found in Appendices 7 and 8.

Initial examination of the data revealed that the variance-covariance matrixes appeared to be heterogeneous, and that the distribution curves were not normal. It was decided that the lack of normality was the real cause of the difficulty, and possible solutions were explored. After investigating the effects of various transformations, it was decided to use an arcsine transformation.

A total of three transformations were carried out, in order to eliminate any variation in scores due to the particular class or location of a subject, and in order:

1. to achieve homogeneity of error variance, and,
2. to achieve normality of treatment-level distributions.[5]

The first transformation involved recalculating subjects' scores as proportions by dividing each of the six tests by

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[4] Larry Richard Nelson, Laboratory of Educational Research Test Package (New Zealand, 1974).

[5] Roger E. Kirk, Experimental Design: Procedures for the Behavioural Sciences (California: Brooks/Cole Publishing, 1968), p. 63.

twelve, the total number of items. The proportions thus obtained were then converted using an arcsine transformation to obtain a more normal distribution of all scores. The formulas given in Marascuilo and McSweeney were used for this transformation.[6] This procedure yielded scores with values expressed in radians.

Following the arcsine transformation, scores were then converted into standard scores (mean zero, standard deviation one) by first standardizing across the six dependent variables within each class, then standardizing across each class within each institution, and finally standardizing across each institution. This procedure produced scores with a mean value of zero and a standard deviation of one for the total distribution of scores. Comparison of any score with any other score could, therefore, be meaningfully made since all scores were effectively on the same scale.[7]

A multivariate analysis of variance (MANOVA) was performed, using PPEM and FETE as the independent variables (three levels each) and the six scores attained on the melodic interval identification test as the dependent variables (Table 1).

A separate MANOVA was performed on the same dependent

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[6] Leonard A. Marascuilo and Maryellen McSweeney, Nonparametric and Distribution-Free Methods for the Social Sciences (California: Brooks/Cole Publishing, 1977), pp. 147-151.

[7] The computer program which performed these transformations was written by Dr. R. E. Bruce, of the Educational Research Service Center at the University of British Columbia. A copy of the program will be found in Appendix 9.

variables but using the subjects' declared major instrument (MAJOR) as the only independent variable. This two stage analysis was necessary since there was an insufficient number of subjects to permit blocking on all three independent variables simultaneously.

TABLE 1

3 X 3 MANOVA DESIGN

		PPEM		
		GROUP ONE	GROUP TWO	GROUP THREE
FETE	GROUP ONE	N=22	N=12	N=8
	GROUP TWO	N=31	N=30	N=33
	GROUP THREE	N=22	N=21	N=33

TOTAL N=212

Chapter 4

RESULTS

Summary of the Problem

This investigation was carried out in an attempt to explore the effect of musical timbre on subjects' ability to passively identify dictated melodic intervals. The independent variables were playing/performing experience (PPEM), formal ear training experience (FETE), and familiarity of timbre (MAJOR). The dependent variables were the scores attained on six author-written tests of melodic dictation.

For purposes of analysis, subjects were grouped into three levels of PPEM and three levels of FETE. An additional five-level grouping was made on the basis of declared major instrument (MAJOR). A multivariate analysis of variance (MANOVA) analysis was used to determine which of the data results were statistically significant. Where appropriate, Scheffé post-hoc multiple comparison tests were performed.

Statistical Results

Introduction

The multivariate analysis of variance (MANOVA) tests were performed on the data using the MULTIVAR computer package.[1] This statistical package performs a MANOVA as generally described by Harris.[2] The analysis was performed at the University of British Columbia Computer Center on the Amdahl 470 V/8 computer, operating under the Michigan Terminal System (MTS).

The results of the statistical tests are reported from the most complex to the least complex, since the presence of an interaction between two factors makes difficult any interpretation of one of those factors alone. The MANOVA analysis of PPEM and FETE will be discussed first, followed by the MANOVA analysis of MAJOR.

A significant multivariate *F* ratio in the summary table indicates a relationship between the dependent variables and the appropriate independent variable. The absence of a significant univariate *F* ratio implies that the relationship among the dependent variables and the independent variable may be a complex one. No interpretation was made of such a relationship, since, for example, it would make little sense to present a

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[1] MULTIVAR: Version 6.2 (Chicago: National Educational Resources, 1972).

[2] Richard J. Harris, A Primer of Multivariate Statistics (New York: Academic Press, 1975).

result which says that "The scores on the piano timbre of Level 2 of PPEM are significantly different from one-half of the score on the clarinet timbre of PPEM Level 3 plus one-half of the score on the trumpet timbre of PPEM Level 1." If there was at least one significant univariate *F* ratio, then appropriate post hoc comparisons were made to determine where the significant differences were located.

Statistical tests were carried out, for main effects, at the $\alpha = .05$ level of significance. For post hoc analyses, the significance level was maintained at $\alpha = .05$, since this was an exploratory study. All post hoc tests were conducted using Scheffé's *F* ratio test.

Tests of Hypothesis I

Null Hypothesis:

> There will be no statistically significant interaction between formal ear training experience (FETE) and playing/performing experience (PPEM) as measured by scores attained on an author-produced test of melodic interval identification.

From Table 2, it may be seen that the PPEM/FETE interaction *F* ratio was non-significant for both the multivariate and the univariate tests.[3] Accordingly, the null hypothesis was accepted; there was no interaction between PPEM and FETE.

[3] Shown as "PF Interaction" in the table.

TABLE 2

MANOVA SUMMARY TABLE FOR PPEM AND FETE

	Multivariate Test		Univariate Statstics							
Source	F	(df)	df	Cl	Tr	Pi	Vi	Xy	Sy
(PPEM)	3.52	(12,396)	2	9.81*	10.31*	10.51*	9.68*	10.79*	15.70*
(FETE)	1.97*	(12,396)	2	1.22	0.70	0.54	2.42	0.00	0.14
PF Interaction	0.86	(12,692)	4	0.69	0.42	0.85	0.26	0.44	0.11
Within			203						

*p<.05

NOTE · Cl, Clarinet, Tr, Trumpet, Pi, Piano, Vi, Violin, Xy, Xylophone, Sy, Synthesizer.

TABLE 3

SCHEFFE POST HOC COMPARISON OF PPEM LEVELS

INSTRUMENT	1-2	1-3	2-3
CLARINET	0.003	11.43*	17.59*
TRUMPET	0.288	9.07*	19.36*
PIANO	0.301	14.97*	15.88*
VIOLIN	0.492	8.47*	19.99*
XYLOPHONE	0.413	9.17*	20.59*
SYNTHESIZER	0.999	23.52*	23.30*

* p<.05

TABLE 4

SCHEFFE POST HOC PAIRWISE COMPARISON OF PPEM LEVELS

COMPARISON	1-2	1-3	2-3
VLN/SYNTH	6.12*	4.65	0.08
XYLO/SYNTH	4.65	6.05*	0.22

* $p<.05$

TABLE 5

SCHEFFE POST HOC COMPARISON OF PPEM

COMPARISON	1	2	3
CLAR/PNO	0.27	4.31	0.51
CLAR/TPT	4.57	18.92*	7.48*
CLAR/VLN	0.38	4.08	0.04
CLAR/XYLO	2.12	0.48	1.35
CLAR/SYNTH	2.37	0.01	1.66
TPT/PNO	6.83*	41.29*	11.51*
TPT/VLN	0.21	0.07	0.26
TPT/XYLO	3.95	8.37*	3.62
TPT/SYNTH	0.72	4.37	3.29
PNO/VLN	4.07	34.51*	7.31*
PNO/XYLO	0.48	17.82*	3.09
PNO/SYNTH	13.02*	16.54*	1.77
VLN/XYLO	2.14	6.49*	1.74
VLN/SYNTH	2.36	4.65	2.40
XYLO/SYNTH	8.88*	0.34	0.01

* $p<.05$

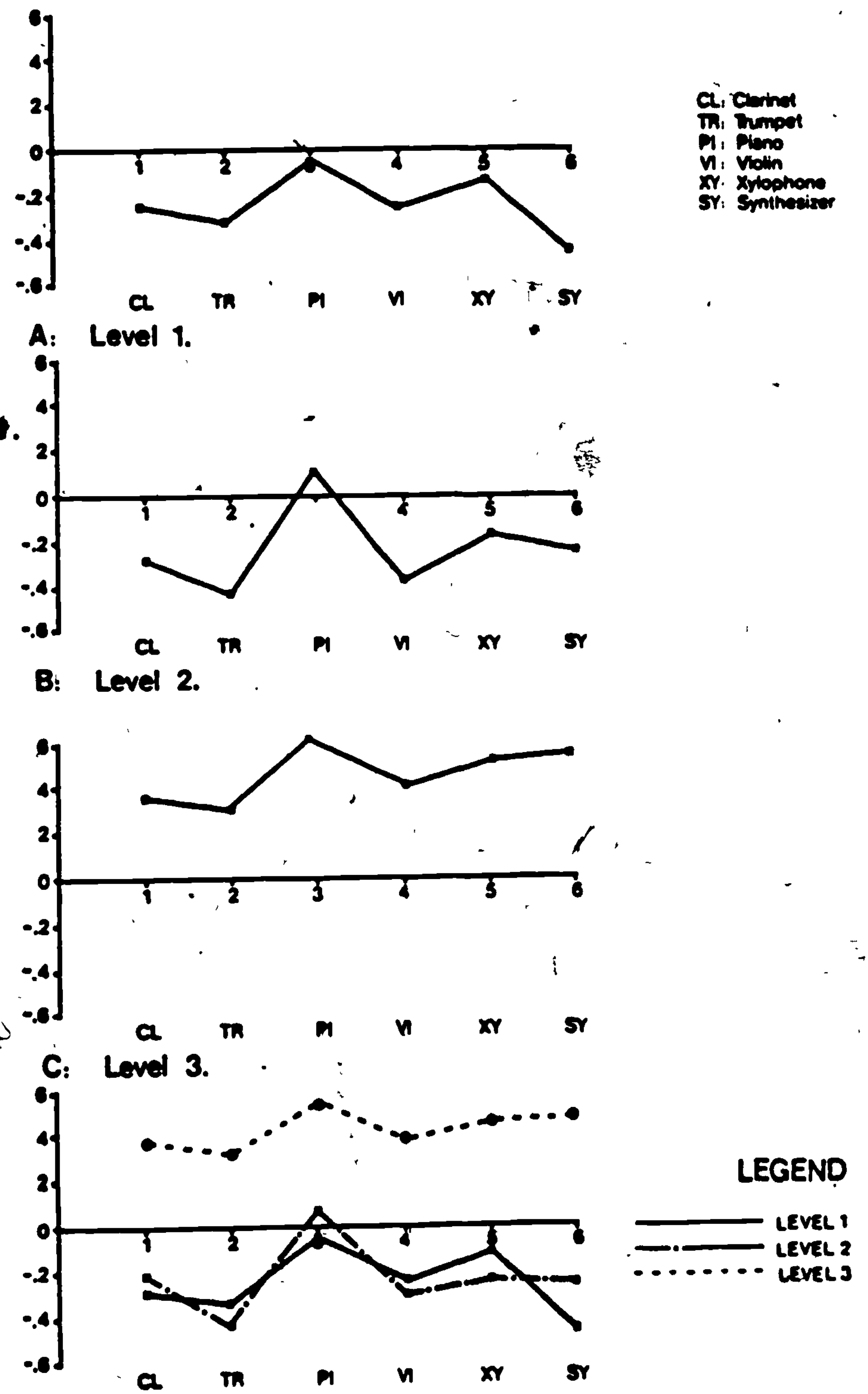


Figure 2. PPEM COMPARED WITH SCORES.

Tests of Hypothesis II

Null Hypothesis:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals, as measured by scores attained on an author-produced test of melodic interval identification, regardless of the amount of PPEM each has had.

As can be seen from Table 2, the PPEM multivariate F ratio and all of the related univariate F ratios were significant at the $\alpha = .05$ level. Post hoc investigations revealed that test scores achieved by subjects at Level 1 of PPEM were not significantly different from those at Level 2, but that subjects at Level 2 were significantly different from those at Level 3. Additionally, subjects' scores at Level 1 were significantly different from subjects' scores at Level 3 (Figure 2, Table 3).

Post hoc investigations also revealed that the differences between the scores on certain instruments changed as the levels of PPEM changed (Table 4), and also that the differences between the scores on certain pairs of instruments changed as the levels of PPEM changed (Table 5).

In view of these results, the null hypothesis was rejected; there were statistically significant differences in the ability of subjects to identify certain melodic intervals, when the amount of PPEM each has had was taken into consideration.

Tests of Hypothesis III

Null Hypothesis:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals, as measured by scores attained on an author-produced test of melodic interval identification, regardless of the amount of FETE each has had.

As can be seen from Table 2, only the multivariate F ratio was significant for the FETE factor. This finding suggests that there was some significantly different combination of variables among the levels of FETE. Such a combination was not, however, meaningful in terms of this study. Post hoc investigation revealed that while the levels of FETE were not different from one another, there were statistically significant differences between scores attained on various instruments at each level of FETE (Table 6). It was also found that the differences between the scores on certain test timbres changed as the level of FETE changed (Table 7, and Figure 3).

Accordingly, the null hypothesis was rejected; there was a statistically significant difference in the ability of subjects to identify certain melodic intervals when the amount of FETE each has had was taken into consideration.

TABLE 6

SCHEFFE POST HOC COMPARISON OF FETE

COMPARISON	1	2	3
CLAR/PNO	7.22*	2.11	5.16
CLAR/TPT	8.99*	14.09*	7.68*
CLAR/VLN	1.45	3.03	0.08
CLAR/XYLO	0.12	6.70*	0.10
CLAR/SYNTH	0.33	1.43	0.06
TPT/PNO	33.73*	3.14	26.70*
TPT/VLN	2.47	9.64*	6.02
TPT/XYLO	10.24*	0.62	3.85
TPT/SYNTH	4.29	0.28	3.85
PNO/VLN	15.02*	25.66*	5.31
PNO/XYLO	9.47*	1.39	8.26*
PNO/SYNTH	12.01*	5.77	8.67*
VLN/XYLO	2.11	16.97*	0.29
VLN/SYNTH	0.38	8.97*	0.29
XYLO/SYNTH	0.84	1.97	0.32

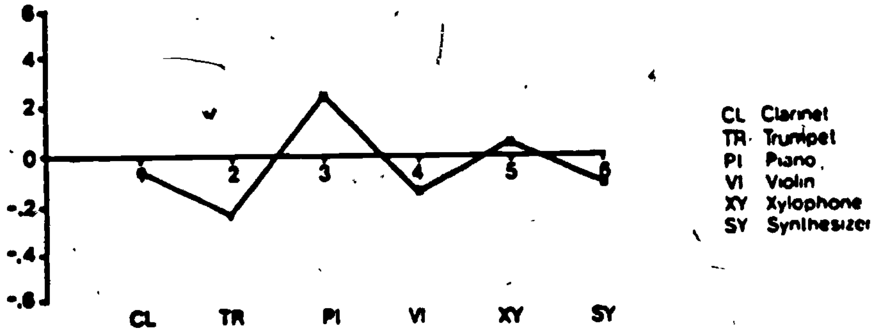
* p<.05

TABLE 7

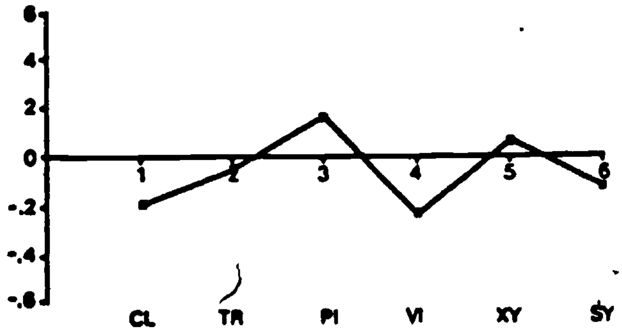
SCHEFFE POST HOC PAIRWISE COMPARISON OF FETE LEVELS

COMPARISON	1-2	1-3	2-3
CLAR/TPT	9.18*	0.08	7.57*
TPT/PNO	6.85*	0.18	4.84
TPT/VLN	11.23*	0.40	15.57*
VLN/XYLO	4.21	0.98	8.95*
VLN/SYNTH	3.21	0.67	6.00*

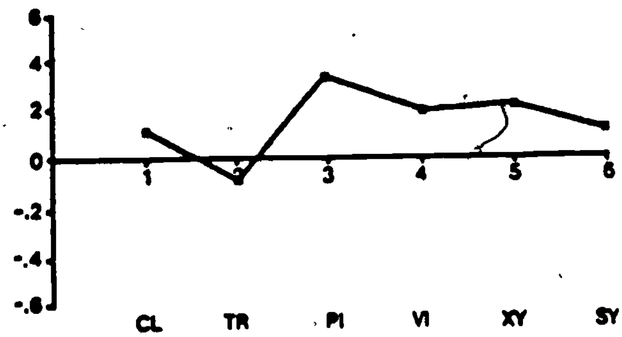
* $p<.05$



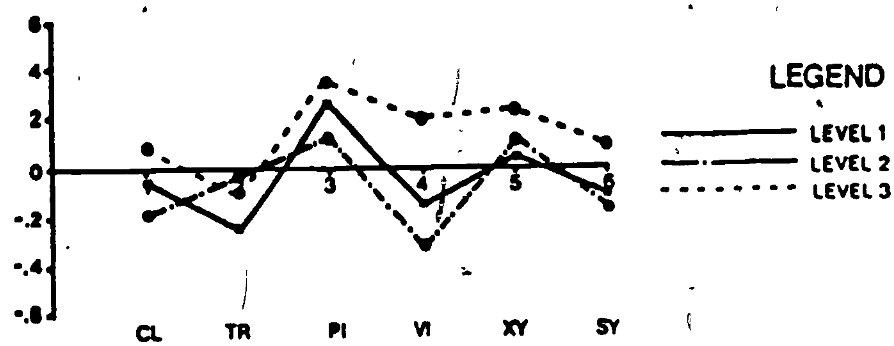
A: Level 1.



B: Level 2.



C: Level 3.



D: All Levels.

Figure 3. FETE COMPARED WITH SCORES.

Tests of Hypothesis IV

Null Hypothesis:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals presented using different timbres, as measured by scores attained on an author-produced test of melodic interval identification.

Since FETE and PPEM were both found to be significant, no explicit tests were made of this hypothesis. The rejection of this hypothesis was a consequence of the rejection of Hypotheses II and III.

Tests of Hypothesis V

Null Hypothesis:

> There will be no statistically significant difference in the mean ability of subjects to identify certain melodic intervals presented using timbres that differ in familiarity, as measured by scores attained on an author-produced test of melodic interval identification.

As seen in Table 8, all MAJOR F ratios, both multivariate and univariate, were significant at the $\alpha = .05$ level.

Post Hoc comparisons revealed that there were significant differences among the scores attained on certain timbres for only two declared major instruments ("voice" and "other"), but there were many significant differences among declared major instruments for each of the test timbres (Tables 9 and 10, Figures 4 and 5). Accordingly, the null hypothesis was rejected; there was a statistically significant difference in the ability of subjects to identify certain melodic intervals when the declared major instrument was taken into consideration.

TABLE 8

MANOVA SUMMARY TABLE FOR MAJOR

Multivariate Test			Univariate Statistics						
Source[a]	F	(df)	df	Cl	Tr	Pi	Vi	Xy	Sy
Major	1.77*	(24,727)	4	3.75*	3.52*	2.80*	4.36*	6.34*	3.78*
Within			213						

*p < .05

NOTE - [a]Cl, Clarinet, Tr, Trumpet, Pi, Piano, Vi, Violin, Xy, Xylophone, Sy, Synthesizer.

TABLE 9

SCHEFFE POST HOC COMPARISON OF MAJOR

COMPARISON	VOICE	OTHER
TPT/PNO	0.28	33.10*
PNO/SYNTH	12.69*	10.51*
XYLO/SYNTH	14.66*	0.06

* p<.05

TABLE 10

SCHEFFE POST HOC COMPARISON OF DECLARED MAJOR

MAJOR	CLAR	TRPT	PIANO	VIOLIN	XYLO	SYNTH
CLAR/TPT	1.94	1.50	3.83	0.08	31.54*	11.28*
CLAR/PNO	45.61*	33.83*	32.93*	65.43*	30.42*	29.16*
CLAR/VOICE	20.28*	13.48*	12.25*	20.26*	22.38*	0.25
CLAR/OTHER	3.28	0.13	3.62	7.01	0.28	0.34
TPT/PIANO	66.35*	49.66*	59.25*	69.95*	123.90*	76.71*
TPT/VOICE	34.76*	24.03*	29.76*	22.81*	107.10*	14.88*
TPT/OTHER	10.26*	2.51	14.90*	8.54	25.85*	15.52*
PIANO/VOICE	5.00	4.60	5.03	12.87*	0.62	24.03*
PIANO/OTHER	24.42*	29.83*	14.73*	29.60*	36.58*	23.22*
VOICE/OTHER	7.24	11.00*	2.54	3.43	27.70*	0.01

* $p < .05$

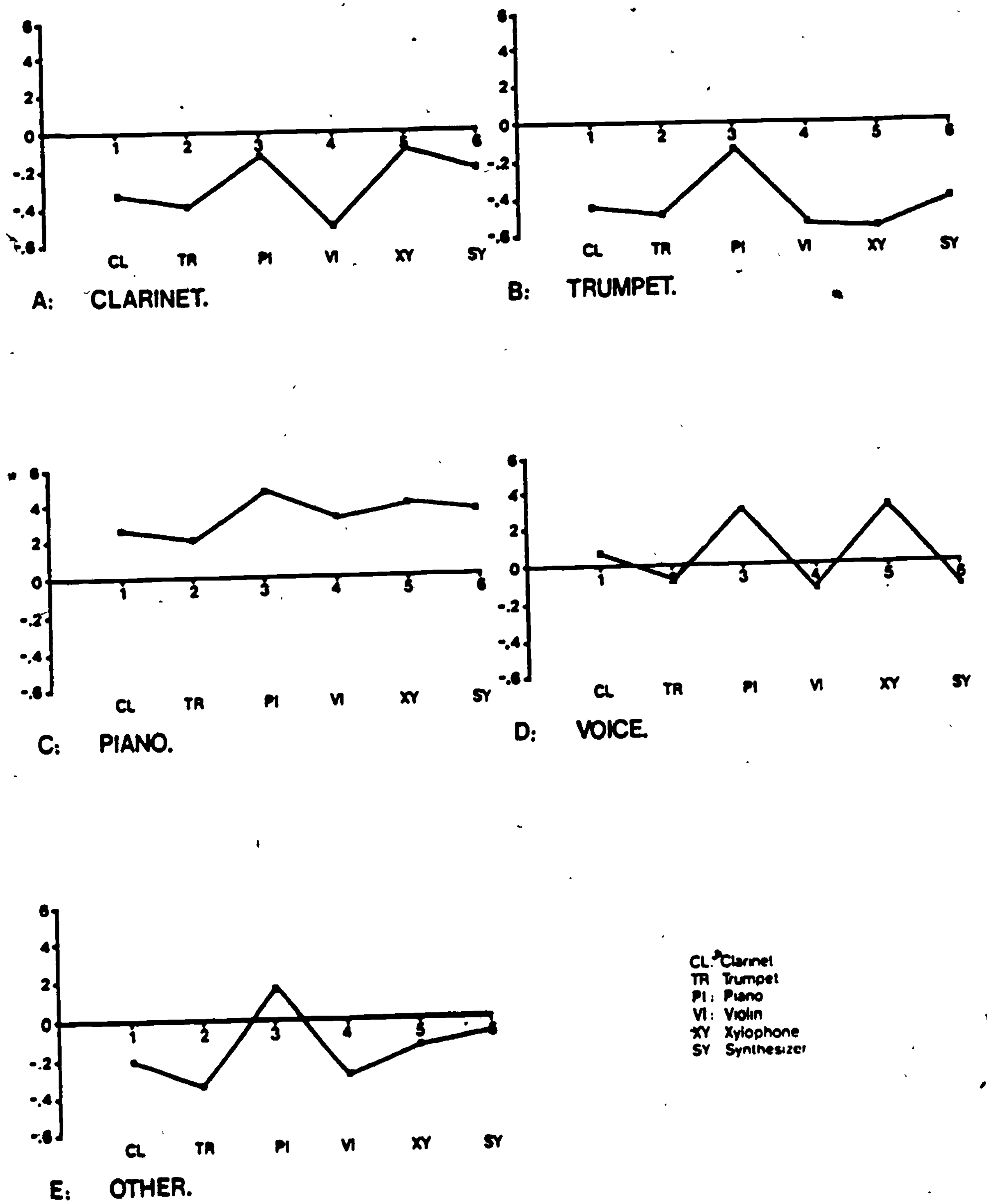


Figure 4. MAJOR COMPARED WITH SCORES.

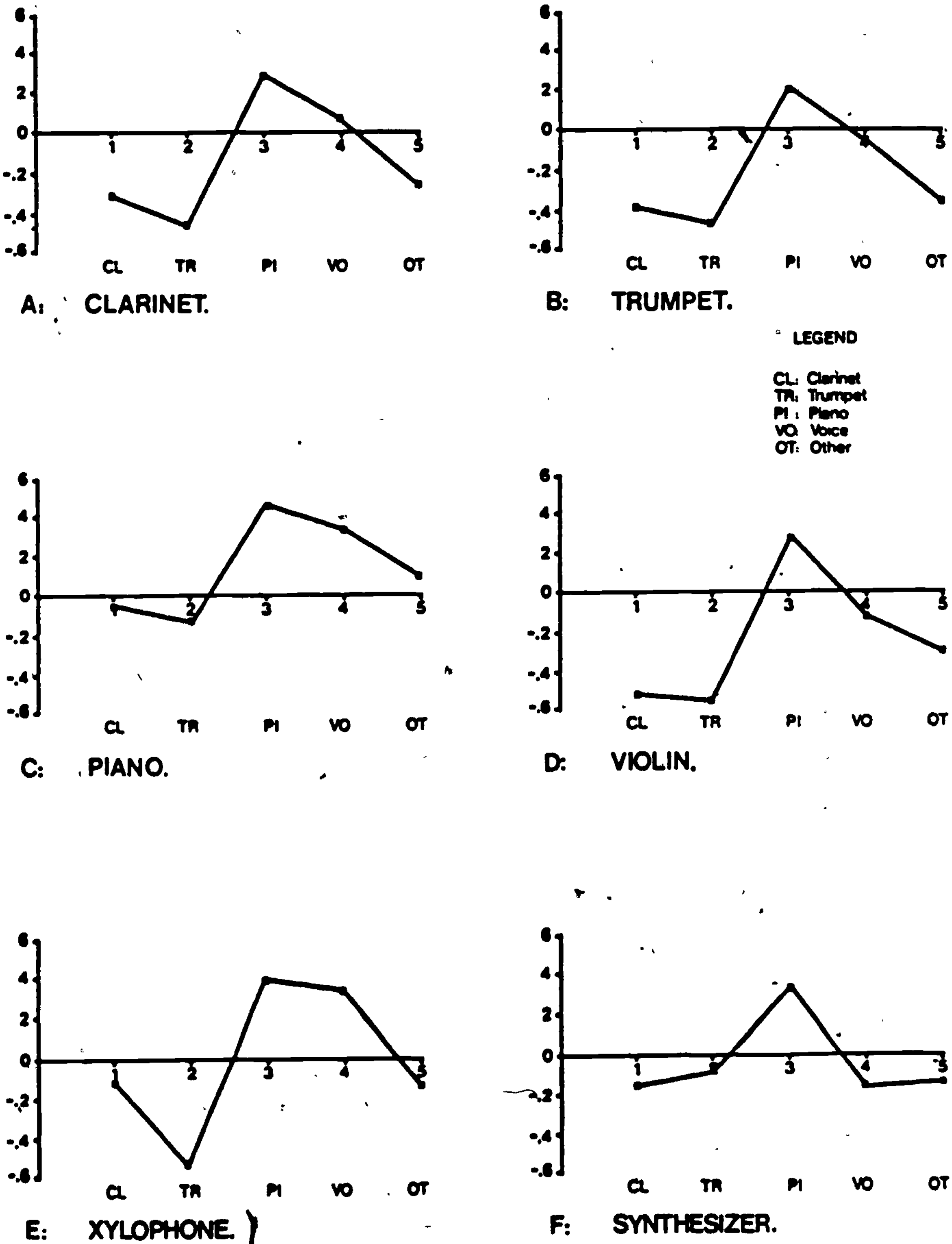


Figure 5. SCORES COMPARED WITH MAJOR.

Chapter 5

CONCLUSIONS

Introduction

The purpose of this study was to explore the effect of timbre upon the identification of melodic intervals. The question was asked: "Do differences in timbre affect students' ability to identify melodic intervals during dictation?" Since it was suggested by some researchers that this ability might be affected by a subject's familiarity with a particular timbre (the MAJOR instrument), the amount of playing/performing experience on that instrument (PPEM), and the length of time he has been formally studying ear training (FETE), these three factors were used in defining the formal hypotheses.

Five null hypotheses were formulated and tested, using a test of melodic interval identification created by the author. The results of the study, as discussed in Chapter 4, have led to the following conclusions:

Null Hypothesis I: PPEM/FETE interaction--accepted;

Null Hypothesis II: effect of playing/performing experience (PPEM)--rejected;

Null Hypothesis III: effect of formal ear training experience (FETE)--rejected;

Null Hypothesis IV: differences in timbre--rejected;

Null Hypothesis V: familiarity of timbre (MAJOR)--rejected.

Summary of Results

The population investigated consisted of college and university students with a minimum of two months of formal ear training in university/college level harmony/theory courses. For this population, variations in timbre seemed to have an effect on students' ability to perform simple melodic dictation tasks. This effect was present when either the amount of PPEM or the amount of FETE was considered, and also was true for each instrumental timbre examined. Investigation of the relationship of PPEM and timbre showed clearly that students who had the largest amount of PPEM (more than ten years of experience) attained the highest scores. There were no statistically significant differences between the scores attained by students at Level 1 of PPEM and those attained at Level 2 (less than six years and six to ten years, respectively).

When differences among instrumental timbres were examined at each level of PPEM, it became evident that there was no clear pattern of variation. For all levels, there were no differences between the scores attained on clarinet and those attained on violin. Similarly, there were no differences at any level of PPEM between scores on clarinet and xylophone, clarinet and synthesizer, trumpet and violin, trumpet and synthesizer, or violin and synthesizer. The number of statistically significant differences at each level of PPEM and the relative scores at each level suggest that Level 1 students may be unable to identify melodic intervals well enough to be affected by timbre, while Level 3 students may be able to identify melodic intervals so well that they are not misled or confused by timbre. Level 2 students, as might perhaps be expected, scored between Levels 1 and 3. An alternative interpretation might be that clarinet, trumpet, violin, xylophone and synthesizer timbres yielded essentially the same scores, but that the effect of the piano timbre was different. This alternative interpretation implies that scores attained on piano intervals may have been higher because of familiarity with the piano from the students' regular ear training sessions. While the nature of the relationship is not clear, there appears to be a definite relationship between PPEM and timbre. In addition, it is clear that the score attained, regardless of the timbre, increases with the amount of a subject's playing or performing experience.

An examination of the effect of FETE also leaves some questions unanswered. There seems no doubt that FETE did interact with the instrumental timbre to produce scores which were different at different levels of FETE; it is not clear as to the nature of that interaction. In some ways, it would appear that Levels 1 and 3 are very similar: both levels have almost identical combinations of significant results. This similarity is supported by the pairwise comparisons. Examination of the graphs, however, tends to suggest that Level 1 and Level 2 may have more in common. The results of the study indicate, then, that FETE and timbre are interrelated, but fail to make clear the details of that relationship.

The effect of familiarity of timbre in this study seems to suggest that while there is a relationship between the declared major instrument and the timbre presented, there is not a direct relationship. That is, a student who is familiar with a particular timbre does not necessarily attain a higher score on dictation presented with that particular timbre than with other timbres. It is clear that students with experience on piano or on voice attained significantly higher scores than did students with experience on other instruments; it is not clear how formal ear training experience interacts with timbre.

Conclusions

The timbre in which melodic intervals are presented during dictation does make a difference to the scores attained, at least for the population examined in this study. Timbre then, is of sufficient importance that educators should not:

> . . . ignore it and concern [themselves] exclusively with rhythm and pitch.[1]

Depending upon the amount of FETE and PPEM a subject has, the results of this study would seem to suggest that presenting material with different timbres can make the task of identifying

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[1] William E. Thomson and Richard P. Delone, Introduction to Ear Training (California: Wadsworth Publishing, 1968), p. 1.

intervals different from the task of identifying intervals presented with a consistently uniform timbre. The nature of that difference is not clear from this study, and has not been clear in studies done prior to this one.

Although the results of this study are somewhat ambiguous regarding the effect of familiarity of timbre, it appears that being familiar with a timbre source used, through playing/performing experience with an instrument producing that timbre, does not aid in the identification of pitches produced with that timbre. It is possible that subjects did not respond accurately to the question regarding their "major instrument", since many university/college students change their major instrument during their academic studies. The result may be that some students have more experience on their "secondary" instruments than on their declared majors. It is interesting to note, however, that students who claimed voice as their declared major instrument achieved the same scores as did piano students. It may be that voice students, by virtue of making frequent use of piano in their studies, are not very different from piano students in terms of familiarity with the timbre of the piano.

It appears that the timbre in which dictation material is presented can affect a student's ability to perform identification of melodic dictation intervals. Since ear training is, presumably, a preliminary stage in learning to work with more complex musical materials, it would seem that students should be exposed to various timbres as part of their training in interval identification.

Suggestions for Further Study

Several suggestions for further investigation have arisen from this study:

1. The effect of familiarity of timbre needs to be explored in depth, using subjects with a wide range of experience.
2. The effect of fixed and moveable doh should be explored in relation to timbre, since there is evidence to suggest that tonality influences musical perception.
3. The effect of the type of interval used (ascending, descending, harmonic, and melodic) should be explored, as should the speed of presentation.
4. The effect of the types of timbres presented should be examined more thoroughly, including different combinations of instruments, and also including the effect of removing the attack and release from the sound. It is suggested in the literature that the attack and release may be of great importance in identification of timbre.
5. There are now available a number of ear training programs for use on microcomputers fitted with synthesizers. An examination of the effects of using synthesized instead of real instruments should be made, to determine the applicability of such synthesizers to ear training courses.
6. The question of subjects' declared major instrument

needs to be re-examined, taking into acount the length of time spent studying the major instrument, and the length of time spent studying any secondary instruments.

7. A recent change in the Secondary Music Curriculum of the British Columbia public school system should soon make it possible to replicate this study, since ear training is now to be offered as a regular part of the music class in secondary schools. The information gathered might shed greater light upon the effect of chronological age on interval identification, and should provide a wider range of FETE for study.

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Appendix 1

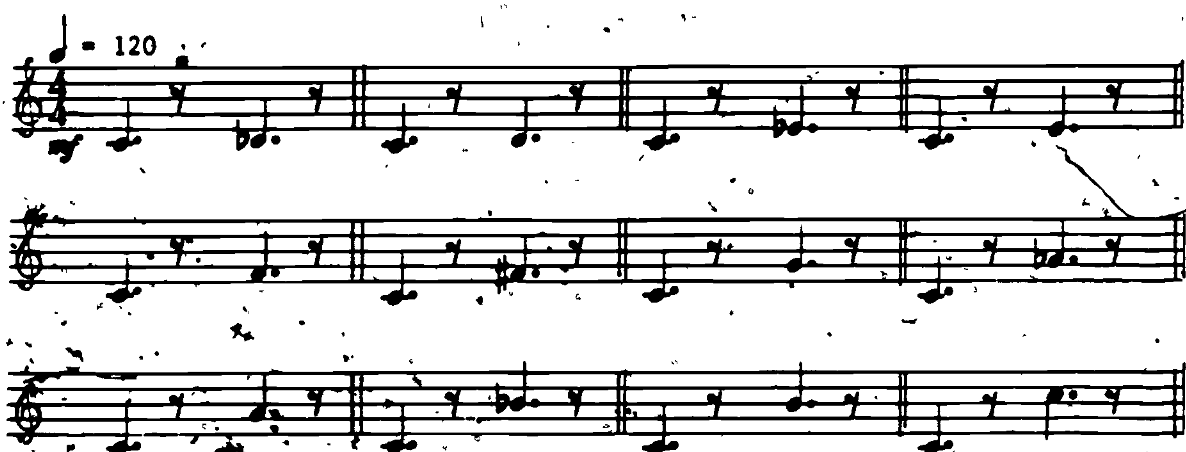
Melodic Interval Identification--Instructions to Performers

The following pages are the instructions that were given to the performers who were doing the recording of intervals.

Melodic Interval Identification--Instructions to Performers

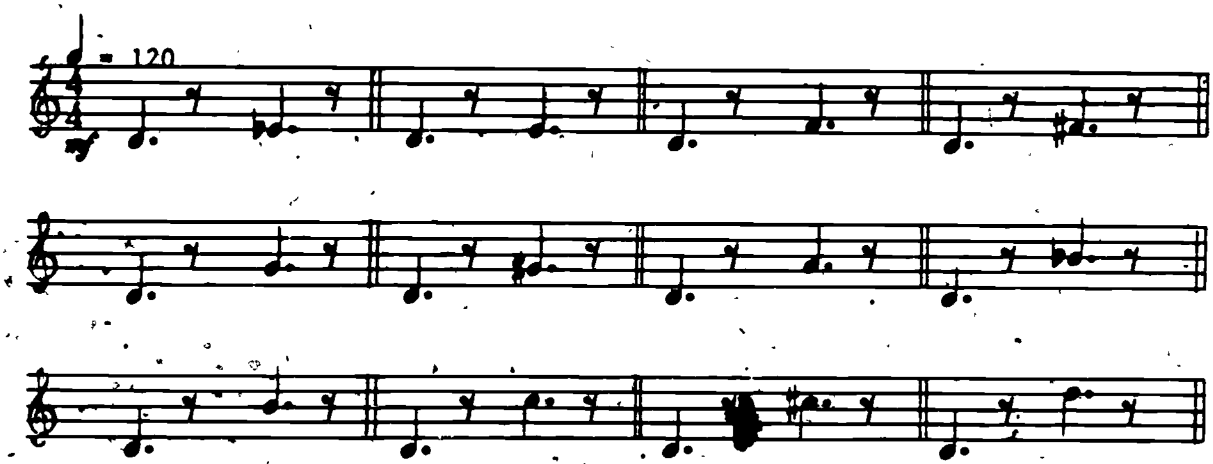
Piano, Violin, Xylophone, Synthesizer ("Concert Pitch Instruments")

Please play each note at a mezzo forte volume. Use a normal tone, and use vibrato if you would normally do so. You are attempting to produce a "good" tone which could serve as an examplar.

Stop at each double bar; the recording engineer will advise you when he is ready for the next bar. Make use of the stroboscope to ensure you are playing exactly on pitch (A = 440 Hz), and the metronome to ensure that you are playing exactly in time.

Melodic Interval Identification--Instructions to Performers

Clarinet, Trumpet ("Transposing" Bb instruments)

Please play each note at a mezzo forte volume. Use a normal tone, and use vibrato if you would normally do so. You are attempting to produce a "good" tone which could serve as an examplar.

Stop at each double bar; the recording engineer will advise you when he is ready for the next bar. Make use of the stroboscope to ensure you are playing exactly on pitch (A = 440 Hz), and the metronome to ensure that you are playing exactly in time.

Appendix 2

Questionnaire and Interval Answer Form

The following pages contain the information and answer sheets which were given to subjects.

Questionnaire and Interval Answer Form

INSTRUCTIONS

PART A

> This test is designed to explore the effect of timbre (tone colour) on the perception of pitch. The test will take approximately 20 minutes. Although your participation is appreciated, you are free to withdraw at any time or to refuse to answer any questions without prejudice. If the questionnaire is completed, your consent will be assumed.

Please turn to the next page, "Background Information", and answer the questions. Complete the questions and the answer form anonymously. Do not write your name on these pages.

PART B

You are going to hear a series of melodic intervals. Each interval will be played twice, with an announcement of the question number between each pair. Only intervals in the octave C4 (middle C) to C5 will be used, as shown in the list below.

> m2 M2 m3 M3 P4 X4(dim5) P5 m6 M6 m7 M7 P8

Six different instruments will be used to produce the intervals.

YOU DO NOT NEED TO IDENTIFY THE INSTRUMENT BEING USED.

Write down the name of each interval in the space provided. Ignore the smaller numbers to the right of each box. Try to answer every question, even if you are not sure of the answer; guessing is permitted.

THIS TEST IS ANONYMOUS, AND DOES NOT COUNT TOWARD ANY EVALUATION.

Are there any questions?

The following section is a sample quiz only, to give you a chance to practise. It will not be scored.

NUMBER	NAME
1	

9

NUMBER	NAME
2	

10

NUMBER	NAME
3	

11

This completes the practice session. Are there any further questions? Please turn to the Answer Sheet--in a moment, we will begin the actual quiz.

BACKGROUND INFORMATION

1. In what year of university/college are you currently enrolled? (Use 9 if you are Faculty)

7

2. ....Age? (Years)

9-10

3. ....Sex? (M or F)

12

4. What is your MAJOR instrument (i.e. the instrument on which you spend most of your time and energy)?
   1. CLARINET 2. TRUMPET 3. PIANO 4. VIOLIN
   5. XYLOPHONE 6. SYNTHESIZER 7. NONE
   8. OTHER (INCLUDING VOICE--PLEASE SPECIFY) __________

14

5. How long have you played this instrument? (Years)

16-17

6. What is your SECONDARY instrument (i.e. the instrument on which you spend somewhat less of your time and energy)?
   1. CLARINET 2. TRUMPET 3. PIANO 4. VIOLIN
   5. XYLOPHONE 6. SYNTHESIZER 7. NONE
   8. OTHER (INCLUDING VOICE--PLEASE SPECIFY) __________

19

7. How long have you played this instrument? (Years)

21-22

8. How many actual MONTHS of university/college level theory/harmony courses have you taken? [Note: one university/college year equals eight months.]

24-26

Now turn back to PART B on the Instruction page and listen to the tape.

MELODIC INTERVAL IDENTIFICATION ANSWER SHEET

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

NUMBER	NAME	
25		33
26		34
27		35
28		36
29		37
30		38
31		39
32		40
33		41
34		42
35		43
36		44
37		45
38		46
39		47
40		48
41		49
42		50
43		51
44		52
45		53
46		54
47		55
48		56

NUMBER	NAME	
49		57
50		58
51		59
52		60
53		61
54		62
55		63
56		64
57		65
58		66
59		67
60		68
61		69
62		70
63		71
64		72
65		73
66		74
67		75
68		76
69		77
70		78
71		79
72		80

Appendix 3

List and Specifications of Equipment used for the Study

The following is the list of equipment which was used for the study.

List and Specifications of Equipment used for the Study

Recording:

Microphone:	AKG C34
Mixing Board:	Soundcraft Series Two
Tape deck:	Otari MX 5050 quarter-inch half track
Tape:	Ampex #456, recorded at 15 i.p.s.
Synthesizer:	Roland 100M
Analyzer:	Klark Technic Model DN60 Real Time Spectrum Analyzer
Equalizer:	Audio Design Scamp Sweep Equalizer
Noise Gate:	Orange County Electronics Model CLX Dynamic Range Processor
Oscilloscope:	Heathkit Model IO-4550 DC to 10 MHz Dual-trace oscilloscope

Playback:

Tape Recorder:	Sony TC-630 combined tape recorder, amplifier, and speakers
Frequency Response:	30 Hz - 18000 Hz ±3 dB at 7.5 i.p.s.
Wow and Flutter:	.08 % at 7.5 i.p.s.
Harmonic Distortion:	.4 % at 0 VU at 7.5 i.p.s.
Signal/Noise Ratio:	-56 dB at 7.5 i.p.s.

Meters:

Realistic Model 42-3019 Sound Level Meter, set on dBA scale
Peterson Model 400 Stroboscope (±2 cents)
Pearl Model TC-102 Tuning Meter (±2 cents)
Boss Model DB-33 electronic metronome

Appendix 4

Contents of the Test Tape

The following is the sequence in which items were recorded on the test tape which was played to subjects.

Contents of the Test Tape

A one minute reference tone (A = 440 Hz) was placed on the tape, followed by the instructions. Appropriate pauses were inserted to allow time for subjects to complete the questionnaire and to ask any questions. Three practice intervals were placed on the tape after the instructions. These three intervals consisted of P4, P5, and P8, played on piano. No answers were provided for the practice intervals. Following these instructions was the actual test, which had the following pattern:

question #	interval	pause	interval	pause
6 seconds	2 sec.	2 sec.	2 sec.	2 sec.

At the end of the tape, subjects were told: "This completes the testing. Thank you for your assistance and cooperation."

Appendix 5

Interval Randomization Program

The following program was written by Mr. Steve White of the Educational Research Service Center of the University of British Columbia. It is designed to run on an Apple micro-computer with a minimum memory of 16K.

Interval Randomization Program

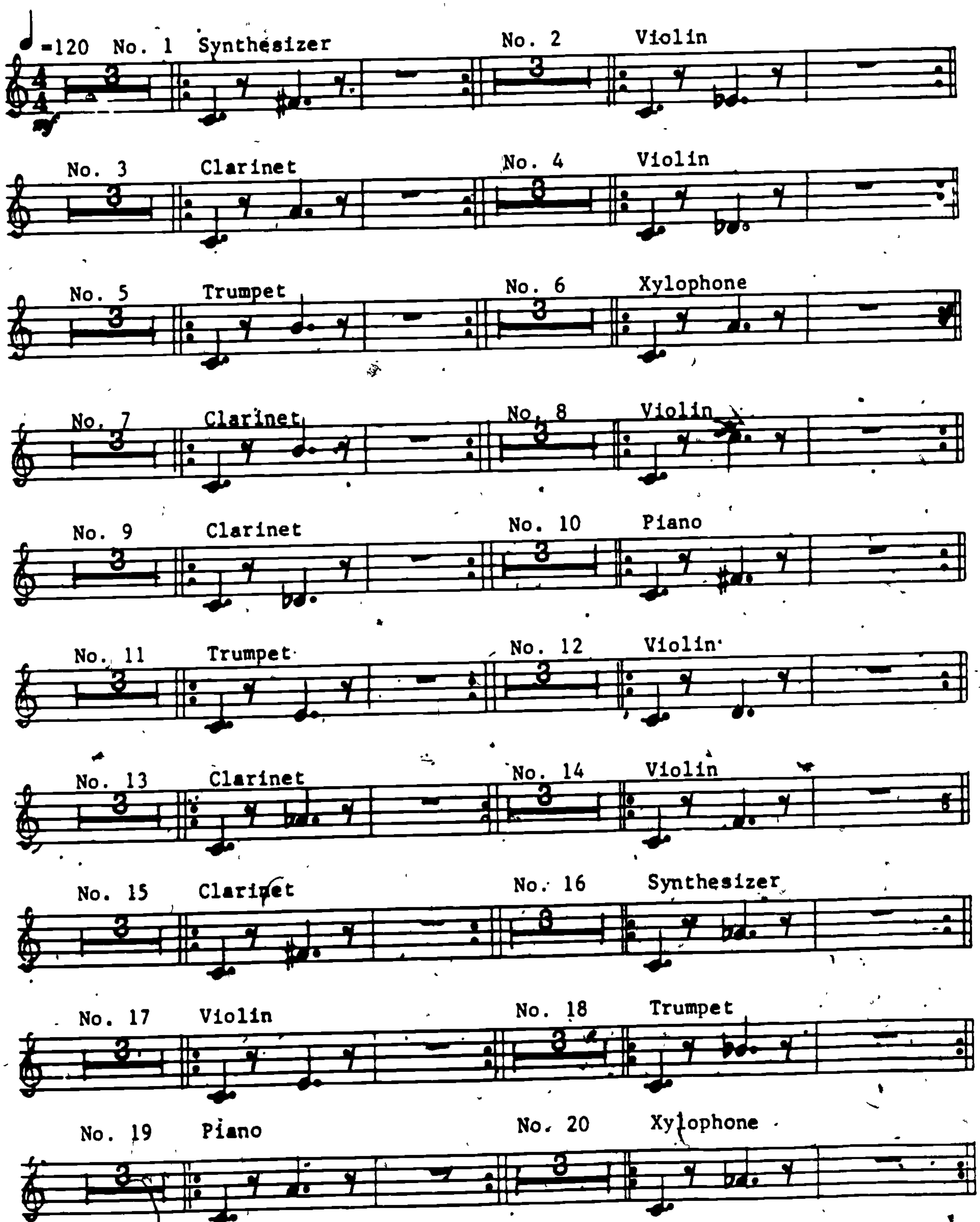
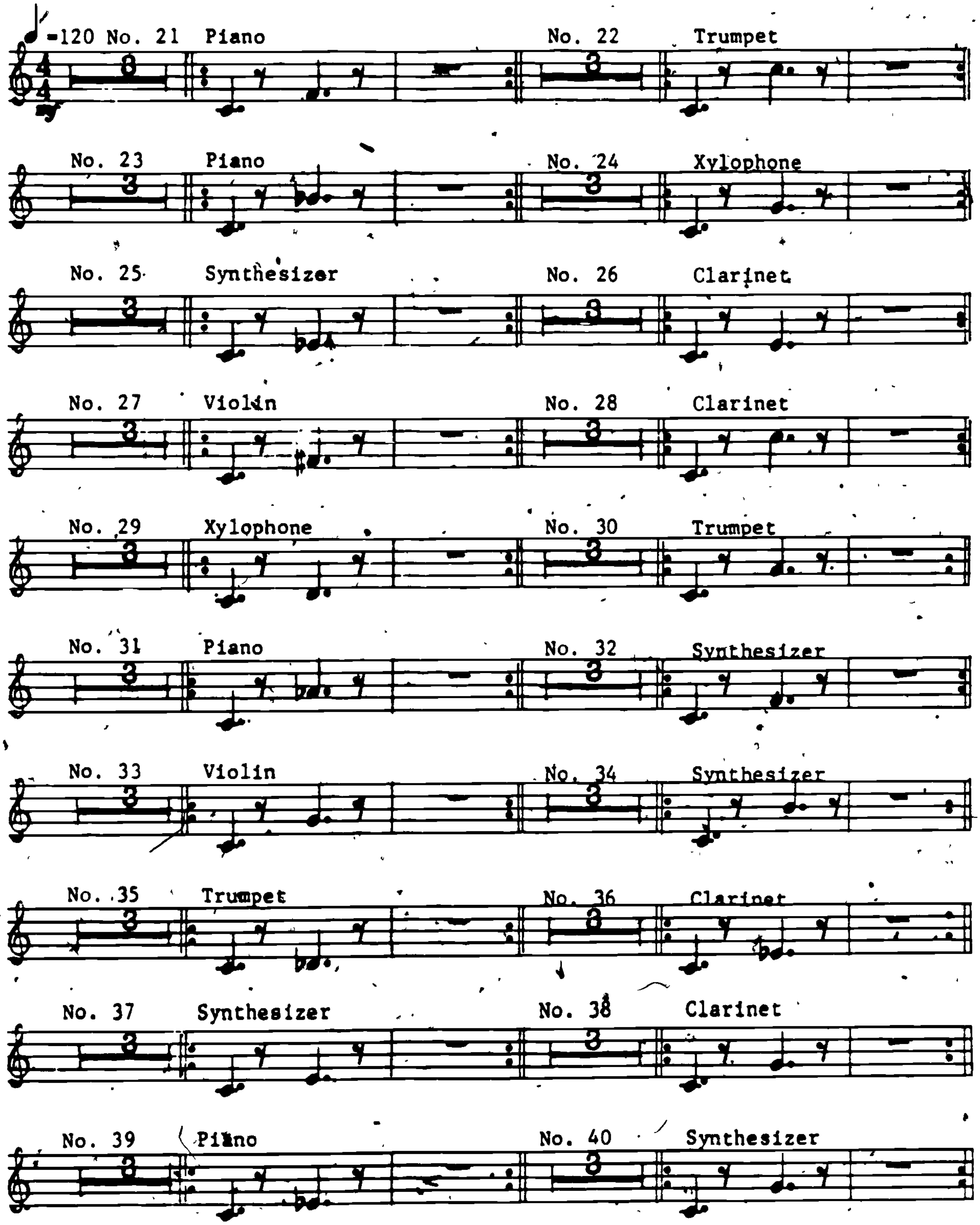
```
10  DIM A(72),S$(72),V(72),U(72)
20  FOR I = 1 TO 72
39  READ A(I)
40  NEXT I
60  FOR I = 1 TO 72
69  READ S$(I)
70  NEXT I
100 DATA  101,102,103,104,105,106
101 DATA  107,108,109,110,111,112
102 DATA  201,202,203,204,205,206
103 DATA  207,208,209,210,211,212
104 DATA  301,302,303,304,305,306
105 DATA  307,308,309,310,311,312
106 DATA  401,402,403,404,405,406
107 DATA  407,408,409,410,411,412
108 DATA  501,502,503,504,505,506
109 DATA  507,508,509,510,511,512
110 DATA  601,602,603,604,605,606
111 DATA  607,608,609,610,611,612
200 DATA  "PIANO -2","PIANO +2","PIANO -3"
201 DATA  "PIANO +3","PIANO P4","PIANO X4"
202 DATA  "PIANO P5","PIANO -6","PIANO +6"
203 DATA  "PIANO -7","PIANO +7","PIANO P8"
204 DATA  "CLAR -2","CLAR +2","CLAR -3"
205 DATA  "CLAR +3","CLAR P4","CLAR X4"
206 DATA  "CLAR P5","CLAR -6","CLAR +6",
207 DATA  "CLAR -7","CLAR +7","CLAR P8"
208 DATA  "TPT  -2","TPT  +2","TPT  -3"
209 DATA  "TPT  +3","TPT  P4","TPT  X4"
210 DATA  "TPT  P5","TPT  -6","TPT  +6"
211 DATA  "TPT  -7","TPT  +7","TPT  P8"
212 DATA  "VIOLIN -2","VIOLIN +2","VIOLIN -3"
213 DATA  "VIOLIN +3","VIOLIN P4","VIOLIN X4"
214 DATA  "VIOLIN P5","VIOLIN -6","VIOLIN +6"
215 DATA  "VIOLIN -7","VIOLIN +7","VIOLIN P8"
216 DATA  "XYLOPH -2","XYLOPH +2","XYLOPH -3"
217 DATA  "XYLOPH +3","XYLOPH P4","XYLOPH X4"
218 DATA  "XYLOPH P5","XYLOPH -6","XYLOPH +6"
219 DATA  "XYLOPH -7","XYLOPH +7","XYLOPH P8"
220 DATA  "SYNTH  -2","SYNTH +2","SYNTH -3"
221 DATA  "SYNTH  +3","SYNTH P4","SYNTH X4"
222 DATA  "SYNTH  P5","SYNTH -6","SYNTH +6"
223 DATA  "SYNTH  -7","SYNTH +7","SYNTH P8"
```

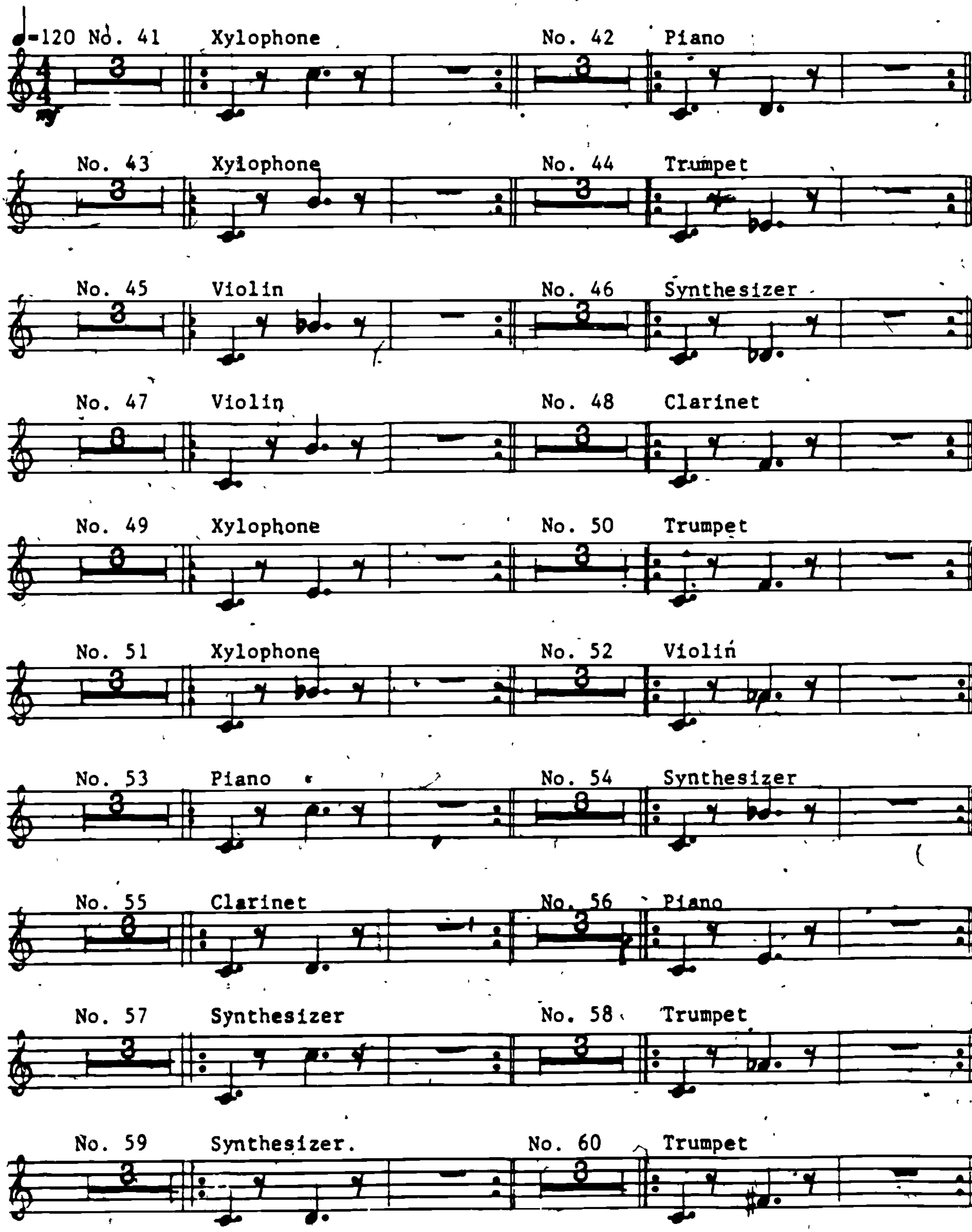
```
300  OLDN =  INT (72 *  RND (1) + 1)
310  V(1) = OLDN:U(OLDN) = 1
320  I = 2
400  N =  INT (72 *  RND (1) + 1)
410  IF  INT (A(N) / 100) =  INT (A(OLDN) / 100) THEN 400
420  T1 =  INT (A(OLDN)) - ( INT (A(OLDN) / 100) * 100)
422  T2 =  INT (A(N)) - ( INT (A(N) / 100) * 100)
423  IF T1 = T2 THEN 400
425  IF U(N) = 1 THEN 400
430  U(N) = 1
440  V(I) = N:OLDN = N:I = I + 1
450  IF I = 73 THEN 1000
460  GOTO 400
1000 REM  PRINTOUT
1111 FOR I = 1 TO 72
1122 PRINT  SPC( I < 10)I;"
1125 " SPC( V(I) < 100) SPC( V(I) < 10)V(I) TAB( 10)A(V(I));"
1130 TAB(20)S$(V(I))
1133 NEXT I
3333 END
```

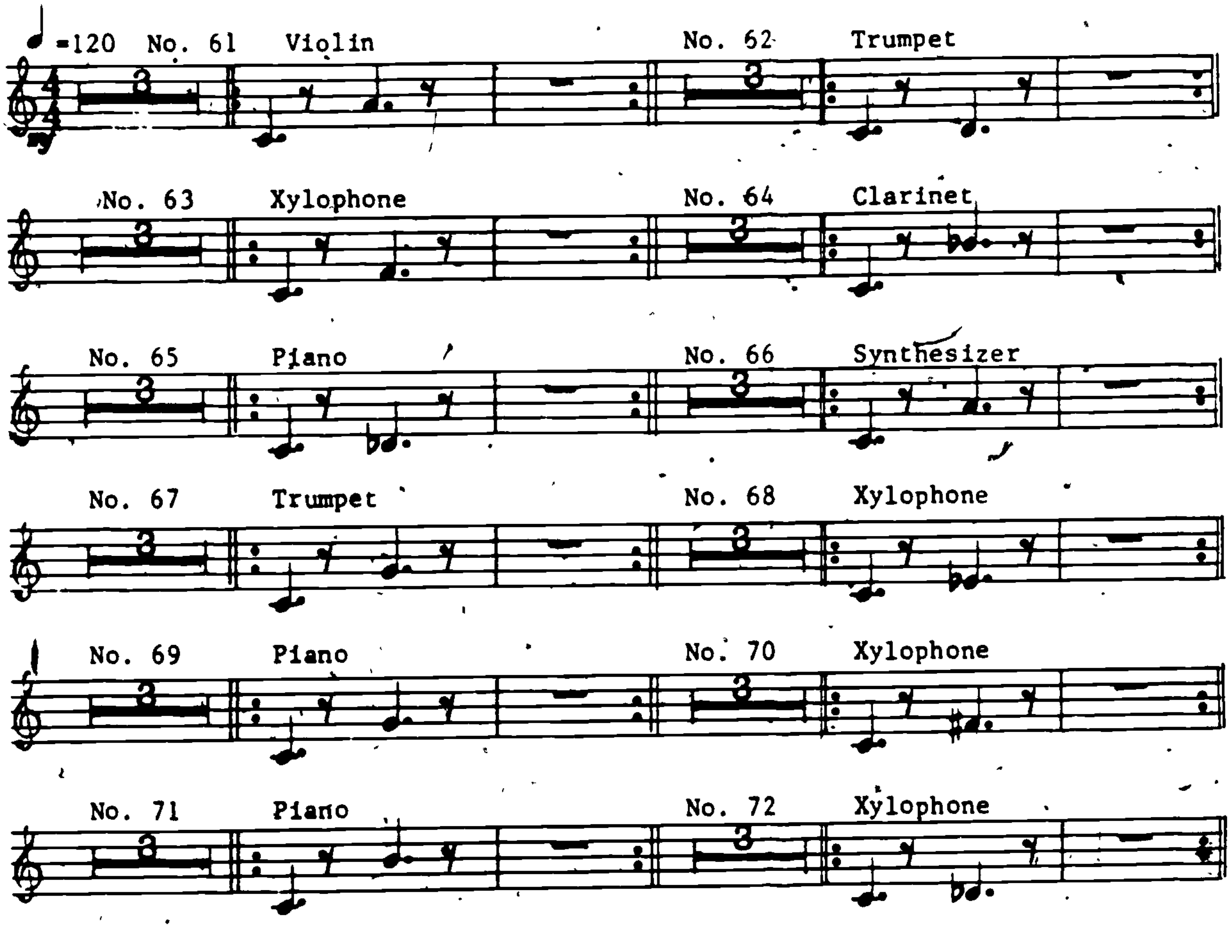
Appendix 6

Order of Intervals as Played to Subjects

The following pages contain the order in which the various intervals were presented to subjects.

Order of Intervals as Played to Subjects


♩=120 No. 21 Piano
No. 22 Trumpet
No. 23 Piano
No. 24 Xylophone
No. 25 Synthesizer
No. 26 Clarinet
No. 27 Violin
No. 28 Clarinet
No. 29 Xylophone
No. 30 Trumpet
No. 31 Piano
No. 32 Synthesizer
No. 33 Violin
No. 34 Synthesizer
No. 35 Trumpet
No. 36 Clarinet
No. 37 Synthesizer
No. 38 Clarinet
No. 39 Piano
No. 40 Synthesizer


♩=120 No. 41 Xylophone
No. 42 Piano
No. 43 Xylophone
No. 44 Trumpet
No. 45 Violin
No. 46 Synthesizer
No. 47 Violin
No. 48 Clarinet
No. 49 Xylophone
No. 50 Trumpet
No. 51 Xylophone
No. 52 Violin
No. 53 Piano
No. 54 Synthesizer
No. 55 Clarinet
No. 56 Piano
No. 57 Synthesizer
No. 58 Trumpet
No. 59 Synthesizer.
No. 60 Trumpet


=120
No. 61 Violin
No. 62 Trumpet
No. 63 Xylophone
No. 64 Clarinet
No. 65 Piano
No. 66 Synthesizer
No. 67 Trumpet
No. 68 Xylophone
No. 69 Piano
No. 70 Xylophone
No. 71 Piano
No. 72 Xylophone

Appendix 7

Coding Method Used for Identifying Responses

The following page contains the details of the coding method used to identify subjects' responses in order to facilitate computer scoring and analysis.

Coding Method Used for Identifying Responses

Subjects' response forms were hand coded, and the coding checked for accuracy according to the following code:

m2	M2	m3	M3	P4	X4	P5	m6	M6	m7	M7	P8	Blank
1	2	3	4	5	6	7	8	9	0	-	+	?

The subjects' answers to the background information questionnaire were also coded, with a letter code being used for those instruments which subjects listed under "OTHER". Once these codings had been done and the data had been keypunched, all response codings and the keypunched cards were checked to ensure accuracy. The few errors which were found were corrected, and analysis of the data was then carried out. In order to simplify the analysis, a program was written to translate the interval answers from the original thirteen level code to a two level code which indicated only whether an answer was correct or incorrect:

Wrong	Right
1	2

The LERTAP output of scores was subsequently used as input for SPSS and MULTIVAR programs.

Appendix 8

The Computer Program used for Conversion of Scores

The following program was written by Dr. R. E. Bruce of the Educational Research Service Center (ERSC) at the University of British Columbia.

The Computer Program used for Conversion of Scores

```
00050 REM THIS PROGRAM RUNS UNDER WATEROO BASIC V2.0
00100 REM THIS CODE CONVERTS DATA FROM '1 THRU 9,0,-,+,?'
00150 REM TO '00-12'.
00200 REM DHDATA CONTAINS INPUT DATA IN FORM 'XXXX   YY:::Y'
00225 REM WHERE XXXX IS THE RECORD ID,
00250 REM AND Y EQUALS THE RESPONSE-72 RESPONSES ALLOWED.
00300 REM DATA CONTAINS OUTPUT IN THE FORM '00-05' FOR LERTAP
00350 REM -CONVERTS CONTAINS DATA IN THE FORM '00-12'.
00400 REM DALMUSKEY CONTAINS THE CORRECT RESPONSES FOR
00425 REM QUESTION AT 1 PER CARD.
00450
00500 DIM CHAR$(151),RIGHT(151)
00550 ON EOF IGNORE
00600 OPEN #2,'DHDATA',INPUT
00650 OPEN #3,'-CONVERTS',OUTPUT
00700 FORMAT$ ="######################################"&
00750 &+"#########################################"
00800 PRINT "PLEASE ENTER THE NUMBER OF CASES"
00850 INPUT CASES
00900 FOR J=1 TO CASES
00950   INPUT #2,USING FORMAT$,A$
01000   B$ = STR$(A$,1,7)
01050   FOR I=8 TO 79
01100     CHAR$(I) = STR$(A$,I,1)
01150     IF CHAR$(I) = "0"
01200     CHAR$(I) = "10"
01250     ELSEIF CHAR$(I) = "-"
01300     CHAR$(I) = "11"
01350     ELSEIF  CHAR$(I) = "+"
01400     CHAR$(I) = "12"
01450     ELSEIF CHAR$(I) = "?"
01500     CHAR$(I) = "00"
01550     ELSE
01600     CHAR$(I) = "0"+CHAR$(I)
01650     ENDIF
01700     B$ = B$ + CHAR$(I)
01750   NEXT I
01800   PRINT #3,B$
01850 NEXT J
01860
01870
01900 REM THIS CODE CONVERTS DATA FROM '00-12' TO '01-02'
01925 REM FOR LERTAP RUN
```

```
01950   OPEN #4,'DALMUSKEY',INPUT
02000   OPEN #5,'-CONVERTS',INPUT
02050   OPEN #6,'DATA',OUTPUT
02100   FORMS$="####################################"&
02150         &+"####################################"&
02200         &+"####################################"&
02250         &+"###########################################"
02300   FOR I=8 TO 150 STEP 2
02350        INPUT #4, RIGHT(I)
02400   NEXT I
02450   FOR C=1 TO CASES
02500        INPUT #5,USING FORMS$,A$
02550        B$ = STR$(A$,1,7)
02600        FOR I=8 TO 150 STEP 2
02650             CHAR$(I) = STR$(A$,I,2)
02700             IF CHAR$(I)="00"
02750    ANS$="01"
02800                GOTO 3650
02850             ENDIF
02900             WRONG = RIGHT(I) - VALUE(CHAR$(I))
03000    IF WRONG = 0
03050       ANS$="02"
03100    ELSE
03150       ANS$="01"
03600             ENDIF
03650             B$ = B$ + ANS$
03700         NEXT I
03750         PRINT #6,B$
03800   NEXT C
03850   END
```

Appendix 9

The Computer Program used for Transformation and Standardization of Scores

The following program was written by Dr. R. E. Bruce of the Educational Research Service Center (ERSC) at the University of British Columbia.

The Computer Program used for Transformation and Standardization of Scores

```
00100     REM THIS PROGRAM RUNS UNDER WATERLOO BASIC V2.0
00100     DIM TOTAL(19),DEV(19),MEAN(19),STDDEV(19),NUMSCORE(19)
00110     PRINT "DATA MUST BE IN SCORES1 IN FOLLOWING FORMAT:
00115     FORMAT ICLCAbbbS1S2S3S4S5S6";
00120     PRINT " WHERE I=INSTITUTE, CL=CLASS, CA= CASE, S1-S6
00122     ARE SCORES"
00125     PRINT"RESULTS WILL BE IN '-AZSCORES6' A SCRATCH FILE!"
00130     CASES=0
00150     ON EOF IGNORE
00200     OPEN #2,'SCORES1',INPUT
00250     OPEN #3,'-ASCORES2',OUTPUT
00253     OPEN #4,'-ASCORES3',OUTPUT
00255     FORMAT$="####################"
00260     INPUT #2,USING FORMAT$,A$
00265     FIRST$=A$
00270     GOTO 280
00275     INPUT #2,USING FORMAT$,A$
00280     IF IOSTATUS(2)=1 THEN GOTO 730
00282     REM NO RECORD FOUND IN SCORES1
00285     CASES=CASES+1
00295     C = VALUE(STR$(A$,2,2))
00300     FOR I=9 TO 19 STEP 2
00350           B$ = STR$(A$,1,8)
00400           OLDSCORE=VALUE(STR$(A$,I,2))
00405           OLDSCORE = OLDSCORE/12
00410           IF OLDSCORE=0
00420              NEWSCORE=2*ASIN(SQR(1/48))
00430           ELSEIF OLDSCORE=1
00440              NEWSCORE=PI - 2*ASIN(SQR(1/48))
00450           ELSE
00460               NEWSCORE=2*ASIN(SQR(OLDSCORE))
00470           ENDIF
00480           NEWSCORE$ = VALUE$(NEWSCORE)
00490           B$= B$ + NEWSCORE$
00500           PRINT #3,B$
00510           TOTAL(C) = TOTAL(C) + NEWSCORE
00520           NUMSCORE(C) = NUMSCORE(C) + 1
00600     NEXT I
00720     GOTO 275
00730     FOR C = 1 TO 19
00733           IF NUMSCORE(C) = 0 THEN GOTO 750
00740           MEAN(C) = TOTAL(C)/NUMSCORE(C)
```

```
00745      SUMM = SUMM + NUMSCORE(C)
00750  NEXT C
00760  CLOSE #3
00765  PRINT "TOTAL # OF CASES AND FIRST CASE =";CASES;FIRST$
00770  OPEN #3,'-ASCORES2',INPUT
00800  INPUT #3,A$
00850  D = VALUE(STR$(A$,2,2))
00900  SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
00950  DEV(D) = DEV(D) + (SCORE - MEAN(D))**2
01000  FOR L = 2 TO SUMM
01025      INPUT #3,A$
01040      D = VALUE(STR$(A$,2,2))
01050      SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
01100      DEV(D) = DEV(D) + (SCORE - MEAN(D))**2
01150  NEXT L
01155  FOR C = 1 TO 19
01160      IF TOTAL(C) = 0 THEN GOTO 1170
01165      STDDEV(C) = SQR(DEV(C)/(NUMSCORE(C)-1))
01170  NEXT C
01180  CLOSE #3
01182
01183
01185  PRINT"CALCULATING ZSCORES FOR EACH CLASS"
01190  OPEN #3,'-ASCORES2',INPUT
01200  INPUT #3,A$
01225  B$ = STR$(A$,1,8)
01250  D = VALUE(STR$(A$,2,2))
01300  SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
01330  ZSCORE = (SCORE - MEAN(D))/STDDEV(D)
01350  B$ = B$ + VALUE$(ZSCORE)
01360  FORMS$ ="##########.######"
01390  PRINT #4,USING FORMS$,B$
01400  FOR L = 2 TO SUMM
01450      INPUT #3,A$
01475      B$ = STR$(A$,1,8)
01500      D = VALUE(STR$(A$,2,2))
01550      SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
01600      ZSCORE = (SCORE - MEAN(D))/STDDEV(D)
01605      IF ZSCORE > 0
01610          IF ZSCORE < 1
01613              CORRANS$ ="0"+VALUE$(ZSCORE)
01614              B$ = B$ +CORRANS$
01615              GOTO 1630
01617          ENDIF
01619      ENDIF
01620      B$ = B$ +VALUE$(ZSCORE)
01630      PRINT #4,USING FORMS$,B$
01650  NEXT L
01700  CLOSE #2
01725  CLOSE #3
01750  CLOSE #4
01760
01770
```

```
01800   PRINT"CALCULATING ZSCORES FOR EACH INSTITUTION"
02000   DIM INSTOTAL(3),INSDEV(3),INSMEAN(3),INSSTDDEV(3),
02005   INSNUMSCORE(3)
02010   OPEN #2,'-ASCORES3',INPUT
02020   OPEN #4,'-ASCORES5',OUTPUT
02030   FOR J=1 TO SUMM
02040        INPUT #2,A$
02050        IF STR$(A$,1,1)<>" "
02060             C = VALUE(STR$(A$,1,1))
02070        ELSEIF STR$(A$,2,1)<>" "
02080             C = VALUE(STR$(A$,2,1))
02090        ELSEIF STR$(A$,3,1)<>" "
02100             C = VALUE(STR$(A$,3,1))
02110        ELSEIF STR$(A$,4,1)<>" "
02120             C = VALUE(STR$(A$,4,1))
02130        ENDIF
02140        NEWSCORE = VALUE(STR$(A$,9,9))
02150        INSTOTAL(C) = INSTOTAL(C) + NEWSCORE
02160        INSNUMSCORE(C) = INSNUMSCORE(C) + 1
02170   NEXT J
02180   FOR C = 1 TO 3
02190        IF INSNUMSCORE(C) = 0 THEN GOTO 2220
02200        INSMEAN(C) = INSTOTAL(C)/INSNUMSCORE(C)
02210        PRINT "C AND INSNUMSCORE(C) ARE";C,INSNUMSCORE(C)
02220   NEXT C
02230   OPEN #3,'-ASCORES3',INPUT
02240   INPUT #3,A$
02260   IF STR$(A$,1,1)<>" "
02270       D = VALUE(STR$(A$,1,1))
02280   ELSEIF STR$(A$,2,1)<>" "
02290       D = VALUE(STR$(A$,2,1))
02300   ELSEIF STR$(A$,3,1)<>" "
02310       D = VALUE(STR$(A$,3,1))
02320   ELSEIF STR$(A$,4,1)<>" "
02330       D = VALUE(STR$(A$,4,1))
02340   ENDIF
02350   SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
02370   INSDEV(D) = INSDEV(D) + (SCORE - INSMEAN(D))**2
02380   FOR L = 2 TO SUMM
02390        INPUT #3,A$
02400        IF STR$(A$,1,1)<>" "
02410             D = VALUE(STR$(A$,1,1))
02420        ELSEIF STR$(A$,2,1)<>" "
02430             D = VALUE(STR$(A$,2,1))
02440        ELSEIF STR$(A$,3,1)<>" "
02450             D = VALUE(STR$(A$,3,1))
02460        ELSEIF STR$(A$,4,1)<>" "
02470             D = VALUE(STR$(A$,4,1))
02480        ENDIF
02490        SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
02500        INSDEV(D) = INSDEV(D) + (SCORE - INSMEAN(D))**2
02510   NEXT L
02520   FOR C = 1 TO 3
```

```
02530          IF INSTOTAL(C) = 0 THEN GOTO 2550
02540          INSSTDDEV(C) = SQR(INSDEV(C)/(INSNUMSCORE(C)-1))
02550      NEXT C
02560      CLOSE #3
02570      OPEN #3,'-ASCORES3',INPUT
02580      INPUT #3,A$
02600      B$ = STR$(A$,1,8)
02610      IF STR$(A$,1,1)<>" "
02620          D = VALUE(STR$(A$,1,1))
02630      ELSEIF STR$(A$,2,1)<>" "
02640          D = VALUE(STR$(A$,2,1))
02650      ELSEIF STR$(A$,3,1)<>" "
02660          D = VALUE(STR$(A$,3,1))
02670      ELSEIF STR$(A$,4,1)<>" "
02680          D = VALUE(STR$(A$,4,1))
02690      ENDIF
02700      SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
02710      ZSCORE = (SCORE - INSMEAN(D))/INSSTDDEV(D)
02720      B$ = B$ + VALUE$(ZSCORE)
02730      PRINT #4,USING FORMS$,B$
02740      FOR L = 2 TO SUMM
02750           INPUT #3,A$
02760           B$ = STR$(A$,1,8)
02770           IF STR$(A$,1,1)<>" "
02780               D = VALUE(STR$(A$,1,1))
02790           ELSEIF STR$(A$,2,1)<>" "
02800               D = VALUE(STR$(A$,2,1))
02810           ELSEIF STR$(A$,3,1)<>" "
02820               D = VALUE(STR$(A$,3,1))
02830           ELSEIF STR$(A$,4,1)<>" "
02840               D = VALUE(STR$(A$,4,1))
02850           ENDIF
02860           SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
02870           ZSCORE = (SCORE - INSMEAN(D))/INSSTDDEV(D)
02880           IF ZSCORE > 0
02890               IF ZSCORE < 1
02900                   CORRANS$ ="0"+VALUE$(ZSCORE)
02910                   B$ = B$ +CORRANS$
02920                   GOTO 2960
02930               ENDIF
02940           ENDIF
02950           B$ = B$ +VALUE$(ZSCORE)
02960           PRINT #4,USING FORMS$,B$
02970      NEXT L
02980      CLOSE #2
02985      CLOSE #3
02990      CLOSE #4
02992
02993
02995      PRINT "CALCULATING ZSCORES FOR WHOLE STUDY"
03000      OPEN #2,'-ASCORES5',INPUT
03010      OPEN #4,'-AZSCORES6',OUTPUT
03020      FOR J=1 TO SUMM
```

```
03030          INPUT #2,A$
03040          NEWSCORE = VALUE(STR$(A$,9,9))
03050          TOTAL = TOTAL + NEWSCORE
03060          NUMSCORE = NUMSCORE + 1
03070     NEXT J
03080     MEAN = TOTAL/NUMSCORE
03100     OPEN #3,'-ASCORES5',INPUT
03110     INPUT #3,A$
03130     SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
03150     DEV = DEV + (SCORE - MEAN)**2
03160     FOR L = 2 TO SUMM
03170          INPUT #3,A$
03180          SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
03190          DEV = DEV + (SCORE - MEAN)**2
03200     NEXT L
03210     STDDEV = SQR(DEV/(NUMSCORE-1))
03220     CLOSE #3
03230     OPEN #3,'-ASCORES5',INPUT
03240     INPUT #3,A$
03260     B$ = STR$(A$,1,8)
03270     SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
03280     ZSCORE = (SCORE - MEAN)/STDDEV
03290     B$ = B$ + VALUE$(ZSCORE)
03300     PRINT #4,USING FORMS$,B$
03310     FOR L = 2 TO SUMM
03320          INPUT #3,A$
03330          B$ = STR$(A$,1,8)
03340          SCORE = VALUE(STR$(A$,9,LEN(A$)-8))
03350          ZSCORE = (SCORE - MEAN)/STDDEV
03360          IF ZSCORE > 0
03370               IF ZSCORE < 1
03380                    CORRANS$ ="0"+VALUE$(ZSCORE)
03390                    B$ = B$ +CORRANS$
03400                    GOTO 3440
03410               ENDIF
03420          ENDIF
03430          B$ = B$ +VALUE$(ZSCORE)
03440          PRINT #4,USING FORMS$,B$
03450     NEXT L
03460     END
```

Appendix 10

Cell Means, Variance, and Standard Deviation for PPEM and FETE

Cell Means, Variance, and Standard Deviation for PPEM and FETE

	1 CLAR	2 TPT	3 PIANO	4 VIOLIN	5 XYLO	6 SYNTH
1	-0.093367	-0.471181	-0.078006	-0.217122	-0.159962	-0.383301
2	-0.728841	-0.201721	-0.180303	-0.591978	-0.179510	-0.580371
3	0.034976	-0.054967	0.373590	0.134626	0.26[illegible]914	-0.291997
4	-0.190111	-0.438849	0.182536	-0.326063	-0.199174	-0.178917
5	-0.357150	-0.223257	-0.093314	-0.669506	-0.191807	-0.275256
6	-0.202091	-0.577450	0.096061	-0.211612	-0.193966	-0.262738
7	0.340628	0.223819	0.620512	0.319088	0.519422	0.451820
8	0.323035	0.328169	0.618532	0.224381	0.493131	0.450802
9	0.382758	0.306526	0.510326	0.420357	0.381271	0.475596

CELL	N	FACTOR LEVELS PPEM	FETE
1	22	1	1
2	12	1	2
3	8	1	3
4	31	2	1
5	30	2	2
6	33	2	3
7	22	3	1
8	21	3	2
9	33	3	3

TOTAL N= 212.

VARIABLE	VARIANCE (ERROR MEAN SQUARES)	STANDARD DEVIATION
1 CLAR	0.865008	0.9301
2 TPT	1.085915	1.0421
3 PIANO	0.682491	0.8261
4 VIOLIN	1.127537	1.0619
5 XYLO	0.850596	0.9223
6 SYNTH	0.902126	0.9498

Appendix 11

Cell Means, Variance, and Standard Deviation for MAJOR

Cell Means, Variance, and Standard Deviation for MAJOR

OBSERVED CELL MEANS

CELL	N	1 CLAR	2 TPT	3 PIANO	4 VIOLIN	5 XYLO	6 SYNTH
1	15	-0.353136	-0 399545	-0.016087	-0.557783	-0.109476	-0 188768
2	18	-0.478090	-0 522879	-0.175050	-0.586022	-0.596281	-0.502687
3	73	0.252929	0.183662	0 449624	0.273159	0.368608	0.316087
4	39	0.051041	-0.031357	0.267674	-0.099400	0.300601	-0.142131
5	73	-0.190509	-0.363950	0.138231	-0.285756	-0.155613	-0.134370

TOTAL N= 218

VARIABLE	VARIANCE (ERROR MEAN SQUARES)	STANDARD DEVIATION
1 CLAR	0.877934	0.9370
2 TPT	1.095814	1.0468
3 PIANO	0.717905	0.8473
4 VIOLIN	1.150263	1.0725
5 XYLO	0.819196	0.9051
6 SYNTH	0.952603	0.9760