69-21,990

SISSON, Jack Ulness, 1922-

PITCH PREFERENCE DETERMINATION, A COMPARATIVE STUDY OF TUNING PREFERENCES OF MUSICIANS FROM THE MAJOR PERFORMING AREAS WITH REFERENCE TO JUST INTONATION, PYTHAGOREAN TUNING, AND EQUAL TEMPERAMENT.

The University of Oklahoma, D.Mus.Ed., 1969
Music

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

PITCH PREFERENCE DETERMINATION, A COMPARATIVE STUDY OF TUNING PREFERENCES OF MUSICIANS FROM THE MAJOR PERFORMING AREAS WITH REFERENCE TO JUST INTONATION, PYTHAGOREAN TUNING, AND EQUAL TEMPERAMENT

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF MUSIC EDUCATION

BY

JACK ULNESS SISSON

Norman, Oklahoma

1969

PITCH PREFERENCE DETERMINATION, A COMPARATIVE STUDY OF TUNING PREFERENCES OF MUSICIANS FROM THE MAJOR PERFORMING AREAS WITH REFERENCE TO JUST INTONATION, PYTHAGOREAN TUNING, AND EQUAL TEMPERAMENT

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGEMENTS

I would like to express appreciation to the many student musicians at the University of Oklahoma and Central State College and to other musicians, both teachers and performing professionals who gave of their time so that this study could be made.

Thanks should also go to my colleagues at Central State College, Mr. Robert Dillon and Mr. Melvin Lee, for their interest and helpful suggestions in regard to the development of this study.

Thanks should also go to the members of my committee, Dr. Robert C. Smith, who served as chairman, Dr. Gene Braught, Dr. Gail deStwolinski, and Dr. Margaret Haynes for their helpful suggestions in regard to preparing the final copy.

I am especially appreciative of the help and encouragement given to me by Dr. Smith. He gave liberally of his time in preparing the study and later in interpreting and reporting the data.

Special thanks are due my wife, Dorothy, for her assistance in typing and proofreading the manuscript. Without her valuable assistance it is doubtful that this study would have been completed.

TABLE OF CONTENTS

LIST OF TABLES

PITCH PREFERENCE DETERMINATION, A COMPARATIVE STUDY OF TUNING PREFERENCES OF MUSICIANS FROM THE MAJOR PERFORMING AREAS WITH REFERENCE TO JUST INTONATION, PYTHAGOREAN TUNING, AND EQUAL TEMPERAMENT

CHAPTER I

INTRODUCTION

The problems of intonation in musical performance practices are so complex that the results achieved by some of our fine musical organizations, when taking into consideration all of these problems, are most remarkable. Prominent among these problems are: the effects of temperature upon the pitch level of instruments, the acoustical defects of instruments, the physical effects of extended playing upon the performer, and the varying philosophies in regard to pitch tendencies and systems of tuning. The last of the above-mentioned problems served as motivation for this study.

Over a period of approximately thirty years, first as a performing musician and then as a conductor, the writer has become acutely aware of certain rules of pitch performance that seem to contradict one another. For example, there are two much-repeated rules in regard to the treatment of the third of a major triad. One rule states that the major third should be raised. This rule is substantiated by Bartholomew when he makes the following statement: "Certain modern *a cappella* groups are trained to sing certain intervals more or less altered. . . . Particularly are the major thirds on tonic and dominant made sharper."[1] The other rule states that the major third should be lowered. Redfield makes the following statement to substantiate this rule: "Play all the major thirds as flat as the ear can bear . . . don't listen to or be influenced by any keyboard instrument."[2] Here are two completely opposite views; yet the interested student can readily find additional support for either as will be shown later. Another contradiction occurs when melodic and harmonic pitch tendencies are compared. In melodic tendencies it is often stated that the leading tone should be raised and that sharped notes should be played higher than their enharmonic flatted notes. For example, F sharp should be higher than the enharmonic G flat. In harmonic instances, the major thirds should be lowered and the seventh of the dominant seventh should be played extremely low in the direction of its resolution. The contradiction

[1]Wilmer T. Bartholomew, *Acoustics of Music* (Englewood Cliffs, New Jersey: Prentice Hall Company, 1942), pp. 185-186.

[2]John Redfield, *Music, A Science and an Art* (New York: Tudor Publishing Company, 1935), p. 307.

here lies not so much in the rules as in their application. The Nickerson study[1] was made in order to test the validity of these two statements in regard to harmonic and melodic tendencies. When do melodic considerations take precedence over harmonic considerations? Consider a melody in the key of C major where B natural appears as the leading tone. By applying the rule of melodic tendencies, this note would be played high. In addition to its occurrence as the leading tone, this B natural could also be the third of a dominant triad, a fact that would cause it to be played low when applying the rule in regard to harmonic tendencies. In music involving melody and accompaniment it would be difficult to conceive of a situation where a tone common to both melody and accompaniment should be raised in the solo part and lowered in the accompaniment and still give satisfactory results. Yasser states, "The better an intonation serves for harmonic constructions, the worse does it answer melodic purposes and vice versa."[2] To add to the confusion, when such rules are given they often lack positive directions. Consider the melodic rule in regard to raising the third degree of the scale. If this tone is raised, it presupposes some standard third degree, which is a point of reference.

---

[1]James F. Nickerson, "Comparing Intonation of Solo and Ensemble Performance," Music Journal, VII (March-April, 1950), pp. 21, 50, 51.

[2]Joseph Yasser, A Theory of Evolving Tonality (New York: American Library of Musicology, 1932), p. 28.

There must also be some limitation placed upon the amount that this pitch can be raised and still not lose its identity as the third degree of the scale.

When standards of tuning are examined, the greatest contradiction of all arises. In the past one found evidence of many systems of tuning; but there are still in existence three, each of which has its staunch supporters. Some musicians still hold to the Pythagorean System of tuning, particularly in melodic considerations; others advocate just intonation, and still others adhere to the system of equal tempered tuning. Recognition should here be given to the existence of a system of mean-tone tuning, although its use today is limited.

Need for the Study

Since musicians, as a group, are dedicated to excellence in performance, an attempt should be made to clarify these contradictions that exist in pitch practices. Pitch as a major factor in musical performance can completely destroy an otherwise satisfactory musical rendition. Misguided or misunderstood directions can vitally affect the pitch performance of a musical organization.

Ralph Pottle stresses the importance of intonation in the following statement: "When instrumentalists achieve precise tuning the resultant tone is one of mellowness--possessed of a lush quality--devoid of stridence."[1]

An examination of these contradictory rules in regard to pitch performances shows that the contradictions usually arise in regard to different areas of musical performance. In the two arguments presented in regard to the major third, Bartholomew was referring to an a cappella choir when he advocated raising the pitch of the major thirds. Redfield was referring to wind instrument groups when he advocated lowering the pitch of the major thirds. The instructions that relate to raising the pitch of sharps over their enharmonic flats were advocated by a prominent string teacher. These rules, which have been passed around rather freely, may apply to one particular group of musicians but not to another.

Each of the three systems of tuning seems to favor a special area of musical performance. Pythagorean tuning with its perfect fifths, raised leading tone, raised sharp chromatic tones and lowered flat chromatic tones relates most naturally to the stringed instruments. Just intonation with its intervals expressed as ratios of small whole numbers relates most naturally to the wind instruments, particularly the brass instruments whose natural intervals relate to the harmonic series. Equal tempered tuning is the outgrowth of

---

[1]Ralph Pottle, Tuning the School Band (Hammond, Louisiana: Individually published, December, 1960), p. 41.

keyboard instruments with their fixed pitches and their need for playing in all keys. One can readily see the reasons for the existence of all three systems of tuning; however, the contradictions in relation to pitch performance, which arise as a result, should be clarified.

Do instrumentalists because of the physical and acoustical nature of their medium of performance actually develop pitch preferences for certain harmonic configurations tuned to conform to the natural intervals of their instruments? Do vocalists because of constant practice with the piano develop a preference for tempered tuning? When emphasis is placed upon melodic tuning, do musicians prefer pitches that differ from those preferred in harmonic tuning?

Purpose of the Study

Because of the existence of these contradictions in basic tuning philosophy, it was decided that a study should be made in an attempt to clarify some of the problems. The purposes of this study then are: (1) to determine the pitch preferences of qualified musicians for various melodic and harmonic intervals tuned according to the three systems of tuning: Pythagorean, just, and equal tempered; (2) to classify these musicians according to performing areas as strings, winds, piano, and voice to ascertain if any consistent patterns of preference can be related to performance media; and (3) to determine if harmonic and melodic configurations affect the pitch preferences in any consistent pattern.

CHAPTER II

SYSTEMS OF TUNING

> It is advisable to guard at the outset against the familiar misconception that the scales are made first and the music afterwards. Scales are made in the process of endeavoring to make music, and continue to be altered and modified, generation after generation, even till the art has arrived at a high degree of maturity.[1]

It would be difficult to ascertain whether the first primitive scales came as the result of early musical instruments or whether the instruments were made to conform to existing scales. The important consideration is that people recognize the close relationship that has existed between the two. Much knowledge of early scales and systems of tuning has come about through the study of the musical instruments in the various periods of musical development.

Pythagorean Tuning

Of the three systems of tuning in use today the one devised by Pythagoras (c. 550 B.C.) was the first to be developed. Barbour defined this system thusly:

---

[1] Hubert H. Parry, The Evolution of the Art of Music (New York: D. Appleton-Century Company, Inc., 1930), p. 20.

> The Pythagorean system is based upon the octave and the fifth, the first two intervals of the harmonic series. Using the ratios 2:1 for the octave and 3:2 for the fifth, it is possible to tune all the notes of the diatonic scale in a succession of fifths and octaves, or, for that matter, all the notes of the chromatic scale. Thus a simple but rigid mathematical principle underlies the Pythagorean tuning. . . . In this tuning the major thirds are a ditonic comma (about 1/9 tone) sharper than the pure thirds of the harmonic series. When the Pythagorean tuning is extended to more than twelve notes in the octave a sharped note, as G sharp, is higher than the synonymous flatted note, as A flat.[1]

A relatively simple method of arriving at the diatonic scale tuned according to the Pythagorean system would be as follows: Using a standard keyboard instrument, tune F^3 to a given reference pitch. With this as the generating note of a scale, tune C^3 to sound the interval of a perfect (beat free) fourth down. Then, making all intervals beat free, tune up a perfect fifth from C^3 to G^3, down a perfect fourth from G^3 to D^3, up a perfect fifth from D^3 to A^3, down a perfect fourth from A^3 to E^3, and finally, up a perfect fifth from E^3 to B^3. Now tune C^4 a perfect octave above C^3. By this method all of the diatonic tones of the C major scale can be tuned.

According to Norden the diatonic scale in Pythagorean tuning can be expressed by the following ratios:

---

[1]J. Murray Barbour, Tuning and Temperament, A Historical Survey (East Lansing, Michigan: Michigan State College Press, 1951), p. 1.

C	D	E	F	G	A	B	C
384	432	486	512	576	648	729	768[1]

Since Pythagoras worked with string lengths and their oscillation rates, the above figures would represent the ratios of varying string lengths which would be necessary to produce the desired vibrating frequencies for each of the tones of the diatonic scale tuned to Pythagorean proportions. The C (384) would naturally be a longer string than the D (432). If a unit of length represents the C string, 384 such units would be equal to 432 units of the length which represents the D string.

Present day practice has been to represent the relative values of scale degrees by cents. According to this system, which is based upon equal temperament as a standard, each semitone of the scale equals 100 cents. The entire octave represents 1200 cents. If the Pythagorean scale were converted into cents, the results would be as follows:

C	D	E	F	G	A	B	C
0	204	408	498	702	906	1110	1200[2]

The complete chromatic scale according to Pythagorean tuning would be represented by the following values in cents:

C	C#	D^{b}	D	D#	E^{b}	E	F	F#
0	114	90	204	318	294	408	498	612

[1]N. Lindsey Norden, "A New Theory of Untempered Music," The Musical Quarterly, XXII (April, 1936), p. 218.

[2]*Ibid.*, p. 221.

G^b	G	G#	A^b	A	A#	B^b	B	C
588	702	816	792	906	1020	996	1110	1200[1]

These figures can be arrived at by adding two cents in pitch for each extension of a perfect fifth from the generating tone C or by subtracting two cents for each extension of a fourth from the generating tone C. For example, the interval from C to G in the Pythagorean system is two cents sharp to equal tempered tuning and the interval from C to F is two cents flat. If instrumentalists do use the Pythagorean system of tuning, particularly in melodic instances, then each chromatically sharped tone must be played 24 cents sharp to its enharmonic flatted tone. The sharped chromatic tones of Pythagorean tuning become progressively more sharp compared to equal temperament as one moves through the cycle of fifths from F sharp to A sharp. To adhere to strict Pythagorean tuning A sharp would have to be raised a total of 20 cents over its corresponding note in equal temperament and B flat, its enharmonic equivalent, would be lowered only four cents below its corresponding equal tempered note.

From the above description of the Pythagorean system of tuning one can see that certain rules of performance practice are related to the characteristics of this system. For example, string players tune their instruments in perfect fourths and fifths. String players tend also to play sharps

---

[1] Ibid.

higher than their enharmonic flats. Boyden brings out this fact when he states, "Violinists today tend to play leading tones quite sharp and in enharmonic pairs, to play sharps higher in pitch than flats."[1]

This is not just one isolated example. An examination of prominent string methods reveals many similar rules in regard to pitch performance practices. Cadek, in his concluding remarks from an article on intonation for the strings states, "I maintain, therefore, that the violin is an instrument best served by the Pythagorean system of intervals as a point of departure."[2]

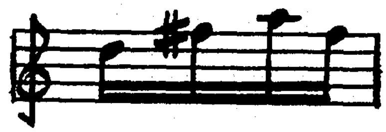
A further examination of instructional material for strings disclosed another point that, although understandable, could be a source of contradiction. The above mentioned recommendations for pitch tendencies in string playing all refer to melodic intervals. When harmonic tendencies are predominant, the rules in regard to pitch tendencies undergo drastic changes. For example, Carl Flesch states that the pitch of a tone differs according to its harmonic affiliations:

> We know, for instance, that a tone on the seventh step (leading tone) must be played higher than when it merely appears as a third. Hence we play F sharp in

---

[1]D. D. Boyden, "Prelluer, Geminiani, and Just Intonation," American Musicological Society Journal, IV (Fall, 1952), p. 219.

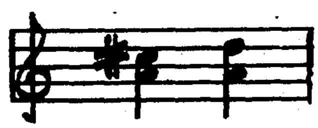
[2]Ottokar Cadek, "Intonation in Theory and Practice," Music Journal, VII (May-June, 1949), pp. 39-40.



with the customary number of vibrations, while the same tone in

would be played a few vibrations higher, since it moves toward the tonic. . . . Or take

Case I



Case II

In Case I, the pitch level of the C sharp is normal and is determined in accordance with the perfect major third to be formed with the A without reference to the D which follows. In Case II, however, the C sharp is nothing more than the raised leading tone, resolved on the D.[1]

This, then, would indicate that the performer must make snap judgments in performance as to whether the harmonic or melodic tendencies are stronger. In the example (Case I) cited both tones are written as double stops. This would make judgment a simple matter. Suppose, however, that the first violin had been assigned the C sharp to D on his part and the second violin had been assigned the quarter note A's. With no prior knowledge of the music, the first violin would naturally treat the C sharp as the leading tone to D or as the C sharp, which should naturally be played higher

[1]Carl Flesch, <u>The Art of Violin Playing</u> (New York: Carl Fischer, 1924), p. 22.

because of the rules governing the performance of enharmonic tones. In either case the result would be a higher C sharp. There would be no difference harmonically in the desired sound of the passage; yet the results would be different. This, then, would emphasize the contradictory nature of the two situations.

Isted, when considering this conflict, stated the following:

> Departure from Pythagorean tuning seems to begin at some point along the border line between the art and the science of musical expression, where the violinist feels that he must cease considering melodic line and give attention to the harmonic effect.[1]

Even if the violinist does intuit the correct treatment of harmonic and melodic instances, there are still features of the violin that make it difficult to adhere to the rules. Suppose that the tones

are to be played as double stops. The C would be formed on the A string in its proper position and the E would be played on the open E string. The resulting interval would be a Pythagorean third because of the inability of the open string to be lowered. The alternative would be to raise the C until this interval had the recommended sound of a pure third. This would be possible if only one instrument were involved.

---

[1]Leslie Isted, "A Study of Violin Pitch Intonation" (unpublished Master's dissertation, School of Music, Indiana University, 1946), p. 86.

To further complicate the situation, suppose that a second violin were playing a low G on the open G string giving the second inversion of the C major triad. The C would logically be tuned to form a perfect fourth with the low G. The third (E) then would have to be sharp (Pythagorean tuning) to the C unless it were formed on the A string. This would not be possible in this case because the C is formed on the A string.

Standard orchestration books refer to instances of double, triple, and quadruple stops in which one or more of the tones are produced on open strings. Kennan[1] gives an example of a quadruple stop that contains the following tones:

This example is quite similar to the one mentioned above except that the E has been doubled at the octave below on the D string. In this instance it has been recommended by Kennan that the G^2 and E^4 be produced on open strings. The resulting pitches would have to conform to the Pythagorean system of tuning if the violin was tuned in perfect fifths.

One might argue that the incidence of quadruple stops is so rare in violin playing that they might not be used as an example, but the fact remains that string players

---

[1]Kent Kennan, <u>The Technique of Orchestration</u> (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1952), p. 16.

tend to refer to the open tones when playing intervals. If these four tones were played by separate instruments, is it not logical to assume that the E^4 would still be produced on the open string as would the low G^2? This, then, could be a reason for the continued use of Pythagorean tuning today centuries after its inception.

Theoretically, Pythagorean tuning would have proven quite adequate in the performance of Gregorian chants of the Middle Ages since normally only the intervals of the Octave, fourth, and fifth were involved. Not until thirds and sixths began to be used harmonically did musicians begin to express dissatisfaction with the Pythagorean system of tuning.

Barbour, in speaking of the continued use of Pythagorean tuning, states:

> It was still strongly advocated in the early sixteenth century by such men as Gafurius and Ornithoparchus, and formed the basis for the excellent modification made by Grammateus and Bermudo. . . . Like the systems of Agricola in the sixteenth century and of Dowland in the early seventeenth century, many of the irregular systems of the eighteenth century contain more pure than impure fifths. The instruments of the violin family, tuned by fifths, have a strong tendency toward the Pythagorean tuning. And a succession of roots moving by fifths is the basis of our classic system of harmony from Rameau to Prout and Goetschius. Truly the Pythagorean tuning system has been long-lived and is still hale and hearty.[1]

[1]Barbour, op. cit., pp. 3-4.

Just Intonation

The second system of tuning still in use today is called just intonation. It was first called to our attention by Ptolemy. Barbour makes the following comment in regard to this system:

> To him (Ptolemy) we are in debt for an excellent principle in tuning lore: that tuning is best for which ear and ratio are in agreement. . . . For him a tuning was correct if it used superparticular ratios such as 5:4, 11:10, etc. All tuning varieties which he advocated himself are constructed exclusively with such ratios.[1]

The just scale is constructed by using perfect fifths in the ratio of 3:2 and just thirds as they occur in the natural harmonic series in the ratio of 5:4 built on the tonic, subdominant, and dominant scale degrees. An examination of the three resultant triads shows that they contain all of the notes of the diatonic major scale. The ratio of the three triads is 4:5:6. The minor triads on A, D, and E have perfect fifths and minor thirds in the ratio of 6:5. The just intervals, octaves, fifths, fourths, major thirds, and minor thirds bear the same relationship to one another as similar intervals found in the natural harmonic series. The octave is the same as the interval between the fundamental and the second tones of the harmonic series. The fifth is the same as the interval between the second and third tones of the series. The fourth is the same as the interval between the third and fourth tones of the series.

[1] *Ibid*., p. 2.

The major third is the same as the interval between the fourth and fifth tones of the harmonic series and the minor third the same as the interval between the fifth and sixth tones of the harmonic series.

A simple method of tuning the just diatonic scale of C major would be as follows: Tune C^3 to any given standard reference pitch, then set the pitch of F^3 and G^3 so that the resulting perfect fourth and perfect fifth are both beat-free. From F^3 and G^3 tune perfect (beat-free) fifths to C^4 and D^4. Now add the major thirds E^3 to C^3 and G^3, A^3 to F^3 and C^4, and B^3 to G^3 and D^4. The resulting major triads should all be tuned so that no beats can be detected. An examination of the tones of these triads will show that all eight tones of the C major scale are represented.

According to Norden, the pitch levels of each tone of this just scale in cents would be as follows:

C	D	E	F	G	A	B	C
0	204	386	498	702	886	10088	1200[1]

If one compares this scale to the Pythagorean scale listed on page 9, one finds that the major thirds C-E, F-A, and G-B of the just scale are each 22 cents flat to the related interval of Pythagorean tuning. The just minor thirds on A-C, D-F, and E-G are all 22 cents sharp to the related intervals of Pythagorean tuning.

---

[1] Norden, op. cit., p. 221.

The principal disadvantages of just intonation are the presence of a fifth between the second and sixth scale degrees that is 22 cents flat and the necessity of including two different size whole steps (Ratios 10:9 and 9:8); also, the supertonic triad does not contain two just minor thirds (Ratio 6:5). Another disadvantage would be that a dominant seventh chord built on the tones G, B, D, and F would not be pure. The desirable F would need to be tuned identical to the intervallic relationship between the sixth and seventh tones of the harmonic series. The F of this chord, pitched as it appears in the diatonic scale, would be considerably sharp to the F that would produce a pure (beat-free) dominant seventh. In addition to these intervallic difficulties of the diatonic scale, no modulation from the original key would be possible without the addition of new tones to a keyboard of fixed pitches.

Advocates of just intonation are, for the most part, physicists or wind instrument players. Jeans makes the following comments in regard to just intonation:

> It is found to be a quite general law that two tones sound well together when the ratio of their frequencies can be expressed by the use of small numbers and the smaller the numbers the better the consonance. . . .[1]
>
> . . . .
>
> The note that our ear wants to hear with C is not the Pythagorean E but the harmonic E.[2]

---

[1]Sir James Jeans, <u>Science and Music</u> (New York: The MacMillan Company, 1937), p. 154.

[2]<u>Ibid</u>., p. 171.

Here it should be noted that he is writing about harmonic intervals rather than of melodic intervals.

Brass instruments are built on the principle of the overtone series. The valves are designed to furnish the tones not normally found within a harmonic series. For example, a trumpet can produce, in open tones, all of the notes of the harmonic series based on the fundamental C. If the middle valve is depressed, the trumpet can produce all of the notes of the harmonic series based on the fundamental B. Thus by use of valve combinations the trumpet is capable of playing seven different overtone series. The same principle can be applied to all valved brasses. This relationship of the brass instruments to the harmonic series could possibly influence the ear of the brass player to the extent that he might naturally prefer justly tuned intervals.

Suppose that we have a major triad scored for a horn quartet. If the C^3 is assigned to the fourth horn, E^3 to the second horn, G^3 to the third horn, and the octave C^4 to the first horn, each of these tones can be produced as the fourth, fifth, sixth, and eighth harmonics of the series with C as its fundamental. If the players accept these natural tones without humoring up or down, the resultant triad will be tuned justly without beats provided each instrument was critically tuned to the fundamental C.

This could have been an influencing factor in Redfield's[1] instructions to play all major thirds flat.

Another factor that favors just intonation is the acoustical phenomenon of beats. When a fundamental tone is produced, it rarely consists of a single wave in its pure form but is made up of various segmental vibrations that form a complex of higher tones of greater or lesser intensity blended into the fundamental sound. Stauffer comments on these upper partials in this manner:

> It is these upper partial tones that determine by their presence or absence of interference whether a third or fifth is tempered or pure. The beating that is the disturbing factor in tempered intervals does not occur between the fundamental frequencies of notes that are far apart, but between upper partials of each tone of the interval that do come in close proximity to each other. Thus in the fifth, C to G, it is the overtone G that occurs as the third harmonic in C and the second harmonic in G that will, by its smoothness, determine the degree or purity of the interval.[2]

This presence of beat interference is a fact that is emphasized constantly by wind instrument instructors. Unisons and octaves are tuned by this method in fine performing organizations.

Another acoustical phenomenon that emphasizes the use of just intonation is the presence of difference tones. Bartholomew describes difference tones in the following manner.

---

[1]John Redfield, "Just Intonation in Band and Orchestra," Musical Courier, XCI (October, 1926), pp. 6-7.

[2]Donald W. Stauffer, Intonation Deficiencies of Wind Instruments in Ensemble (Washington, D.C.: The Catholic University of America Press, 1954), p. 9.

> When beats from strong sources follow each other at the rate of about 20 or more per second, and particularly when they are produced by two loud tones on the same instrument, instead of by two different instruments, they produce a tone called <u>beat tone</u> or <u>difference tone</u> with a frequency equal to the difference between the generating frequencies.[1]

Helmholtz gives the following instructions in regard to producing difference tones: "To hear it at first, choose two tones which can be held with great force for some time, and form a justly intoned harmonic interval."[2] The important comment here is that the intervals must be justly intoned. If they are not, the difference tone resulting from a contracted interval gives a difference tone that is flat while that from an expanded interval gives a difference tone that is sharp. These resulting difference tones will cause objectionable beats that can be identified by a buzz in the composite sound.

Helmholtz makes the following comment in regard to difference tones resulting from Pythagorean and justly intoned thirds:

> For the Pythagorean thirds c^1 and e^1 and e^1 and g^1 the combinational tones (difference tones) are nearly c sharp and b both differing by a semitone from the combinational tone c, which would result from the perfect intervals (justly tuned) in both cases.[3]

---

[1]Wilmer T. Bartholomew, <u>Acoustics of Music</u> (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1942), p. 61.

[2]Hermann L. F. Helmholtz, <u>Sensations of Tone</u>, trans. by A. J. Ellis to conform to the 4th German edition of 1877 (New York: Longmanns, Green, and Co., 1930), p. 314.

[3]<u>Ibid</u>.

The Pythagorean major third in this case would be larger than the just major third and the Pythagorean minor third would be smaller than the just minor third.

For musical instruments that are capable of making minor pitch adjustments it is conceivable that just intonation could give more satisfactory results. The trombone, which is capable of adjusting the pitch up or down readily and which is also based upon the tones of the harmonic series, would seem to be an ideal instrument for performing music according to just intonation.

Historically, forms of just intonation came into use as early as the fifteenth century. The thirds of the Pythagorean system were considered to be imperfect consonances. Referring to Barbour again we find this statement:

> At least one Englishman, Walter Odington, had stated that consonant thirds had ratios of 5:4 and 6:5, and that singers intuitively used these ratios instead of those given by the Pythagorean monochord.[1]

Probably the strongest argument in favor of just intonation and its principal reason for existing today is the preference of many musicians for justly tuned beat-free triads.

Equal Temperament

The third system of tuning discussed is equal temperament. The term "temperament" will give some idea as to the background of this system of tuning. Tempered tuning

---

[1]Barbour, op. cit., p. 3.

means that an existing scale such as the just or Pythagorean has been altered or tempered in order to satisfy the needs of a particular instrument or group of instruments. Equal temperament is then an adaption or modification of one of the existing systems of tuning.

Barbour makes the following statement in regard to the historical background of this system of tuning:

> It is not definitely known when the practice of temperament first arose in connection with instruments of fixed pitch, such as organs and claviers. . . . Undoubtedly this was being done during the fifteenth century, for we find Gafurius at the end of that century, mentioning that organists assert that fifths undergo a small diminuition called temperament (participata).[1]

The theory of equal temperament, as it is known today, is extremely simple. The octave is divided into twelve equal parts called semitones with each semitone containing 100 cents. The mathematical value of the semitone is not expressed in rational numbers, but required the irrational number $\sqrt[12]{2}$ as a term of its ratio. The advantages of equal temperament are, (1) that each interval has one stable value, (2) that enharmonic equivalents have the same value, (3) that complete tonal mobility is available with modulation to remote keys, and (4) that all keys sound equally good (or bad).

The Harvard Dictionary refers to equal temperament as a compromise in tuning and defines it thusly:

---

[1]Barbour, op. cit., p. 5.

> The term denotes those systems of tuning in which the intervals deviate from the "pure," i.e., acoustically correct intervals as used in the Pythagorean system and in just intonation.[1]

The obvious reason for using "systems" rather than "system" in the above statements is that many different tuning methods were used in an attempt to make practical the playing of keyboard instruments in all the keys. In the words of Willi Apel,

> It follows that compromise methods are necessary which, instead of being perfect in the simple keys and intolerably wrong in the others, spread the inevitable inaccuracy over all the tones of the keys. The most consistent realization of this principle is the equal temperament which is universally used today.[2]

Apel was probably referring to mean-tone tuning as the system that was perfect in the simple keys. Mean-tone tuning is a compromise between just and Pythagorean tuning. Since a continuation of the cycle of fifths gives a sharp third between C and E, an attempt was made to shrink the size of each successive fifth from C to E until the resulting third was pure, i.e., C - G - D - A - E. The resultant sound of the triads according to this system was very satisfactory in the simple keys; however, the continuation of the series of mean-tone fifths leads to a very noticeable discrepancy between the sharp and flat tones. G sharp and A

---

[1]Willi Apel, Harvard Dictionary of Music (Cambridge, Massachusetts: Harvard University Press, 1944), p. 734.

[2]Ibid., pp. 734, 735.

flat as enharmonic tones of this system are almost a quarter tone apart with the A flat considerably sharp.

Although this system was very acceptable in the simple keys, modulation to the more remote keys was not possible. This might account for the fact that most keyboard music during the time from 1500 to 1700 was written in the simpler keys; however, by using a different fundamental note as the starting point, mean-tone tuning could give a satisfactory tuning within any area of nearly related keys.

It becomes evident then that the only satisfactory system of tuning for keyboard instruments without pitch flexibility is equal temperament.

The diatonic scale in cents for equal temperament would be as follows:

C	D	E	F	G	A	B	C
0	200	400	500	700	900	1100	1200[1]

At first glance this would seem to be a relatively easy temperament to set, but the problems of equal tempered tuning are legion. As was stated previously, the ratio that expresses the relationship of the chromatic intervals is $\sqrt[12]{2}$, which is an irrational number. Apel gives the following formula for arriving at equal temperament:

> Since the frequency of the octave is 2, the frequency of S of this semitone is given by the equation: $S^{12} = 2$ $S = \sqrt[12]{2} = 1.05946$. The

[1] Ibid., p. 735.

> successive powers of this figure give the frequencies for the tones of the chromatic scale, e.g., c = 1; c# = 1.05946; d = 1.05946^2 = 1.1225; d# = e^b = 1.05946^3 = 1.14973, etc.[1]

Simply stated, this would mean that each tone of the scale must conform to its assigned ratio from the above formula.

While just and Pythagorean systems tune fifths by the elimination of beats, equal temperament tunes by gauging the number of beats per second per interval.

Equal tempered fifths must be tuned smaller than Pythagorean fifths by two cents, or 1/50th of a semitone. One can readily see that this would be no easy task. Here are the instructions for tuning a tempered fifth as they appear in a standard manual of instructions: "Tune C^4 to a standard pitch. Play C^4 and tune the F below to be a beatless fifth to it; then slowly raise the F until a slow beat is heard (0.59)."[2] This means that for the piano tuner to set the temperament correctly, he must be able to determine by one means or another when he has achieved a beat rate of 0.59 beats per second. A metronome could be used to assist the tuner, but this would present problems. A metronome marking of M.M. 35.4 would be equal to 0.59 beats per second. Most metronomes only go to M.M. 40 as the lower limit. Of course, the tuner could double the metronome rate to 71, an

---

[1] *Ibid*., p. 29.

[2] *Application Manual for the Johnson Intonation Trainer* (Waseca, Wisconsin: E. F. Johnson Co., 1966), p. 28.

approximation, which would mean that the metronome is beating at twice the rate of the tuned interval. Since 71 is not one of the standard calibrations on the metronome, it would be necessary to use another approximation.

Consider the following instructions from an article in a prominent trade magazine for piano tuners:

> To check a 5th, compare the beat rate between the minor 3rd up from the bottom note (F - A^b) and the major 3rd down from the top note (A^b - C) and when the 5th is in tune the minor third will beat slightly faster than the major third. . . .[1]

The key word in the above reference is "slightly." The point is that, in spite of the theoretical calculations, the tuner himself works with approximations.

The purpose here is not to go into a detailed study of the art of piano tuning but to emphasize the fact that equal temperament is an approximation of the theoretical division of the octave into twelve equal semitones. The writer has had occasion to observe many piano tuners at work. In every instance, the speed of the beats has been a judgment value made by the tuner on the spot. The main point is that equal temperament is what the tuner makes it. The musician who swears by equal temperament is swearing by a multitude of tuning systems.

Another problem that presents itself in the setting of equal temperament is related to the method of tuning in

---

[1]La Roy Edwards, "A 'Unic' Method of Checking a Temperament," The Piano Technicians Journal, IV (May, 1961), p. 31.

octaves once a temperament has been set in the middle register of a piano. Consider the following information taken from the Johnson Application Manual:

> Because of the stiffness of piano strings and for other reasons, the upper partials are sharp in relation to the fundamental. For example: In tuning A880 to A440 the fundamental of A880 is tuned to the second partial (harmonic series) of A440; but the second phase partials are sharp to the fundamental and may have a frequency of about 881. The A880 fundamental (if tuned as a pure octave) then becomes 881.
>
> Table Showing Inharmonicity in Upper Partials of an A440 string:

Theoretical	Frequency	Actual Frequency	Difference
First Phase (fundamental)	A440	440	-
Second Phase Partials	880	881	Sharp 1 cps.
Third Phase Partials	1320	1325	Sharp 5 cps.
Fourth Phase Partials	1760	1770	Sharp 10 cps.
Fifth Phase Partials	2200	2215	Sharp 15 cps.
Sixth Phase Partials	2600	2670	Sharp 30 cps.[1]

An application of the above information would mean that each octave on the piano is stretched if these octaves are tuned beat-free. The result would be that the top tones of the piano are tuned sharp and the low tones are tuned flat if the temperament is set in the middle register and octaves are tuned up and down from that point.

Another problem that affects equal temperament is the variation in tuning philosophies. J. C. Hougaard relates an experience that he had in Denmark when he found that some European piano tuners employ a system of tuning which

---

[1] Johnson, op. cit., p. 34.

theoretically recommends that the beat rates for fifths and thirds be the same for each octave of the piano.[1]

Barbour makes the following statement in regard to the historical development of equal temperament:

> In almost all of these irregular systems, from Grammateus to Young, all the major thirds were sharp to some extent thus differing from just intonation and the meantone temperament, in which the usable thirds were perfect and the others very harsh. For practical musicians it would have been an easy matter as time went on to tune the "Common" thirds still sharper, so that all the thirds would be equally sharp, and his instrument would be substantially in equal temperament. Probably, this is exactly what did happen.[2]

Note here should be taken of the fact that equal temperament, or at least an approximation of it, existed long before the time of J. S. Bach and that, contrary to common beliefs, Bach was not the inventor of this system of tuning.

Because of the inability of the keyboard instruments to adjust pitches, it goes without saying that equal temperament is the best system of tuning for this particular group of instruments. If the piano cannot adjust, should instrumentalists and vocalists discard the other tuning systems and make a unified effort to conform to the standard of tuning established by keyboard instruments?

The Raging Argument

One of the strongest arguments in favor of the just system of tuning has been presented by Helmholtz. This

---

[1]J. C. Hougaard, "Two Equal Temperaments," The Piano Technicians Journal, VIII (January, 1965), p. 16.

[2]Barbour, op. cit., p. 13.

noted physicist, writing in the nineteenth century, offers the following statements:

> When quartets are played by finely cultivated artists it is impossible to detect any false consonance. To my mind the only assignable reason for these results is that practiced violinists, with a delicate sense of harmony, know how to stop the tones they want to hear, and hence do not submit to the rules of an imperfect school. That performers of the highest rank do really play in just intonation has been directly proven by the very interesting and exact results of Delezenne.[1]

It should be pointed out that Helmholtz was principally a physicist; yet he seems to have been a discriminant listener as is indicated by the following statement:

> We often hear four musical amateurs who have practiced much together, singing quartettes in perfectly just intonation. Indeed my own experience leads me to affirm that quartettes are most frequently heard with just intonation when sung by young men who scarcely sing anything else, and often and regularly practice them, than when sung by instructed solo singers who are accustomed to the accompaniment of the pianoforte or the orchestra.[2]

Helmholtz goes on to suggest that singers not practice with the piano, as this tends to cause them to adopt tempered intervals that do not give satisfactory results in vocal ensembles.

A point to be noticed here is that he classified the orchestra also in this category of offenders to just or pure intonation. His case is built around these pure sounds and one might wonder if his judgment is not influenced greatly by his knowledge of physics and the fact that the upper

---

[1] Helmholtz, op. cit., p. 324.

[2] Ibid., p. 326.

partials of the overtone series, particularly the partials forming octaves, fifths, major and minor thirds are all beat free, forming pure intervals.

An equally strong case can be presented for either of the other remaining systems of tuning. Consider the following points made by Cadek, a noted violin teacher, in support of the Pythagorean system of tuning:

> My conclusion is supported by the following reasons:
> 1. Being tuned in perfect fifths the violin is naturally adapted to the Pythagorean system, which is based on perfect fifths.
> 2. The four open strings are fixed notes that serve as a basis for the system. All perfect intervals, being the most sensitive should remain perfect, the open strings will then vibrate in sympathy with their octaves and fifths, thereby increasing the resonance of the instrument.
> 3. Thirds and sixths, being less consonant, may be tempered without serious offense to the ear. Major thirds and sixths would be enlarged, minor thirds and sixths contracted. The major seventh is higher than in equal temperament, thus accentuating leading-tone tendencies. The minor seventh is lower, and thus in modulation approaches the tone of resolution.
> 4. This tempering permits a single placement for each note in relation to both upper and lower strings, instead of two as advocated by Sevcik. Regular finger patterns are maintained and assurance of finger placement is thereby gained.
> 5. Sharps become higher and flats become lower by the process of successive perfect fifths. . . . So G^b is lower than F#, as Flesch would like to have it.
> 6. Sharp keys have a progressively increasing number of high notes, flat keys a progressively increasing number of low notes thereby differentiating the tone color of keys. Enharmonic changes in the system are actual pitch changes.[1]

---

[1]Ottokar Cadek, "String Intonation in Theory and Practice," Music Journal, VII (May-June, 1949), pp. 39-40.

These statements by Cadek present a strong case for Pythagorean tuning. It should also be noted that his statements coincide with many of the conflicting rules in regard to intonation that were mentioned in the introduction.

The two examples by Helmholtz and the one by Cadek are not isolated instances. Many more examples could be quoted with equally strong support for either side of the argument.

The third system, equal temperament, can find an equal number of supporters willing to extol its virtues and refute the statements of its opponents. Consider now Barbour's concluding statements in regard to the various systems of tuning:

> This contemporary (1951) dispute about tuning is perhaps a tempest in a teapot. It is probably true that all singers and players are singing and playing false most of the time. But their errors are errors from equal temperament. No well informed person today could suggest that these errors constantly resemble departure from just intonation or from any other tuning system described in these pages. Equal temperament does remain the standard, however imperfect the actual accomplishment may be.[1]

Culver defends just intonation in the following statement: "Music played in such a system (equal temperament) must of necessity be inferior to that rendered in true intonation (just intonation)."[2]

---

[1] Barbour, op. cit., p. 201.

[2] Charles Culver, Musical Acoustics (Philadelphia: The Blakiston Co., 1947), p. 77.

One of the most confusing conclusions of all is expounded by Yasser: "The better an intonation serves for harmonic construction, the worse does it answer melodic purposes and vice versa."[1]

This statement could really cause confusion if an attempt were made to apply these facts to musical performance. Melody and harmony are two of the ingredients of practically all of the great music literature that is performed today. How, then, can a decision be reached as to which, melody or harmony, is going to be the principal emphasis in selection of pitch preferences?

Mursell weighs the arguments and contributes the following:

> By and large, the bulk of the theorizing has turned upon the physical properties of sound and the arithmetical relationships of tones, and as such, it can never go to the root of the matter. For the musical scale, like any other esthetic phenomenon is an "au fond" psychological consideration and any fundamental "laws" that may determine it are not those of physics or mathematics but the mental organization.[2]

The preceding arguments bear witness to the fact that a problem exists in regard to pitch preferences. This problem has been the basis of many experimental studies in the past. The results of these studies are, in many instances,

---

[1]Joseph Yasser, A Theory of Evolving Tonality (New York: American Library of Musicology, 1932), p. 38.

[2]James Mursell, "Psychology and the Problems of the Scale," Musical Quarterly, XXXII (October, 1946), pp. 564-573.

almost as contradictory as the problems they set out to solve.

The next chapter will concern itself with a reporting and comparing of the results of a few of these studies.

CHAPTER III

RELATED STUDIES

Early Studies

Helmholtz was one of the first experimentalists to do serious research into the various systems of tuning. His attitude toward tuning, as has been previously stated, was that equal temperament was a necessary compromise in tuning. Its purpose was to make possible playing in all keys for those keyboard instruments that had no pitch flexibility. This compromise in tuning was, as he believed, a substitute for just intonation.

> The principal fault of our present tempered intonation, therefore, does not lie in the Fifths; for their imperfection is really not worth speaking of, and is scarcely perceptible in chords. The fault rather lies in the Thirds, and this error is not due to forming the Thirds by means of a series of imperfect Fifths, but it is the old Pythagorean error of forming the Thirds by means of an ascending series of four Fifths.[1]

Helmholtz believed that the only true intonation was just intonation. His first experiments were with a keyboard instrument called the harmonium. This was a specially

---

[1]Helmholtz, *op. cit.*, p. 315.

constructed instrument that had two sets of twelve-key octaves. All fifths were slightly mistuned and all thirds were tuned justly in much the same manner as mean-tone tuning. This arrangement of twenty-four keys within the octave made possible the playing of justly tuned triads on each of the scale degrees and eliminated the "wolf" of mean-tone tuning. A complete description of the harmonium can be found in Sensations of Tone.[1] There were some difficult problems involved in musical performance on an instrument of this sort, the most prominent of which is the necessity for analyzing and knowing exactly which tones were to be played on upper and lower manuals in order to supply justly tuned chords at all times. It also seems that modulations that involved enharmonic spelling of tones common to both keys might have presented problems that were insurmountable. Whatever the reasons, Helmholtz's harmonium did not become a practical performing instrument. It may well have been because of the above-mentioned facts, or it may have been that just intonation was not acceptable to musicians and connoisseurs.

Helmholtz, in an attempt to prove his theory about just intonation, performed another experiment with Josef Joachim, a prominent violinist of his time. Joachim tuned his violin exactly to the notes of the harmonium for G, D, A, and E. He was then requested to play the scale. After

---

[1] Helmholtz, op. cit., p. 316.

each of Joachim's pitches was sounded, the identical pitch was performed on the harmonium. By means of beats it was determined that Joachim played his violin according to the just scale.[1]

Regardless of the intensity of Helmholtz's arguments for just intonation, he himself readily admitted that there were limitations to performance in this system of tuning and offered the following statement in support of equal temperament:

> There can be no question that the simplicity of tempered intonation is extremely advantageous for instrumental music, that any other intonation requires an extraordinarily greater complication in the mechanism of the instrument, and would materially increase the difficulties of manipulation, and that consequently the high development of modern instrumental music would not have been possible without tempered intonation.[2]

There were many attempts to construct instruments that were patterned after Helmholtz's harmonium, some of these with as many as 53 keys to the octave. Ellis, in his addition to the translation of <u>Sensations of Tone</u>, states the following:

> But none of them meets the wants of the student. They are all too expensive and require so much special education to use that they have remained musical curiosities, some of them entirely unique.[3]

Closely related to Helmholtz's studies in intonation for violin are the experiments of Cornu and Mercadier. The

---

[1] <u>Ibid</u>., p. 325.

[2] <u>Ibid</u>., p. 320.

[3] <u>Ibid</u>., p. 466.

results of these experiments have been reported by Ellis in the addendum to Sensations of Tone:

> Musical intervals belong to at least two different systems of different value: (1) The intervals employed in melodies which have no modulations are with those of the Pythagorean scale. (2) The intervals between two notes sounded together in chords, the basis of harmony, have for their ratios the following numbers: 2 for Octove, 3/2 Fifth, 4/3 Fourth, 5/4 major Third, 6/5 minor Third, 5/3 major Sixth, 8/5 minor Sixth, and 7/4 Seventh, where the Fourth and Sixths were deduced from observation of the Fifths and Thirds, and the Seventh from the dominant chord.[1]

This study is then contradictory in one way to that of Helmholtz. If Joachim were asked to play the scale, this would have been considered as melodic in nature. The studies of Cornu and Mercadier stated that in melodies the violinists used Pythagorean tuning while Helmholtz, in a melodic example, related that Joachim played in just intonation. Another contradiction that was found in the recorded results of Cornu and Mercadier was the fact that melody and harmony exist as concurrent properties of a musical performance. This fact, then, gives rise again to the question as to which is stronger, melodic or harmonic tendencies. It also seems rather strange that, after examining the tabulated results of the studies of Cornu and Mercadier, which give varying pitch values for each of the tones played by violinists, they could arrive at these conclusions. The indicated pitches have a rather wide range of variation from just to Pythagorean equivalent for any one note of the scale

[1] Ibid., p. 487.

either melodically or harmonically performed. From this rather varied table of results[1] it seems highly unlikely that they could arrive at a positive evaluation in favor of either just or Pythagorean tuning. At the most, they indicate trends and not positive values. Further reasons for questioning the results of this study can be found in the recorded pitch values for the octave. In all three systems of tuning, the octave is represented as being 1200 cents above the fundamental tone. In the recorded results of Cornu and Mercadier, not one of the violins tested had a recorded value that agreed with this figure. Of eight performers tested, three were below this figure, the lowest being 1196 and the highest being 1210. The average of all eight was 1203 cents, which would not coincide with their reported results that the octave was in the ratio of 2:1. Probably a more accurate evaluation would be that violinists tend to play sharp in the upper register.

The Iowa Studies

Although the Iowa Studies were concerned primarily with the psychological aspects of musical performance, many of the findings from research in this area are pertinent when considering their relationship to the various systems of tuning. For the purpose of analyzing musical performances this group of men under the supervision of

---

[1] Ibid., pp. 486-487.

Carl E. Seashore[1] developed technical procedures for measuring pitch, vibrato rates, time, timbre, and volume of musical performances. Their subjects, for the most part, were famous artists. Some of these artists were tested ~~in the~~ laboratories at the University of Iowa, and others were evaluated from the study of recordings of performances by these artists.

Probably the most significant piece of scientific equipment developed by this group of men was the Phonophotograph.

> The apparatus consists of two parts: a strobophotograph camera recording the pitch by photographing a continuous picture of the stroboscope effect produced by a stroboscope disc illuminated by a light flashing in frequency with the voice; and, a vacuum tube voltmeter, connected to an oscillograph, recording the intensity of the sound as picked up by a condenser microphone. These two records are photographed on the same film which moves through the camera at a constant speed. The pitch graph is read in terms of tenths of a tone and the intensity graph in decibels.[2]

By using this instrument as a measuring device, pertinent information in regard to pitch variations has been made available for further examination.

The study by Harold Seashore[3] has particular significance as it relates to the present study. Harold Seashore, by using the phonophotographic technique, measured the

---

[1]Carl E. Seashore (ed.), University of Iowa Studies in the Psychology of Music (4 vols.; Iowa City, Iowa: The University Press, 1932-1937).

[2]*Ibid*., Vol. I, p. 118.

[3]*Ibid*., Vol. IV, p. 14.

performance of a select group of singers. Nine singers were studied. The technique was varied in that several of the singers were tested in the University of Iowa Laboratories and others were tested by the use of available commercial recordings. The songs used were of a concert type in legato style and technically rather simple. In the live performances tested, a recording was made of the performance simultaneously with photophonographic charts. Some of the tests were made with accompaniments and some were made without accompaniments.

In reporting the results of this study no mention was made of a comparison of pitch tendencies for those who used accompaniment as compared to those who did not use the accompaniment. It would appear that this should have been done in the study since the nature of the accompaniment could conceivably have an effect upon the pitch response of the performer.

The measured graphs of the singers recorded pitch variations up to one-tenth of a tone. Represented in cents, this would mean that the pitch variations are measured in intervals of pitch up or down ten cents for each recorded pitch variation.

To further complicate the evaluation of the results of the pitch graphs, each singer used a vibrato that has a pitch variation of approximately five-tenths of a tone or, stated in cents, a variation of 50 cents from top to bottom of each registered variation in pitch due to the use of vibrato. In order to determine the pitch of any single tone, it then became necessary to arrive at a mean pitch that was to represent the pitch of that particular tone without the use of vibrato.

In the reported conclusions from two of the Iowa Studies, statements can be found that relate closely to this study. The first of these deals with vocalists and their pitch preferences: "The mean pitch, i.e., the mean between the crest and the trough of the vibrato cycles, coincides fairly with true pitch."[1] By "true pitch" it must be assumed that Seashore was referring to equal temperament, since he used as a guide for accuracy the pitch established by the piano or organ.

The second of these two statements deals with violinists as instrumentalists who do not conform to the tempered scale: "Exception to this rule is found in what may be called tendency notes, for which there are recognized reasons for augmenting or diminishing the interval."[2] These tendency notes are obviously relating to Pythagorean tuning with its raised leading tone and chromatic pitch alterations.

The Iowa Studies then tend to support arguments in favor of the tempered scale as being the "true pitch" as documented by printed notes; however, a critical analysis of

---

[1] Ibid., Vol. III, p. 35.

[2] Ibid., Vol. IV, p. 43.

methods of measuring pitches in this study would indicate that the divisions of pitch into tenths of a tone are not accurate enough for our purposes. The purposes of these studies was also a concern for the measurement of vibrato and vibrato, as such, tends to eliminate perception of some of the most objectionable features of equal temperament, particularly the presence of beats in chords such as the dominant seventh when performed by wind or string instruments.[1]

The Nickerson Ensemble Experiments

These experiments were designed to permit a comparison of the intonation of solo and ensemble performances of the same melody as well as additional comparisons of equal temperament, just, and Pythagorean tuning.

For a test group Nickerson used six outstanding string quartets. These groups were asked to perform a musical passage, first as a solo and then as a part of the musical ensemble. The music selected was from the Haydn, "Emperor Quartet," a group of variations that assigns the melody successively to each of the quartet instruments in identical harmonic setting.

The instruments were recorded on discs by using uni-directional microphones held one foot from the bridge of each instrument. Frequency analysis was effected by means

---

[1] Ibid., Vol. IV, p. 56.

of an especially designed technique involving sound-on-film loops and stroboscopic analysis.

The results of this study, according to Nickerson, showed some rather significant variations in pitch performance, particularly in instances where harmonic and melodic tendencies conflicted. The most significant reported results are as follows: "Solo and ensemble performances varied significantly only in the performance of thirds."[1] Here the reported tendency was for the harmonic thirds to approach the just intonation while melodic thirds tended toward equal temperament.

In regard to melodic tendencies Nickerson reports, "The marked correspondence of not one but both performances to the Pythagorean intonation was interpreted to suggest the presence of a melodic intonation."[2] This study tends to confirm earlier studies in which a sharp line has been drawn between melodic and harmonic tendencies; however, Nickerson does shed some further light on this contradiction in the following statement: "It is implied from these findings that melodic movement deserves and probably receives far more attention than harmonic blend in order to achieve a satisfactory expression."[3]

---

[1] James F. Nickerson, "Comparing Intonation of Solo and Ensemble Performances," Music Journal (March-April, 1950), p. 21.

[2] Ibid.

[3] Ibid., p. 51.

The Richardson Study

This study was concerned with the effect of certain harmonic configurations upon tuning preferences for the major third. The major third was selected by Richardson because of its position in regard to the various tuning systems. The just third is fourteen cents flat to equal temperament and the Pythagorean third is eight cents sharp to equal temperament. The difference between the just and Pythagorean third is twenty-two cents. This difference of twenty-two cents is easily detected by an unexceptional ear.

For experimental equipment Richardson used an especially constructed Conn organ that had tunable dials so that the experimental subject could tune intervals up or down until the preferred pitch was reached. In order to evaluate the results of the critical tuning of intervals, a stroboscope was used. The subjects tested were categorized into two groups, either as pianists or violinists. Each subject was asked to tune configurations of the third in various musical examples where certain tones had been previously established. These ranged from isolated examples to the third as contained within a major triad, leading tone in a harmonic configuration, sixth scale degree in the subdominant triad, inversions of the major triad, and the third as part of the dominant harmony.

From these tests Richardson concluded, "Apparently the presence of the full major triad lowers tuning preferences in the direction of the just intonation system."[1]

The results of this study tend to contradict the point expressed by Nickerson in regard to the continued tendency of string players to use some form of Pythagorean intonation; however, they are agreed that when harmonic considerations are strongest, violinists tend to lean toward some form of just intonation.

Richardson, upon noting this contradiction, suggested that this tendency to think melodically on the part of some violinists is nothing more than an expression of egotism, which is detrimental to good musical performance.[2]

This study was particularly significant because of the fact that here, for the first time, a comparison was made between performers on different instruments. The results tend to indicate that preferences for pitch can be influenced by the particular medium of musical expression.

The Johnson Study

This study was an investigation of the tuning preferences of a select group of singers with reference to just intonation, Pythagorean tuning, and equal temperament. The

---

[1]Louis Samuel Richardson, "The Effects of Certain Harmonic Configurations Upon Tuning Preferences for the Major Third" (unpublished Doctor's Thesis, Indiana University, Bloomington, Indiana, 1962), p. 100.

[2]*Ibid*., p. 130.

procedure was varied from previous studies in that musical examples were taped. These examples included cadences utilizing just, Pythagorean, and equal tempered tuning. The subjects tested listened to the taped musical examples and selected the preferred examples. The examples were I, V, I cadences in various keys in both open and closed position. The tested subjects were asked to compare equal temperament to just, equal temperament to Pythagorean, and just to Pythagorean in three separate experiments and to record their preferences in each instance.

The results of the comparisons showed "a decided preference for equal temperament over just intonation in all chord variants."[1]

The results of a comparison of just and Pythagorean intonation showed a decided preference for Pythagorean intonation in the examples tested. The results of a comparison between Pythagorean and equal temperament showed that the group of thirty singers was equally divided when asked to select a preference.

The Johnson study concluded that vocalists as a group tend to prefer equal temperament as a system of tuning and reject the writings as proposed by Norden or Helmholtz

[1]Hugh B. Johnson, "An Investigation of the Tuning Preferences of a Selected Group of Singers with Reference to Just Intonation, Pythagorean Tuning, and Equal Temperament" (unpublished Doctor's Thesis, Indiana University, Bloomington, Indiana, 1963), p. 32.

that vocal groups tend to use just or pure intonation when singing unaccompanied.

Although the Richardson study and the Johnson study seem to contradict one another, a significant fact is that the groups tested represented different media of musical performance. This would tend to substantiate the writer's belief that the performance medium does affect the pitch preferences of musicians.

CHAPTER IV

DEVELOPING THE STUDY

Problems To Be Considered

From the information presented in Chapter II there is sufficient evidence to sustain the assumption that all three systems of tuning are still being used to some extent today. In order to test the validity of this assumption, it was decided that a test be devised that would present musical examples tuned according to the three systems of tuning. The subjects tested would then be asked to indicate their preference for intervals tuned according to either just, equal tempered, or Pythagorean tuning.

From Chapter III it is obvious that there are contradictory results reported from related studies. For example, the Richardson Study[1] reported that violinists preferred the just third in instances where the emphasis was placed upon harmonic intervals. On the other hand, Johnson[2] reported that vocalists as a group preferred equal

---

[1]Nickerson, _op. cit._, p. 100.

[2]Johnson, _op. cit._, p. 32.

temperament, regardless of whether the interval was presented harmonically or melodically.

This reported variation in preference between violinists and vocalists leads quite naturally to the assumption that there might be a marked difference in tuning preference between violinists and vocalists; also, if this is true, then perhaps other instrumentalists, such as pianists and wind instrumentalists, might have identifiable preferences. These preferences might be different from those preferred by the vocalists or violinists.

With these assumptions in mind it was decided that the subjects to be tested should be divided into groups representing each of the major performance areas such as strings, voice, piano, winds, and percussion. In order to discover if there were any noticeable variations in preference among the wind instrumentalists, they were further classified according to major instruments such as clarinet, cornet, horn, flute, etc.

Previous related studies indicated that there was a marked difference in tuning preference between melodic and harmonic intervals. The Nickerson Study[1] concerned itself with this particular contradictory aspect of tuning preference. Considering this fact, it was decided that the intervals selected for testing should be presented twice: first as melodic intervals, then as harmonic intervals. The

---

[1]Nickerson, op. cit.

obvious reason was to discover if the manner in which the intervals were presented had any effect upon the preference for one or the other of the three systems of tuning.

The Seashore Study[1] stated that vibrato when measured in terms of mean-pitch showed gross pitch errors, but that these errors were basically variations from tempered tuning and not intentional attempts to tune according to another system of tuning, such as the just or Pythagorean. Although no attempt was made to test the validity of these statements by Seashore, it did arouse curiosity as to what effect the presence of vibrato might have upon the selection of tuning preferences. For this reason it was decided that several of the examples should be repeated with vibrato in order to determine if its presence would in any way affect the pitch preferences.

The studies of Helmholtz[2] pointed out that harmonic intervals which were mistuned (not justly tuned) set up patterns of beat interference and also caused difference tones that were objectionable to the ear. A study of beats shows that the fundamental tones are not the major reason for beating but that the upper partials are the cause of most beating. For example, if C^3 and G^3 are tuned so that G^3 is slightly flat to the justly tuned fifth, the beats, which are audible from this harmonic interval, are not caused

[1] Seashore, Vol. III, p. 43.

[2] Helmholtz, p. 314.

primarily by C^3 and G^3, but rather by the variation in pitch between the third partial of C^3 and the second partial of G^3. This fact would cause instruments that have strong upper partials to be more susceptible to beat interference than those that have a more fundamental sound.

In order to determine the effect that beating has upon tuning preference, it was decided that one of the intervals tested should be presented in its usual manner and then repeated, identically in every respect except that the timbre be changed so as to emphasize the upper partials and thus emphasize the beating effect of this harmonic interval when not tuned justly.

The problems under consideration within this study are: (1) To determine the pitch preference for certain intervals tuned according to just, equal tempered, and Pythagorean tuning, (2) To present these intervals both harmonically and melodically in order to determine if this will have an effect upon tuning preference, (3) To include vibrato in several of the examples in order to determine its effect upon tuning preferences, and (4) To include a change of timbre in one example in order to determine the extent to which the resultant beating affects pitch preference.

Selecting the Intervals

In all three systems of tuning the octave is tuned identically, with the tones in the ratio of 2:1. This would eliminate the use of the octave as an interval for study.

The perfect fifth is identical in just and Pythagorean tuning. In equal temperament the fifth is smaller by two cents than in either the just or Pythagorean systems. This is a very small difference which, according to Bartholomew,[1] is at the threshold of audible discrimination. This would mean that fifths when played melodically according to just and equal tempered tuning would be so similar that even a fairly discriminate ear might not be able to detect the difference; however, when played harmonically the tempered fifth would beat at a very slow rate. Since this beating could be detected by the listener, it was decided that the fifth should be used, but with full awareness of the fact that the results might not be dependable.

Fourths, as inversions of the fifths, were not used because the results would, in a way, be a repetition of those found in the fifths.

The major third was the next interval considered. Here, there is an appreciable difference between the three systems of tuning. The just major third is the smallest interval. Its tones are in the ratio of 5:4. The equal tempered major third is fourteen cents larger than the just

---

[1]Bartholomew, _op_. _cit_., p. 203.

major third. The Pythagorean third is twenty-two cents larger than the just major third and eight cents larger than the equal tempered third. These are pitch variations that are readily detected by the discriminate musical ear. For this reason the major thirds tuned according to each of the three systems of tuning should serve as excellent examples for determining pitch preferences.

The minor thirds were also used. The just minor third in the ratio of 6:5 is fourteen cents sharp to equal temperament and the Pythagorean minor third is six cents flat. These pitch variations can be detected by the discriminant ear and, therefore, should be valuable in determining pitch preferences.

The major and mincr sixths have the same pitch variations as the major and minor thirds. Because of this, their inclusion would have been a duplication of the preference determined from the major and minor thirds and, therefore, they were omitted from the study.

Major and minor seconds were omitted from the study because of the dissonance of these intervals.

In addition to the isolated examples of intervals, it was decided that combinations of intervals should also be tested. For example, a major triad containing the major third, minor third, and the perfect fifth, C - E, E - G, and C - G, could also serve as a means of determining pitch preferences. For the same reason the minor triad was also used.

There are rules of pitch performance that refer to both the major and minor seventh. In melodic tendencies the leading tone, according to violinists, should be played high. In harmonic instances the minor seventh, as found in the dominant seventh, should be played very low in the direction of its resolution.

In order to test these two statements, examples were constructed that would require the application of each of these rules. The minor seventh was presented in the dominant seventh as G - B - D - F in both melodic and harmonic structure. The major seventh was presented in the chord C - E - G - B, both melodically and harmonically.

As a further test of pitch preference, it was decided that a complete cadence tuned according to each of the three systems of tuning should be added. The cadence selected was I, IV, I, V_7, I. Because of the profound use of this cadence as a basic harmonic idiom, it was presented only in its harmonic form. In order to balance out the number of harmonic and melodic selections, the major scale was presented according to all three systems of tuning.

As a summary, the examples used to determine pitch preference were perfect fifths, major thirds, minor thirds, major triads, minor triads, the dominant seventh chord, the major seventh chord, the cadence chords I, IV, I, V_7, I in the major key only, and the major scale. Each example was presented according to each tuning system, and each example was played both melodically and harmonically except for the cadence chords, which were presented harmonically, and the major scale, which was presented melodically. These musical examples appear in manuscript form on page 136 of the appendices.

Producing the Examples

In order to produce the musical examples it was necessary to find some means of producing sound that could be controlled in pitch. The Johnson Intonation Trainer was the answer to this problem.

The Johnson Intonation Trainer is a keyboard instrument with a range from one octave below middle C to two octaves above. It produces sustained, organ-like tones with a choice of four different timbres. Each of the thirty-seven tones has a tunable range of about six semitones. The tuning of each tone is achieved by merely turning a knob clockwise to raise the pitch or turning the same knob counterclockwise to lower the pitch. The "C" tuning knob tunes ~~all~~ "C's" up or down, the "C#" tuning knob tunes all "C#'s" up or down, and so on. There are separate knobs for each of the twelve tones of the chromatic scale. In addition to the adjustable pitch features of this instrument, it has a reference scale that is tuned to equal temperament and can be used constantly as a reference by the flip of a switch. This instrument is equipped with a beat indicator that shows visually the speed of beats in "mistuned" intervals and stands still when intervals are tuned justly. This Intonation Trainer also has a vibrato with variable speed that can be switched on or off as needed. The instrument is easy to operate and is capable of being tuned readily to any one of the three systems of tuning.

In order to conform to the needs of this study, the reference scale, which is in equal temperament, was tuned carefully by a competent tuner. Instructions for tuning the scale were followed as prescribed in the Application Manual.[1] It should be pointed out that this instrument is capable of a more accurate tuning than the piano because each tuning knob tunes all octaves of whichever tone is selected. In other words, the octaves are always perfect regardless of the amount of tuning up or down of a certain pitch knob; also, the fact that the tones can be sustained for as long as is necessary makes it much easier to adjust beat rates to the prescribed speed for tempered intervals. As an added assurance of true tempered intervals, beats per second were converted into metronome speeds and each beat rate was made to conform to the prescribed metronome speed. For example, the Application Manual recommends that the F below C^5 be tuned to a beat-free fifth with the C, and then raised until

---

[1] _Application Manual for the Johnson Intonation Trainer_, _op. cit._, p. 27.

it beats at the rate of 1.18 beats per second. If this beat rate is converted, it will correspond to seventy-one beats per second on the metronome. By using this method, the tempered tuning of the reference scale can be set with a much higher degree of accuracy than would be possible for tuning the piano.

Once the reference scale is set, one can then tune the adjustable scale to whichever of the other scales is needed. The procedure for tuning the adjustable scale would be as follows: Using the reference "A," which is available on the Intonation Trainer, tune C^5 of the adjustable scale so that it produces the same beat rate when sounded with the reference "A" as does C^5 on the tempered scale. As an added check for accuracy the two "C's" were compared by rapidly changing the switch from tempered tuning to adjustable tuning. This was a necessary step because the two "C's" might have given the same beat rate when sounded with the reference "A"; yet one could have been causing beats by being flat and the other causing beats by being sharp. If this were the case, the variation between the "C's" could have been detected by the ear. After the "C's" were tuned identically, the Pythagorean and just scales were each tuned according to the procedure outlined in Chapter II (page 7).

Method of Presenting the Intervals

Experimentation with the Intonation Trainer soon pointed out weaknesses in this particular piece of equipment.

For example, if the instrument were transported, the tuning knobs could easily be brushed causing mistuning of certain intervals. This meant that each time the instrument was moved it became necessary to retune the adjustable scales, a procedure that caused a great loss of time and resulted in inaccuracies. For this reason, it was decided that the examples should be taped.

The taping process itself presented problems. As a standard of accuracy, it was decided that a reference "A" should be recorded on one track of a tape, then recorded on a second track in the same location on the tape. If the playback gave one "A" with no beats detectable, the equipment was deemed satisfactory.

Even though the tape was made in a professional recording studio, the first attempts were not satisfactory. There were problems with distortion from the microphone and also problems with keeping a constant speed to the revolving discs both in recording and in playing back the examples. The problem of distortion in the microphone was overcome by plugging the output of the Johnson Intonation Trainer directly into an Ampex Mixer with high level output. The recordings were made by using Ampex Recording equipment model #354.

Other factors that influenced the quality of the examples were: The volume level on the Intonation Trainer (the best examples were those that were produced at a lower dynamic level), the recording level (here, too, the best results were at a low level), and the quality and condition of the tape. The tape used was Scotch #201 (low noise), and the recorded speed was seven and one-half inches.

Verbal instructions were recorded separately and then spliced onto the examples. These instructions were made by using a Norelco D-24E microphone with low impedience. The tape recorder which performed best for playing the examples was the Roberts #700 model.

Arranging the Examples

A problem was encountered while experimenting with a possible order of presentation of intervals tuned according to the three systems of tuning. For example, the just third, which is 22 cents flat to the Pythagorean third, might sound acceptable when played as an isolated example but when followed by the Pythagorean third caused the Pythagorean third to sound excessively sharp. If the situation were reversed, the Pythagorean third might sound acceptable as an isolated example but caused the just third to sound excessively flat when sounded immediately after the Pythagorean third. Regardless of which of the two intervals was presented first, the first interval caused the second to be unacceptable.

Equal tempered tuning approaches the mean variation between just and Pythagorean tuning in most of the intervals selected for use in this study. This is particularly true of the major and minor thirds, which form a very significant part of this study. Because of this, it was decided that the equal tempered example should always be the second example in order of presentation so as to de-emphasize the above mentioned problem that existed when Pythagorean tuned and justly tuned examples were presented in immediate succession.

Considering the length of time that each interval should sound, it was decided that the interval should sound long enough to establish a critical evaluation but not so long that the ear had time to adjust and develop a tolerance for an interval that was mistuned. This was done in order to minimize the effect that the first example might have upon the second and third examples.

Acting upon the advice and judgment of fellow faculty members from the Music Department of Central State College, the writer adopted the following pattern for presenting the various examples. The just intervals were presented first in each of the twenty examples. Each interval was played twice. The sounding time was three seconds and the lapse time between examples was three seconds.

Spoken instructions preceded each example. The spoken instructions identified the example number, the type interval being presented, and the manner of presentation (melodic or harmonic). Each tuning system was identified by alphabetical listing. Just tuning was "a," equal temperament was "b," and Pythagorean tuning was "c."

The total presentation in each instance would then be: Major thirds played harmonically:

Example 5,a.

1. three second sounding of interval;
2. three second time lapse;
3. three second sounding of interval.

Example 5,b.

1. three second sounding of interval;
2. three second time lapse;
3. three second sounding of interval.

Example 5,c.

1. three second sounding of interval;
2. three second time lapse;
3. three second sounding of interval.

Using the above-described format the entire pitch preference determination sheet was constructed as it appears in Appendix A, page 132.

Developing the Questionnaire

Since the purpose of the test was to determine the pitch preferences of individual musicians, it was decided that certain background information would be necessary in order to discover if there were a connection between pitch preference and the particular area of musical concentration.

According to related studies, it was noted that certain major areas established preferences in tuning.

Johnson[1] reported that vocalists prefer equal temperament, Richardson[2] reported that violinists in harmonic instances prefer just tuning of the major third, and Nickerson[3] reported that violinists, in melodic tendencies "lean" toward Pythagorean tuning. For this reason a questionnaire was constructed, which was to be a part of the test, in order to relate, if possible, the background of the musician to the particular pitch preferences. Since all individuals tested were schooled musicians, of prime importance was their major area. Musicians, although not necessarily piano majors, usually have had years of study on this instrument. For this reason it was necessary to know the extent of piano study of each of the musicians tested.

Helmholtz[4] states very strongly that instrumentalists and singers, when performing in groups that do not rely upon the equal temperament of the piano, tend to use just intonation. Included in the questionnaire was a question designed to determine the nature and extent of this type musical experience.

In a test of this sort certain technical information might make it possible for an individual to determine the structure of the examples, and therefore, make selections

---

[1]Johnson, op. cit.

[2]Richardson, op. cit.

[3]Nickerson, op. cit.

[4]Helmholtz, op. cit.

according to some preconceived notion rather than from an aural evaluation of the examples. The individuals most likely to fall into this category would probably be those who had had experience with piano tuning or those individuals who might have made an extensive study, at one time or another, of the three basic systems of tuning. For this reason, questions were included that would identify these individuals.

Among wind instrumentalists many performers use the elimination of acoustical beats as a basis for tuning harmonic configurations. Hence, a question regarding tuning philosophy was included.

Certain electronic tuners have enjoyed widespread usage among musicians today. The most prominent of these is the Strobo-Conn. This instrument gives reflected pitch readings to the performer in such a way that sharpness or flatness can be determined by a glance at the dials on a panel. This Strobo-Conn gives pitch readings that are based upon equal temperament. A question in regard to the use of the Strobo-Conn could point up some possible contradictions in tuning philosophy. A musician who advocates the elimination of acoustical beats in harmonic tuning and who also advocates the use of the Strobo-Conn is working against himself. A major third that is tuned according to the standards of the Strobo-Conn will beat very obviously.

The questionnaire as it appeared on the first page of the preference test is located in Appendix A, page 132.

The Method of Selecting Pitch Preferences

In most of the examples presented there were three possible choices: just, equal tempered, and Pythagorean. This, however, did not hold true in some of the examples for obvious reasons. The perfect fifths tuned according to just and Pythagorean tuning are identical. When the perfect fifth was used only two choices were possible. Example 1,a. represented both just and Pythagorean tuning, and Example 1, b. represented equal temperament.

In the case of minor thirds and minor triads only the just and equal tempered systems of tuning were used. This was due to a very objectionable difference tone that was present each time the Pythagorean minor third was used. Several experiments with different dynamic levels and change of reproduction equipment failed to eliminate this problem; so the Pythagorean minor third was eliminated from the test rather than to present it in such a way that it might cause unnatural selections for these two examples.

Another problem that presented itself during pilot testing was the fact that musicians become apprehensive when a test is given that could possibly challenge their competence as musicians. Although this preference test did not do this, a concentrated effort was necessary in order to convince the tested individuals that this was not the case. Thus, the final instructions for the preference test began with this statement: "This is not a test of your ability."

The complete instructions for the preference test appear in Appendix A, page 132.

Administering the Test

Two basic methods of testing were used in this study. For the most part the musicians were contacted individually. When this method was used, each individual was given a brief orientation session in which he was informed of the purpose of the study and was also told that there were no incorrect selections. Then time was allowed for filling out the pre-test questionnaire. The tape was then played on a Roberts tape recorder with head-phones used so that there were no external noises to distract the tested subject.

The test itself was twenty-five minutes in length. It was hoped that this length would not cause fatigue (yet many of those individuals tested related that they did experience a certain amount of fatigue by the time the test had been completed).

The other method of testing was in groups. The first group to be tested was a graduate class at the University of Oklahoma. This group consisted of twenty-seven masters and doctoral candidates who were enrolled in "Rationale of Music Education," under Dr. Robert C. Smith. The other groups tested were twelve band directors who were in attendance at the Woodward, Oklahoma, Band Clinic in December, 1966, and a group of eighteen vocal directors who were in attendance at a vocal workshop at Central State College in the summer of 1967.

In the group testing situation the procedure was the same as in individual testing except that the replay of the tapes was amplified through Fender-Tremolux speakers.

Although the writer feels that group testing was not the most satisfactory situation, it did make possible the testing of a larger number of musicians.

No attempt was made to control the specific number of musicians from each of the major areas but care was taken to assure that each area was represented in sufficient numbers to give ample sampling from that area.

The total number of musicians tested was 223. Broken down into major areas the following is the number of musicians from each area:

1. Band directors, 35. These were individuals who were directors of major instrumental ensembles on the high school and college level. Although each of these individuals was a wind instrument major, they were classified, for the purpose of this study, as directors because of their extensive experience in this area.
2. Vocal directors, 18. The majority of the vocal directors were vocal majors but since the majority of their experience was as directors of major

ensembles, they were classified as directors rather than as vocalists.

3. Voice majors, 18. These individuals were either professional singers or outstanding vocal music majors on the graduate and undergraduate level in the music schools of central Oklahoma.
4. Pianists, 46.
5. String instrumentalists, 20.
6. Wind and percussion majors, 86. This group included both performing professional musicians and music majors from the colleges and universities of central Oklahoma.

The following is a breakdown of the distribution of wind and percussion instruments found in group #6:

Percussionists	4
Woodwinds	42
Brasses	40
Total	86

Those who were considered to have a strong piano background were those who had indicated at least ten years of private study on piano and were known to be accomplished performers on that instrument.

A breakdown of the various instruments within the brass and woodwind areas shows the following distribution of instruments:

Flutes	7
Oboes	3
Bassoons	3
Clarinets	23
Saxophones	6
Trumpets and Cornets	14
French Horns	7
Baritone Horns	3
Trombones	11
Tubas	5

Potential Areas of Investigation

For the purposes of this study the major areas of comparison are: band directors, vocal directors, voice majors, pianists, string instrumentalists, and wind and percussion majors. Within the instrumental areas the study can be broken down into individual groups in order to determine whether or not the particular characteristics of wind instruments show any significant trends in pitch preferences. For example, the flute is an instrument that is usually performed with vibrato while the clarinet traditionally is played without the use of vibrato. Since vibrato has as one of its characteristics a variation in pitch, does the constant use of vibrato tend to affect pitch preferences?

Trombone and stringed instruments have more freedom in pitch performance than the other instruments. Does this freedom cause any identifiable difference in pitch preferences? According to Helmholtz[1] these two instruments, if unhampered by the "limitations" of tempered tuning should show a strong tendency toward just intonation.

Pianists are forced to accept the pitch of their instruments as representative of equal tempered tuning. Do pianists, when given a choice, accept equal temperament over just or Pythagorean tuning?

Vocalists, as a general rule, spend hours of practice with the piano as their constant check for accuracy of intervals. The majority of their performances are accompanied by the piano. In lessons, concerts, and private study the piano is a vital part of vocal performance. Does this association cause the vocalist to become equal-temperament oriented? Does *a cappella* experience tend to break down this preference?

The brass instruments are designed to perform according to the harmonic series. The partials of brass instruments respond according to the natural tones of the overtone series. Do these acoustical qualities of the brasses reflect in the pitch preferences of brass players?

Directors of major ensembles are placed constantly in the position of having to correct pitch problems within the ensemble. This responsibility should make the director more conscious of pitch tendencies. Vocal directors rely heavily upon the piano for pitch reference. Instrumental

---

[1]Helmholtz, *op. cit.*

directors are not so dependent upon the piano. Does this difference in rehearsal procedure cause a difference in pitch preferences when the two groups are compared? Does the particular means of presentation of the interval have any effect upon the pitch preference? Is there a noticeable difference between melodic and harmonic pitch tendencies? These are all questions that are to be investigated within this study.

CHAPTER V

FINDINGS

Perfect Fifths Played Melodically

The first example on the pitch preference test was the perfect fifth in its melodic form. As was previously stated, this interval was presented in its just and equal tempered forms. The obvious reason for this was that the perfect fifths are identical in just and Pythagorean tuning. The pitches used were . The pitch difference between the two examples was only two cents, or one-fiftieth of a semitone. The C's were identically tuned (beat-free). The G's were tuned so that the tempered G was two cents flat to the just G.

The results for the 223 musicians tested are as shown in Table 1.

TABLE 1

SELECTED PREFERENCES FOR PERFECT FIFTHS PLAYED MELODICALLY

Just 1a.	Equal Tempered 1b.	Rated Equal 1a. & 1b.
97	85	41

Perfect Fifths Played Harmonically

When the same interval was presented in its harmonic form, the results were as shown in Table 2.

TABLE 2

SELECTED PREFERENCES FOR PERFECT FIFTHS PLAYED HARMONICALLY

Just 2a.	Equal Tempered 2b.	Rated Equal 2a. & 2b.
104	104	15

Even though the pitches of the G's are only two cents apart in Table 2, when the tones were played harmonically the tempered fifth had a slow beat that could be detected.

Perfect Fifths Played Harmonically with Vibrato

When vibrato was added to the perfect fifth the results were as shown in Table 3. The purpose was to determine whether or not vibrato had any effect upon the particular choice of systems of tuning.

TABLE 3

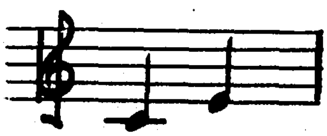
SELECTED PREFERENCES FOR PERFECT FIFTHS PLAYED HARMONICALLY WITH VIBRATO

Just 3a.	Equal Tempered 3b.	Rated Equal 3a. & 3b.
98	90	35

When vibrato was added to the harmonic perfect fifth, the slow beat in the tempered fifth distributed the evenness of the vibrato rate in the tempered fifth very slightly. This was detectable in the example and could have influenced the selections.

Major Thirds Played Melodically

The pitches used for the melodic major third were



. The examples were presented in the following order: just, tempered, and Pythagorean. The just third is fourteen cents flat compared to equal temperament, and the Pythagorean third is eight cents sharp. The preferences for the melodic major third are recorded in Table 4.

TABLE 4

SELECTED PREFERENCES FOR MAJOR THIRDS PLAYED MELODICALLY

Just 4a.	Equal Tempered 4b.	Pythagorean 4c.
43	82	55

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

4a. & 4b.	4a., 4b., & 4c.	4a. & 4c.	4b. & 4c.
3	9	6	25

This chart shows that in a majority of instances those tested preferred equal temperament, second choice was Pythagorean, and third choice was just intonation. Significant is the fact that twenty-five of this group rated the equal tempered and Pythagorean thirds as being equally acceptable.

Major Thirds Played Harmonically

Using the identical pitches as were used in example four but presenting them in a harmonic configuration, the results were as shown in Table 5.

TABLE 5

SELECTED PREFERENCES FOR MAJOR THIRDS PLAYED HARMONICALLY

Just 5a.	Equal Tempered 5b.	Pythagorean 5c.
80	47	57

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

5a. & 5b.	5a., 5b., & 5c.	5a. & 5c.	5b. & 5c.
11	10	6	12

When presented harmonically, the just major third was beat-free. The equal tempered third beat at an obviously detectable rate and the Pythagorean third beat so rapidly that it gave the effect of a barely discernible flutter. Of significance here is the fact that the number preferring justly tuned thirds was almost doubled, eighty as compared to forty-three, while the number preferring equal tempered thirds was cut almost in half, forty-seven as compared to eighty-two. The number preferring Pythagorean thirds remained fairly stable, fifty-seven as compared to fifty-five.

Major Thirds Played Harmonically with a Change of Timbre

The effect of the change of timbre was to emphasize the upper partials of each tone. This caused beats to be much more pronounced in the equal tempered third and also in the Pythagorean third. The pitches were identical to those used in examples four and five. The results are shown in Table 6.

TABLE 6

SELECTED PREFERENCES FOR MAJOR THIRDS PLAYED HARMONICALLY WITH A CHANGE OF TIMBRE

Just 6a.	Equal Tempered 6b.	Pythagorean 6c.
103	65	31

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

6a. & 6b.	6a., 6b., & 6c.	6a. & 6c.	6b. & 6c.
6	7	4	7

When the beating became more pronounced, the shift of preferences was even greater toward just intonation. The number selecting equal temperament increased by eighteen while the number preferring Pythagorean tuning decreased by twenty-six. The number of individuals who made multiple selections dropped from thirty-nine to twenty-four, an indication that positive selection was made easier by the change in timbre. This could have been the result of the clearly detectable beat patterns.

Minor Thirds Played Melodically

The just minor third in this example was fourteen cents sharp to the equal tempered third and the Pythagorean third, which was not used, was six cents flat to the tempered third. As was previously stated, the Pythagorean third was not used because of the persistence of an objectionable difference tone. Repeated experimentation with possible means of eliminating this difference tone disclosed that the only way it could be erased was to mistune the interval slightly. Since this would have defeated the purpose of the study, it was regretfully omitted from the seventh example. The notes used for this example were  . Table 7 shows the preferred selections for the minor third played melodically.

TABLE 7

SELECTED PREFERENCES FOR MINOR THIRDS PLAYED MELODICALLY

Just 7a.	Equal Tempered 7b.	No Preference
80	122	21

As was the case with the melodic major third, the preferred tuning was equal temperament; however, the degree of preference was not so high.

Minor Thirds Played Harmonically

The same pitches were used here as were used in example seven except that the tones were sounded simultaneously. As was the case with the other harmonic intervals, the beats were detectable in the equal tempered example. The results are recorded in Table 8.

TABLE 8

SELECTED PREFERENCES FOR MINOR THIRDS PLAYED HARMONICALLY

Just 8a.	Equal Tempered 8b.	Rated Equal 8a. & 8b.
105	92	26

Here again the preference was for just tuning of the harmonic interval, but the degree of preference was not so high. This is rather unusual when consideration is given to the fact that the just minor third is sharp by the same amount (14 cents) as the just major third is flat when compared to equal tempered tuning.

Major Triads Played Melodically

The notes used for this example were

. The root of the triad was tuned identically for each of the three systems of tuning. The just third was fourteen cents flat to equal temperament, and the Pythagorean third was eight cents sharp. The fifths were tuned identically for both just and Pythagorean tuning with both being two cents sharp to the equal tempered fifth. The results of the tested examples are recorded in Table 9.

TABLE 9

SELECTED PREFERENCES FOR MAJOR TRIADS PLAYED MELODICALLY

Just 9a.	Equal Tempered 9b.	Pythagorean 9c.
25	75	64

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

9a. & 9b.	9a., 9b., & 9c.	9a. & 9c.	9b. & 9c.
10	16	6	27

The number of preferences for just tuning in this example is slightly over 11 per cent of the total tested population. Also of interest is the fact that the number of musicians preferring Pythagorean tuning is only nine less than those preferring equal temperament. Those who rated equal temperament and Pythagorean tuning as being equally acceptable made up 12 per cent of the total tested population.

Major Triads Played Harmonically

The pitches were the same as those used in example nine, the only difference being that the notes were sounded simultaneously. The results are recorded in Table 10.

TABLE 10

SELECTED PREFERENCES FOR MAJOR TRIADS PLAYED HARMONICALLY

Just 10a.	Equal Tempered 10b.	Pythagorean 10c.
135	62	11

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

10a. & 10b.	10a., 10b., & 10c.	10a. & 10c.	10b. & 10c.
3	5	2	5

This example shows one of the most extreme shifts in preference when a comparison is made between melodic and harmonic examples. While only twenty-five individuals preferred the just triad played melodically, 135 preferred this tuning when the examples were played harmonically. Those musicians who preferred Pythagorean tuning for melodic triads numbered sixty-four, whereas only eleven preferred the same triad when presented harmonically. The number of individuals preferring equal tempered tuning for the major triad was fairly stable. There were seventy-five who preferred equal temperament in melodic instances compared to sixty-two who preferred equal temperament in harmonic instances. Also of significance is the fact that the number who rated equal temperament and Pythagorean tuning as being equally acceptable in example nine dropped from twenty-seven to five when the examples were presented harmonically.

Major Triads Played Harmonically with Vibrato

This example is identical to that in number ten except that vibrato was added. The results are recorded in Table 11.

The use of vibrato had a tendency to obscure the detectable beats that were present in the harmonic examples of equal tempered and Pythagorean tuning. Vibrato caused the number preferring justly tuned triads to drop from 135 to 102. This is an appreciable amount; yet those who preferred just tuning outnumbered the combined total of those who preferred equal temperament and Pythagorean tuning.

TABLE 11

SELECTED PREFERENCES FOR MAJOR TRIADS PLAYED HARMONICALLY WITH VIBRATO

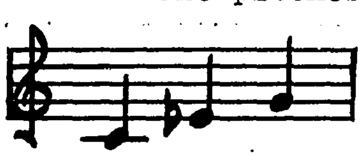
Just 11a.	Equal Tempered 11b.	Pythagorean 11c.
102	53	28

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

11a. & 11b.	11a., 11b., & 11c.	11a. & 11c.	11b. & 11c.
9	11	5	5

Minor Triads Played Melodically

The pitches used for the minor triad were



. The C's were tuned identically, the E^b for just intonation was tuned fourteen cents sharp to equal temperament, and the justly tuned fifth was tuned two cents sharp to the equal temperament fifth.

Pythagorean tuning was omitted because of the same problems that occurred in relation to the minor third. An objectionable difference tone could not be eliminated from the harmonic example of this triad. The results are recorded in Table 12.

The results of this example show the highest preference for equal temperament of any example from the entire test. The only other example that approaches this one in expressing preference for equal temperament is number seven, which relates to tuning of the minor third melodically.

TABLE 12

SELECTED PREFERENCES FOR MINOR TRIADS PLAYED MELODICALLY

Just 12a.	Equal Tempered 12b.	No Preference
53	149	21

Minor Triads Played Harmonically

The pitches used here were identical to those used in example 12, the only difference being that the tones were presented harmonically. The Pythagorean minor triad was omitted as was mentioned above. The results are recorded in Table 13.

TABLE 13

SELECTED PREFERENCES FOR MINOR TRIADS PLAYED HARMONICALLY

Just 13a.	Equal Tempered 13b.	No Preference
89	111	23

These results show, as has been the case throughout, that the preference for just tuning increased each time the example was presented harmonically. This was the only example on the entire test in which the preference for equal temperament was higher than that for just intonation when the examples were presented harmonically. The preferences for the minor triad were similar to those that were indicated in examples seven and eight for the minor third.

Minor Triads Played Harmonically with Vibrato

The pitches were identical to those used in example thirteen except that the vibrato was added. The results are recorded in Table 14.

TABLE 14

SELECTED PREFERENCES FOR MINOR TRIADS PLAYED HARMONICALLY WITH VIBRATO

Just 14a.	Equal Tempered 14b.	No Preference
94	102	27

This was the last of the examples in which vibrato was used. As a general observation, each time that vibrato was used the number of individuals rating the examples as being equally acceptable increased. Also, the number of individuals selecting equal temperament as the preferred tuning decreased each time vibrato was added. This might be explained by the fact that the beating of the equal tempered harmonic intervals was often in conflict with the natural rate of the vibrato.

Dominant Seventh Chords
Played Melodically

The pitches used for this example were

. The C's were identical for each of the systems of tuning, the just E was tuned fourteen cents flat to equal temperament, and the Pythagorean E was tuned eight cents sharp to equal temperament. The G's for both just and Pythagorean tuning were two cents sharp compared to equal tempered tuning. The just B^b was tuned thirty cents flat to equal temperament (so that the chord would be beat-free). The Pythagorean B^b was tuned four cents flat to equal temperament. The results of this example are recorded in Table 15.

TABLE 15

SELECTED PREFERENCES FOR DOMINANT SEVENTH
CHORDS PLAYED MELODICALLY

Just 15a.	Equal Tempered 15b.	Pythagorean 15c.
31	70	81

Number and Nature of Selected Preferences Where Two or
More Examples Were Rated as Being Equally Acceptable

15a. & 15b.	15a., 15b., & 15c.	15a. & 15c.	15b. & 15c.
4	7	8	22

A significant feature of these results is that the Pythagorean tuning is favored by the largest number of those tested. In the major triad played melodically sixty-four preierred the Pythagorean tuning while in the dominant seventh chord played melodically, the number was eighty-one. A reason for this could be that the dominant seventh tuned according to Pythagorean principles most closely relates to the rules for melodic pitch tendencies stated in Chapter II, page 10. The third is raised and the minor seventh is lowered in the direction of its resolution. The minor seventh is also lowered in the example of just tuning but to the extent that it sounds noticeably flat (thirty cents) in a melodic passage.

Dominant Seventh Chords Played Harmonically

In this example the pitches were the same as in number fifteen but the tones were played simultaneously. The results are recorded in Table 16.

As has been the case in each of the previous examples, the preference for just tuning in harmonic instances shows a sharp increase. In this respect the preference for just tuning compares with that of major triads played harmonically. The preference for Pythagorean tuning in the dominant seventh played harmonically is much higher than it was for major triads played harmonically (56 to 11).

TABLE 16

SELECTED PREFERENCES FOR DOMINANT SEVENTH
CHORDS PLAYED HARMONICALLY

Just 16a.	Equal Tempered 16b.	Pythagorean 16c.
108	40	56

Number and Nature of Selected Preferences Where Two or
More Examples Were Rated as Being Equally Acceptable

16a. & 16b.	16a., 16b., & 16c.	16a. & 16c.	16b. & 16c.
4	4	4	7

Major Seventh Chords Played Melodically

In this example the pitches used were

. The tuning for the triad C, E, and G was the same as that used in example fifteen. The major seventh of the chord was fourteen cents flat to equal temperament in just tuning. The major seventh was ten cents sharp in Pythagorean tuning. This was considered to be a most significant example since it was one of only two instances where the musicians tested had an opportunity to show preferences for the pitch of the leading tone. In Chapter II it was emphasized that the pitch tendency for the leading tone was that it be played high. The results of this example are recorded in Table 17.

TABLE 17

SELECTED PREFERENCES FOR MAJOR SEVENTH CHORDS PLAYED MELODICALLY

Just 17a.	Equal Tempered 17b.	Pythagorean 17c.
13	63	84

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

17a. & 17b.	17a., 17b., & 17c.	17a. & 17c.	17b. & 17c.
7	17	7	32

The preferences indicated here support the rule that was stated in Chapter II. The preference for Pythagorean tuning is higher in this instance than in any other example on the test. Also, the number who rated equal temperament and Pythagorean tuning as being equally acceptable was higher than in any other example on the test.

Major Seventh Chords Played Harmonically

The pitches were the same as those used in example seventeen. The only difference was the method of presentation. The results are shown in Table 18.

In this example it should be noted that the shift in preference when played harmonically was heavily toward the justly tuned chord, but the largest number of tested subjects indicated a preference for equal temperament. This could be explained by the fact that the B natural in the justly tuned triad does not occur as a natural interval.

By that it is meant that in the harmonic series the seventh partial would normally be a B^b if the tones are generated from C. Although the B natural was tuned justly with the G, it was still in conflict with the fundamental C, a fact that could have accounted for the rejection of justly tuned intervals by some of those tested.

TABLE 18

SELECTED PREFERENCES FOR MAJOR SEVENTH CHORDS PLAYED HARMONICALLY

Just 18a.	Equal Tempered 18b.	Pythagorean 18c.
72	92	81

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

18a. & 18b.	18a., 18b., & 18c.	18a. & 18c.	18b. & 18c.
3	8	2	7

Cadence Chords Played Harmonically

The cadence selected for this example was in C major. The particular progression was I, IV, I, V_7, I. The example was voiced in closed position. The major triads were tuned as they appeared in example ten, and the dominant seventh chord was tuned as in example sixteen except that it was built on G instead of C. The results are recorded in Table 19.

TABLE 19

SELECTED PREFERENCES FOR CADENCE CHORDS PLAYED HARMONICALLY

Just 19a.	Equal Tempered 19b.	Pythagorean 19c.
119	76	15

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

19a. & 19b.	19a., 19b., & 19c.	19a. & 19c.	19b. & 19c.
9	0	2	2

As has so often been the case, the largest number of those tested preferred justly tuned cadence chords. Those selecting Pythagorean tuning were a very small group (fifteen). A probable explanation for this would be that the Pythagorean chords were beating rather obviously and not at the same rate for each change of chord. This was also true for the equal tempered tuning, but the beat rate was much more moderate.

The Major Scale Ascending and Descending

All three systems of tuning were used for this example. The scale used was C major.

The following chart will show how the just and Pythagorean scales varied from equal temperament:

Just	Equal Tempered	Pythagorean
C same	C	C same
D sharp 4¢	D	D sharp 4¢
E flat 14¢	E	E sharp 8¢
F flat 2¢	F	F flat 2¢
G sharp 2¢	G	G sharp 2¢
A flat 16¢	A	A sharp 6¢
B flat 12¢	B	B sharp 10¢
C same	C	C same

Because of the length of the major scale each system of tuning in example 20 was played only once. The results are reported in Table 20.

TABLE 20

SELECTED PREFERENCES FOR THE MAJOR SCALE ASCENDING AND DESCENDING

Just 20a.	Equal Tempered 20b.	Pythagorean 20c.
9	95	74

Number and Nature of Selected Preferences Where Two or More Examples Were Rated as Being Equally Acceptable

20a. & 20b.	20a., 20b., & 20c.	20a. & 20c.	20b. & 20c.
6	12	2	25

The most significant results from this example are found in the almost complete rejection of the tuning of the just scale when presented melodically. Here again, it was found that the Pythagorean melodic scale was widely accepted but that the equal tempered scale was preferred by the largest number.

These reported results for each of the twenty examples involved the total tested population. The next logical step was to investigate the selections of various groups within the total membership in order to see if any one area of performance showed indication of pitch preferences that could be identified as being characteristic of that particular area of musical performance.

Results According to Major Areas

The major areas under consideration are: band directors, vocal directors, voice majors, pianists, string instrumentalists, and wind and percussion majors.

Preference tables for each of these areas may be found in Appendix C, pages 141 to 161. These tables show the pitch preference selections for each of the major areas, the number of musicians within each area, the type interval, the method of presentation, the number of preferences for each system of tuning in raw figures, and a percentage breakdown of pitch selections within each area.

Preference Selections for Band Directors

Thirty-five band directors were included in this study. Not considering the method of presentation of intervals (harmonic or melodic), their preferences were as follows:

TABLE 21

Justly tuned intervals	305	43.6%
Equal tempered intervals	218	31.1%
Pythagorean intervals	80	11.4%
Rated as equally acceptable	97	13.9%

If method of presentation is considered, the figures take on added significance. In those twelve examples where intervals were presented harmonically, band directors indicated the following preferences. (These percentages are based upon clear-cut decisions and do not include equally rated intervals.)

TABLE 22

Justly tuned intervals	176	73.0%
Equal tempered intervals	30	12.5%
Pythagorean intervals	35	14.5%

In the eight examples that were presented melodically there was a drastic change in preference.

TABLE 23

Justly tuned intervals	14	10.5%
Equal tempered intervals	73	54.5%
Pythagorean intervals	47	35.0%

This shift in preference from justly tuned harmonic intervals to equal tempered tuning for melodic intervals is most pronounced in the last two examples of the preference test. In cadence chords played harmonically twenty-nine of the thirty-five band directors indicated a preference for justly tuned intervals. In the major scale, which would be a melodic presentation, none of the band directors indicated a preference for justly tuned intervals. Eighteen of the band directors preferred equal tempered tuning, eight preferred Pythagorean, and six indicated that equal tempered and Pythagorean tuning were equally acceptable.

The examples that included vibrato exercised a consistent effect upon the group of directors. Each time that the vibrato was added the number of justly tuned preferences dropped slightly and the number of equally acceptable choices increased. This would indicate that vibrato does have an influence upon pitch discrimination in that it seems to cause a more tolerant attitude toward pitch variation.

The one example that involved a change of timbre had a most significant effect upon the band directors. In example 5 thirteen of the band directors had indicated a preference for justly tuned major thirds. When the timbre was changed so as to emphasize the upper partials, twenty-four of the group indicated a preference for justly tuned intervals. This is an increase from 37.1% to 68.6% of the total number of selections.

Preference Selections for Vocal Directors

Eighteen vocal directors were included in this study. If no consideration is given to the manner in which intervals were presented, the total selections for vocal directors were as follows:

TABLE 24

Justly tuned intervals	67	18.6%
Equal tempered intervals	198	55.0%
Pythagorean intervals	64	17.8%
Rated as equally acceptable	31	8.6%

Considering only those examples that were presented harmonically, the preference selections for vocal directors were:

TABLE 25

Justly tuned intervals	20	17.4%
Equal tempered intervals	56	48.7%
Pythagorean intervals	39	33.9%

The examples that were presented melodically indicate an even stronger preference on the part of vocal directors for equal tempered tuning.

TABLE 26

Justly tuned intervals	3	3.9%
Equal tempered intervals	49	63.6%
Pythagorean intervals	25	32.5%

Vocal directors do not show a strong preference for justly tuned intervals presented harmonically. A point of interest in regard to vocal directors would be their strong preference for Pythagorean tuning in the dominant seventh and major seventh chords presented harmonically. Their preferences in dominant seventh chords played harmonically were:

TABLE 27

Justly tuned intervals	2	11.1%
Equal tempered intervals	7	38.9%
Pythagorean intervals	8	44.4%
Rated equally acceptable	1	5.6%

Their preferences in major seventh chords played harmonically were:

TABLE 28

Justly tuned intervals	2	11.1%
Equal tempered intervals	7	38.9%
Pythagorean intervals	8	44.4%
Rated equally acceptable	1	5.6%

In each instance their preferences were identical. A check of individual sheets indicated that the two directors who preferred just intonation were the same for both examples.

The one example that involved change of timbre caused vocal directors to shift their preference toward justly tuned intervals. In example five, two of the vocal directors had indicated a preference for justly tuned intervals. When the timbre was changed in example six, five of the directors then preferred justly tuned major thirds.

As was the case with band directors, vocal directors tended to select an increased number of equally rated intervals when vibrato was added. This would add support to the assumption that vibrato develops a more tolerant attitude toward pitch variation.

Although it had been stated earlier that the pitch variation of the perfect fifth was only two cents between just intonation and equal tempered tuning, the vocal directors indicated a definite preference for the smaller fifth of equal temperament in each of the three examples involving the perfect fifth.

Preference Selections for Voice Majors

Eighteen voice majors were included in this study. A list of total selections for this group, not considering the method of presentation of the intervals, shows the following:

TABLE 29

Justly tuned intervals	100	27.8%
Equal tempered tuning	150	41.7%
Pythagorean tuning	54	15.0%
Rated equally acceptable	56	15.5%

The voice majors, like vocal directors, show a preference for equal tempered tuning but the preference is not so clearly defined. The voice majors indicate a stronger preference for just intonation than do the vocal directors and also show an increase in the number of instances in which examples are rated as being equally acceptable.

Considering only those examples that were presented harmonically, the preference selections for voice majors were:

TABLE 30

Justly tuned intervals	74	38.9%
Equal tempered intervals	92	48.4%
Pythagorean intervals	24	12.6%

The voice majors are similar to the vocal directors in their preference for equal tempered tuning in harmonic instances but do not favor Pythagorean tuning to so high a degree. They also show a higher percentage of preference for justly tuned intervals than do the vocal directors.

The selections for voice majors when considering only examples presented melodically were:

TABLE 31

Justly tuned intervals	26	22.8%
Equal tempered intervals	58	50.9%
Pythagorean intervals	30	26.3%

Although voice majors showed a strong preference for equal tempered tuning, the preferences were not so strong as those indicated by the vocal directors.

In the examples containing the dominant seventh chord and the major seventh chord, voice majors showed a strong preference for Pythagorean tuning. The method of presentation (melodic or harmonic) seems to have very little effect upon the preferred selections. For example, in the examples involving the dominant seventh melodically, the voice majors' preferences were:

TABLE 32

Justly tuned intervals	1	5.6%
Equal tempered intervals	5	27.8%
Pythagorean intervals	9	50.0%
Rated equally acceptable	3	16.7%

Their selected preference for the same intervals presented harmonically were:

TABLE 33

Justly tuned intervals	3	16.7%
Equal tempered tuning	5	27.8%
Pythagorean tuning	9	50.0%
Rated equally acceptable	1	5.6%

The only noticeable effect is a slight increase in the number of persons preferring justly tuned intervals in the harmonic presentation and a slight drop in the number of persons rating equally acceptable intervals.

The addition of vibrato had the same effect upon voice majors as it did upon band directors and vocal directors. It caused an increase in the numbers of examples rated equally acceptable.

In the example that involved a change of timbre, the voice majors show a decline in the degree of preference for Pythagorean tuning and an increase in the degree of preference for equal tempered tuning. The number preferring justly tuned intervals remained the same as it was before the change of timbre.

Preference Selections for Pianists

Forty-six pianists were included in this study. With no consideration given to method of presentation their pitch preference selections were as follows in Table 34.

TABLE 34

Justly tuned intervals	258	28.1%
Equal tempered intervals	383	41.6%
Pythagorean intervals	141	15.3%
Rated as equally acceptable	138	15.0%

Pianists' selections were almost identical to those of the voice majors. There was less than .6 per cent variation in any of the above categories.

When the examples were presented harmonically, the pianists' pitch preferences were:

TABLE 35

Justly tuned intervals	188	39.2%
Equal tempered intervals	241	50.2%
Pythagorean intervals	51	10.6%

Here, again, there is a marked similarity between the preferences indicated by pianists and those indicated by voice majors. In examples that were presented melodically the pianists' preferences were:

TABLE 36

Justly tuned intervals	70	24.0%
Equal tempered intervals	132	45.2%
Pythagorean intervals	90	30.8%

In the melodic examples the pianists show a somewhat stronger preference for Pythagorean tuning than do the voice majors. This is rather surprising since the piano is an equal tempered instrument. The twentieth example, which presented the major scale ascending and descending, showed pianists with a very strong preference for Pvthagorean tuning. This preference was so strong that only string instrumentalists rated above them in their preference for this system of tuning. The selections for pianists were as follows:

TABLE 37

Justly tuned intervals	1	2.2%
Equal tempered intervals	13	28.3%
Pythagorean intervals	22	47.8%
Rated as equally acceptable	8	21.6%

The major seventh chord played melodically represented another example in which pianists showed a strong preference for Pythagorean tuning. Their preferences were as follows:

TABLE 38

Justly tuned intervals	3	6.5%
Equal tempered intervals	10	21.7%
Pythagorean intervals	22	47.8%
Rated as equally acceptable	11	23.9%

As was the case with the other groups under consideration, adding vibrato increased the number of instances in which intervals in different systems of tuning are rated as being equally acceptable. Change of timbre did not cause an increase in the number of justly tuned preferences.

Preference Selections for String Instrumentalists

Twenty string instrumentalists were included in this study. This group of twenty includes violins, violas, cellos, and string basses. Their preference selections regardless of method of presentation were as follows:

TABLE 39

Justly tuned intervals	182	45.5%
Equal tempered intervals	140	35.0%
Pythagorean intervals	60	15.0%
Rated as equally acceptable	18	4.5%

It should be noted that the string players preferred justly tuned intervals to a higher degree than any other group included in this study. They also showed a very low percentage of instances where systems of tuning were rated as being equally acceptable. This could be interpreted as an indication that string players are more discriminate listeners. Out of 400 possible selections (twenty subjects tested and twenty examples in the test), there were only eighteen examples of multiple preference.

In examples that were presented harmonically the string players' preferences were:

TABLE 40

Justly tuned intervals	135	60.8%
Equal tempered intervals	73	32.8%
Pythagorean intervals	14	6.3%

These results would tend to support the findings of the Richardson[1] study. His findings, when working with violinists, were that string players preferred justly tuned intervals when harmonic considerations were the dominant factor in a musical example.

In examples that were presented melodically, string instrumentalists indicated the preferences shown in Table 41.

TABLE 41

Justly tuned intervals	47	37.8%
Equal tempered intervals	55	37.1%
Pythagorean intervals	46	31.1%

These preferences would indicate that both band directors (35.0%) and vocal directors (32.5%) preferred Pythagorean tuning in melodic instances to a higher degree than did string instrumentalists. Considering all examples, this is true; however, there were two examples in which string instrumentalists showed a higher preference for Pythagorean tuning than did any of the other groups tested.

[1]Richardson, op. cit., p. 129.

In the major scale, which was a melodic example, their preferences were as follows:

TABLE 42

Justly tuned intervals	2	10.0%
Equal tempered intervals	4	20.0%
Pythagorean intervals	12	60.0%
Rated as equally acceptable	2	10.0%

Here, the degree of preference was almost 15 per cent higher than that indicated by any of the other groups.

It should be pointed out that these were the only two examples that included the leading tone. This would tend to support the statement of Flesch[1] that the leading tone should be played higher in the direction of its natural resolution.

Wind and Percussion Majors

Eighty-six musicians were included within this group. If no consideration is given to method of presentation, the total preference selections for this group were:

TABLE 43

Justly tuned intervals	656	38.2%
Equal tempered intervals	587	34.1%
Pythagorean intervals	199	11.5%
Rated as equally acceptable	278	16.2%

[1]Flesch, op. cit., p. 22.

These results show that the wind and percussion players were quite similar to band directors in their preferences with band directors showing a slightly higher preference for justly tuned intervals.

Considering only those intervals that were presented harmonically the preferences of wind and percussion players were:

TABLE 44

Justly tuned intervals	524	57.5%
Equal tempered intervals	314	34.4%
Pythagorean intervals	74	8.1%

These preference selections are quite similar to those indicated by string instrumentalists. Both groups show a very low degree of preference for Pythagorean tuning in harmonic intervals.

In instances where only melodic intervals were considered, the preferences of wind and percussion players were:

TABLE 45

Justly tuned intervals	132	25.4%
Equal tempered intervals	262	50.6%
Pythagorean intervals	125	24.0%

In melodic intervals the preference selections of the wind and percussion majors resemble most closely those preferences indicated by the vocalists.

Wind and percussion majors show the highest percentage of instances in which examples from different tuning systems were rated as being equally acceptable (16.2%). Voice majors were next (15.5%), followed by pianists (15.0%), band directors (13.9%), vocal directors (8.6%), and then string instrumentalists (4.5%).

Instrumentalists Within the Major Area of Winds and Percussion

The instruments included with this area were: flutes (7), oboes (3), bassoons (3), clarinets (23), saxophones (6), cornets and trumpets (14), French horns (7), trombones (11), baritones (3), tubas (5), and Percussion (4).

In acoustical design all of the woodwinds except the clarinet overblow to the octave. This means that within any one octave twelve holes can be placed in such a way as to produce even divisions of the octave according to equal tempered standards. The clarinet overblows to the third partial (twelfth) and the fifth partial in order to produce the tones within its practical playing range. This means that the fundamental tone holes can be cut according to equal tempered standards but that clarion and altissimo registers will respond according to just standards. The woodwinds, excepting the clarinet, are all characteristically played with vibrato. Although the clarinet is played with vibrato on occasions, it is traditionally played without vibrato. Considering the above facts, the woodwinds were divided into two groups, which included clarinets in one group and all other woodwinds in the other.

Within the brasses a logical grouping would be to divide into valved brasses and trombone. The French horn, however, plays most of the time in the tones of the upper partials of the harmonic series. Since this fact might cause French horn players to develop a stronger preference for justly tuned intervals, they were considered as an individual group. The brasses were then divided into the following categories: (1) Standard valved brasses, cornet, trumpet, baritone, and tuba, (2) French horn, and (3) trombone.

The percussion quite naturally were considered as a separate group.

The selected preferences of these instrumental groups are listed in Appendix D, pages 162 to 182.

The classification of instruments within these groups was:

Woodwind Group I	(Flutes, oboes, bassoons, and saxophones)
Woodwind Group II	(Clarinets)
Brass Group I	(Cornets and trumpets, baritone horns, tubas)
Brass Group II	(French horns)
Brass Group III	(Trombones)
Percussion	

Preference Selections for
Woodwinds, Group I

Considering the total number of selections regardless of method of presentation (melodic or harmonic) the preferences of this group were:

TABLE 46

Justly tuned intervals	119	31.3%
Equal tempered intervals	150	39.5%
Pythagorean intervals	46	12.1%
Rated as equally acceptable	65	17.1%

Preference Selections for
Clarinets, Group II

TABLE 47

Justly tuned intervals	204	44.4%
Equal tempered intervals	141	30.7%
Pythagorean intervals	55	12.0%
Rated as equally acceptable	59	12.9%

A comparison of the two woodwind groups shows that clarinets had a much higher degree of preference for justly tuned intervals than did the other woodwinds. If Group I is broken down into individual instruments, none of the other woodwinds indicated as high a degree of preference for justly tuned intervals as they did for equal tempered intervals.

Preference Selections for
Brasses, Group I

TABLE 48

Justly tuned intervals	154	34.9%
Equal tempered intervals	145	32.9%
Pythagorean intervals	52	11.8%
Rated as equally acceptable	90	20.4%

Only one of this group, the tuba, showed a higher preference for equal tempered intervals when compared to just intervals. The degree of preference was very slight. Thirty-eight selected preferences were for justly tuned intervals and thirty-nine selected preferences were for equal tempered intervals.

Preference Selections for
French Horns, Group II

TABLE 49

Justly tuned intervals	72	51.4%
Equal tempered intervals	34	24.3%
Pythagorean intervals	12	8.6%
Rated as equally acceptable	22	15.7%

Considering all instruments, the French horns indicated the highest preference for justly tuned intervals.

Preference Selections for
Trombones, Group III

TABLE 50

Justly tuned intervals	93	42.3%
Equal tempered intervals	71	32.5%
Pythagorean intervals	23	10.4%
Rated as equally acceptable	33	15.0%

Trombones indicated a high degree of preference for justly tuned intervals. Their preferred selections were surprisingly similar to those of the strings. The one exception is that they have a lower percentage of preferences for Pythagorean intervals.

Preference Selections for Percussion

TABLE 51

Justly tuned intervals	14	17.5%
Equal tempered intervals	45	56.2%
Pythagorean intervals	11	13.8%
Rated as equally acceptable	10	12.5%

Percussionists' preferences were in no way similar to those of the other instrumentalists. As a group their preferences strongly resembled those of the vocal directors.

The preference selections of this group of instruments have all been reported with no consideration for method of presentation. The interested reader will find the specific information for each of the twenty examples in Appendix D, pages 162 to 182.

The findings of this study indicated that there were very positive variations in pitch preferences among musicians from the major performing areas. These individual pitch preferences will, no doubt, have an effect upon the intonation of musical performances by these groups.

CHAPTER VI

CONCLUSIONS

Regarding Tuning Systems

From the pitch preference selections indicated within this study, it can be concluded that all three systems of tuning--just, equal tempered, and Pythagorean--are acceptable to performing musicians. This does not mean to infer that they are all equally acceptable, but ~~that~~, under certain conditions, one or the other of the systems of tuning will satisfy the preferences of some group of musicians.

Just intonation serves best in those musical examples that are presented harmonically. This is particularly true when considering the pitch preferences of band directors, strings, and wind instrumentalists.

Equal temperament serves best in those musical examples that are presented melodically. The vocal directors, vocalists, and pianists show a particularly high degree of preference for equal temperament under these conditions.

Pythagorean tuning, although not preferred to the extent of equal temperament, is given a high degree of preference. The degree of preference for Pythagorean tuning is higher for certain melodic examples, such as the dominant seventh chord, major seventh chord, and the major scale played melodically. The musicians who showed the strongest preferences for Pythagorean tuning under these conditions were pianists, violinists, and voice majors.

Of significance is the fact that in each of the above mentioned melodic examples many of the musicians rated equal tempered tuning and Pythagorean tuning as being equally acceptable.

The findings, then, indicate that harmony is best served by justly tuned intervals and that melody is best served by equal tempered or Pythagorean intervals. A further statement would be that performance medium must also be taken into consideration.

Implementation of these rules in regard to harmonic and melodic tuning would have to involve a judgment factor on the part of the performer. Slow, obviously chordal, passages should be tuned justly since beating obviously offends in some of the areas of performance. Players of instruments that do not use vibrato and that do contain strong upper partials should be most aware of the rules for justly tuned harmonies. Players of instruments that do use vibrato and that do not contain strong upper partials need not be so aware of justly tuned harmonies since the objectionable beating will be less obvious.

This information, although somewhat confusing, does answer questions that were raised at the outset of this study. For example, the rule that stated that the third of the chord should be lowered was obviously a reference to the tuning of major thirds harmonically according to just standards. The rule that stated that the third should be raised was a reference to the tuning of major thirds melodically according to the standards of equal temperament of Pythagorean tuning.

These rules of pitch performance could only apply to musical performances that do not include keyboard instruments. Above all other rules of pitch performance, unisons and octaves must be pure (beat-free). This would not be possible if any other system of tuning were used in an ensemble that utilized equal tempered instruments with no pitch flexibility.

The question in regard to lowering the seventh of the dominant seventh in the direction of its resolution can easily be explained. This tendency stems from the preference for justly tuned harmonic intervals in which it was noted that the seventh is thirty cents flat to equal temperament. This tendency could also be explained as an application of Pythagorean tuning in melodic instances. The Pythagorean seventh of the dominant seventh is four cents flat when compared to the same note tuned to equal temperament.

Regarding Performance Areas

Wind instrumentalists, particularly brass and string instrumentalists, show a high degree of preference for justly tuned intervals. This is especially true of harmonic examples.

If this information is applied to musical performance practices, the preferable sound from a group of brass or string players would be one in which beats were eliminated from the chordal sounds of the ensemble.

Of the thirty-five band directors who, for the most part, were wind instrument majors, twenty-eight stated that they approached intonation from the standpoint of elimination of acoustical beats. This approach is consistent with their indicated preference for justly tuned intervals.

When asked if they used the Strobo-Conn, twenty-five of the twenty-eight indicated that they did. Of course, the manner in which the Strobo-Conn was used would be of significance, but basically this would be a contradictory procedure for achieving the type tuning that had been indicated as being preferable. The Strobo-Conn is an equal tempered instrument and, as such, will be of no assistance in just chordal tuning. The band director who attempts to eliminate beats in chordal tuning and also consults the Strobo-Conn for accuracy of tuning is in conflict with himself.

Vocalists and vocal directors will perform with fewer pitch problems to the accompaniment of keyboard instruments. According to the findings cf this study they would be least satisfied with the results of a slow chordal acompaniment by either a brass choir or a string ensemble.

Regarding Vibrato

One of the findings of this study was that vibrato created a more tolerant attitude toward pitch variation. By that it is meant that when vibrato was added, the number of examples that were rated as being equally acceptable increased sharply. If this information is applied to musical performance, then groups that perform with vibrato will be allowed a wider variation in pitch level without actually offending the musical ear of the listener. On the other hand, a group that wishes to achieve justly tuned chordal sounds can do so more readily if vibrato is eliminated.

Regarding Change of Timbre

It has been pointed out that a contributing factor in poor intonation is the conflict in upper partials of the fundamental tones involved. In this study it was found that when the upper partials of the tones involved were emphasized, the preference for justly tuned chords increased. If this information were utilized in musical performance practices, it would mean that instruments such as clarinets, oboes, and bassoons (strong upper partials) would need a much more critical tuning than instruments such as the flutes (fundamental sound) in order to achieve a satisfactory pitch performance. The conflict of upper partials would tend to make this group of instrumentalists more conscious of beating and, consequently, increase their preference for just intonation in harmonic instances. The findings of this study bear out that statement. In example nineteen, which involves cadence chords played harmonically, the preferences of all oboists, bassoonists, and clarinetists were three to one in favor of justly tuned intervals over equal tempered intervals. Flutists, on the other hand, indicated a preference for equal tempered tuning in the ratio of 5:2.

Regarding Related Studies

The findings of this study concur with those of the Richardson[1] and Johnson[2] studies. Richardson concluded that violinists preferred justly tuned major thirds in harmonic instances. Johnson concluded that vocalists preferred equal tempered tuning regardless of interval or method of presentation. Johnson took exception to some of Richardson's statements in regard to pitch preference when actually the area of musical performance seems to have been the deciding factor in determining the discrepancies that were reported.

---

[1]Richardson, <u>op</u>. <u>cit</u>., p. 129.

[2]Johnson, <u>op</u>. <u>cit</u>.

The results of this study are not in conflict with the reported findings of the Nickerson[1] study since he reported a tendency toward justly tuned thirds in harmonic instances; however, this study does indicate a much stronger tendency than that reported by Nickerson and does not limit this tendency to thirds only.

Helmholtz's[2] contention that _a cappella_ choirs sing justly tuned intervals was not borne out by the findings of this study. Of the vocalists who were members of organized _a cappella_ choirs and who also indicated that they had had extensive experience in this performing group, none showed a strong preference for justly tuned intervals. They did show, instead, a marked preference for equal tempered tuning.

Weaknesses of the Study

The intervals that were presented in this study were all isolated examples. As such they were not a part of an overall artistic musical expression. Whether or not the use of these intervals in an extended musical idea would have affected the selected pitch preferences is not known. Since intervals do constitute elements of an overall musical performance, this must be recognized as a weakness of the study.

The quality of the tone produced by the Intonation Trainer left something to be desired. This could possibly

---

[1] Nickerson, _op. cit._, p. 51.

[2] Helmholtz, _op. cit._, p. 314.

have resulted in the rejection of intervals because of the quality of the sound rather than the pitch of the intervals. This fact was borne out by the tendency on the part of a few of the musicians to give intervals a rating of II or III with no first choice indicated. In instances of this sort, it was assumed that their choices were affected by the quality of the sound rather than their objection to the basic tuning of the intervals.

In tabulating the results of the preference test, there were many instances in which examples were rated as being equally acceptable. Although a certain amount of this was expected, the extent of this practice was not foreseen. Consequently, the percentage of selections for one or the other of the systems of tunings was lowered.

Suggestions for Further Study

With the improvement in electronic equipment it is conceivable that an entire musical composition could be produced electronically. This composition could be produced in triplicate, using basic tuning according to each of the three systems of tuning. Musicians could then be asked to indicate their preferences. A study of this nature would eliminate the necessity for isolated examples and might also serve as a basis for determining which system of tuning is the most acceptable considering all phases and elements of musical performance.

A study that was made by electronic musical equipment could also include examples where melodic inferences were strongest. These melodic inferences could be tuned according to equal tempered standards. Chordal passages could be tuned to just standards so that the composition would reflect the preferences that were indicated within this study. If a composition tuned according to the above subscribed standards were to be duplicated using equal temperament throughout, this would serve as a basis of comparison and show whether or not equal temperament were, after all, the answer to all the conflicts in pitch performance.

Although each of the wind instruments was included in this study, it would be interesting to break the contents of this study down into a series of separate studies, each reporting the preference selections of one individual group but using a much wider cross section of musicians from each of the performance areas. As a further suggestion, it might be well to include a pitch discrimination test as a means of screening those musicians who were under consideration, thereby eliminating those who did not measure up to a certain standard.

There still remains an enigma in regard to melodic and harmonic pitch preferences. Even though a certain degree of pitch variation can be applied to performance, the question as to how to handle this seeming contradiction has not been completely answered. This is definitely a topic for further study.

Of the groups tested, pianists were among the highest in their preference for Pythagorean tuning. Why would they, as musicians who work with equal tempered tuning more than any other group, not be satisfied with equal temperament? Of course equal temperament, as it applies to the piano, is for each piano what the tuner makes it. How much variation exists in this system of tuning that is referred to as equal temperament? This is a question for further study.

A cappella choirs tend to go flat during performance. This could be the result of a tendency to lower certain harmonic tones in order to achieve justly tuned chords. Consider a C major tonic triad that moves to the III chord. If the third is lowered in C major and then held common as the root of the III chord, the B natural of the III chord will then naturally be lowered to form a true fifth with the root E. If this were, in fact, what had happened the chorus would have dropped in pitch by fourteen cents within this one harmonic progression. Could choral exercises be constructed that would exaggerate this tendency to go flat? If so, then exercises could be constructed that would cause the group to go sharp by applying the rules of justly tuned chords. This would be a topic for further study.

Concluding Remarks

Can the findings of this study be applied to musical performance in such a way as to aid in the development of a more perfect ensemble? An awareness of this obvious variation in pitch preferences should make one more tolerant of the problems that arise through conflict of opinion. For example, in a musical group, it would be quite natural for one individual to place emphasis upon a melodic line and another to emphasize the vertical harmonic structure. According to findings of this study a conflict would then arise as to pitch preference within the group. Of course, the final decision in a case of this sort would rest with the director of the organization, but a degree of understanding would assist both performer and director in reaching a decision as to which element of the musical performance is more important.

Consider the instrumental director who has been placed in a position where he must work with a vocal group. As an instrumental director he will probably approach chordal tuning from the standpoint of elimination of acoustical beats. Twenty-eight of the thirty-five band directors included in this study indicated that this was their approach. If this director were to work with the vocal group for any length of time, he might eliminate the use of vibrato from the organization. He might then begin to stress the vertical aspects of the music to a much higher degree and discourage the technique of gliding between pitches. In other words, he would develop within this group a procedure for performance that was in keeping with his own pitch performance practices. Whether or not this would be an improved group would be a matter of opinion, but there is little doubt that the sound of the organization would be different from that of a similar group under the direction of a vocalist who is equal tempered oriented, encourages vibrato as a means of artistic expression, and understands the emotional value of the vocal glide and the effectiveness of slight pitch variations.

The most important conclusion based upon the findings of this study would be that there exists among musicians a difference of opinion as to what is correct in pitch performance. One should recognize this variation, the reasons for its existence, and utilize this information in such a way as to make it a positive contribution toward excellence in musical performance.

SELECTED BIBLIOGRAPHY

Books

Apel, Willi. Harvard Dictionary of Music. Cambridge, Massachusetts: Harvard University Press, 1944.

Auer, Leopold. Violin Playing As I Teach It. New York: Stokes, Inc., 1921.

Baranek, Leo L. Acoustics. New York: McGraw-Hill Book Co., Inc., 1954.

Barbour, James Murray. Tuning and Temperament, A Historical Survey. East Lansing, Michigan: Michigan State College Press, 1951.

Bartholomew, Wilmer T. Acoustics of Music. Englewood Cliffs, New Jersey: Prentice Hall Co., 1942.

Benade, Arthur H. Horns, Strings, and Harmony. New York: Doubleday and Company, Inc., 1960.

Bostelmann, L. An Analysis of Violin Practice. Philadelphia, Penn.: Oliver Ditson, 1947.

Creedy, E. J. The Major Scale. London, England: Oxford University Press, 1950.

Culver, Charles. Musical Acoustics. Philadelphia, Penn.: The Blakiston Co., 1947.

Flesch, Carl. The Art of Violin Playing. New York: Carl Fischer, 1924.

Fokker, A. D. Just Intonation. The Hague: Martinus Nyhoff, 1949.

Hamilton, Clarence G. Sound And Its Relation To Music. Boston, Mass.: Oliver Ditson Company.

Hauptmann, Moritz. The Nature of Harmony and Metre. Trans. W. E. Heathcote. London: Swan Sonnenschein and Co., 1888.

Helmholtz, Hermann. Sensations of Tone. Trans. Alexander J. Ellis. New York, London, Toronto: Longmanns, Green, and Co., 1930.

Hindemith, Paul. The Craft of Musical Composition, I. New York: Associated Music Publishers, Inc., 1945.

Hirsch, Ira J. The Measurement of Hearing. New York: McGraw-Hill Book Co., Inc., 1952.

Jeans, James. Science and Music. New York: The MacMillan Co., 1937.

Kennan, Kent. The Technique of Orchestration. Englewood Cliffs, N. J.: Prentice Hall, Inc., 1952.

Littlehales, Lillian. Pable Casals. New York: W. W. Norton and Co., 1948.

Parry, Hubert H. The Evolution of the Art of Music. New York: D. Appleton-Century Company, Inc., 1930.

Partch, Harry. Genesis of a Musician. Madison, Wisc.: The University of Wisconsin Press, 1949.

Pottle, Ralph. Tuning the School Band. Hammond, Louisiana: Individually Published, December, 1960.

Pratt, Carroll C. The Meaning of Music. New York: McGraw Hill Book Co., Inc., 1931.

Redfield, John. Music, A Science And An Art. New York: Tudor Publishing Co., 1935.

Schoen, Max. The Psychology of Music. New York: The Ronald Press Co., 1940.

Seashore, Carl E. (ed.). University of Iowa Studies in the Psychology of Music. 4 vols. Iowa City, Iowa: The University Press, 1932-1937.

Sevcik, Otaker. School of Intonation On An Harmonic Basis For Violin, Opus 11. New York: Harms, Inc., 1922.

Shirlaw, Matthew. The Theory of Harmony. Dekalb, Ill.: Dr. Richard Coar, 1955.

Stauffer, Donald W. Intonation Deficiencies of Wind Instruments in Ensemble. Washington, D. C.: The Catholic University Press, 1954.

Wever, Ernest. Theory of Hearing. New York: John Wiley & Sons, Inc., 1949.

Wood, Alexander. The Physics of Sound. London: Methner and Co., 1944.

Yasser, Joseph. A Theory of Evolving Tonality. New York: American Library of Musicology, 1932.

Articles and Periodicals

Barbour, James Murray. "Bach and the Art of Temperament," Musical Quarterly, XXXIII (January, 1947), 64-89.

Barbour, James Murray. "Just Intonation Confuted," Music and Letters, XIX (January, 1938), 48-60.

Barbour, James Murray. "The Persistence of the Pythagorean Tuning System," Scripta Mathematica, I, 1933.

Barbour, James Murray. "Violin Intonation of the Eighteenth Century," American Musicological Society Journal, V (Fall, 1952), 224-34.

Boyden, D. D. "Prelluer, Geminiani, and Just Intonation," American Musicological Society Journal, IV (Fall, 1959), 202.

Brues, Austin M. "Fusion of Non-Musical Intervals," American Journal of Psychology, XXXVIII, 1927, 638.

Cadek, Ottokar. "Intonation in Theory and Practice," Music Journal, VII (May-June, 1949), 39-40.

Dallas, Dorothy B. "Paganini's Secret," The Etude, LVI, 1938, 830.

Dallas, Dorothy B. "Temperament for the Violinist," The Etude, LIX, 1941, 531.

Dennington, A. "On Just Intonation," Strad, LXIII (June, 1952), 40-42.

Edwards, LaRoy. "A 'Unic' Method of Checking a Temperament," The Piano Technician's Journal, IV (May, 1961), 31.

Green, Paul C. "Violin Intonation," Journal of the Acoustical Society of America, IX, 1937-38, 43-44.

Guthrie, E. H., and Morrill, H. "Fusion of Non-Musical Intervals," American Journal of Psychology, XXXIX, 1928.

Hougaard, J. C. "Two Equal Temperaments," The Piano Technician's Journal, VIII (January, 1965), 16.

Lewis, Don. "Pitch As A Psychological Phenomenon," Proceedings Of The Music Teachers National Association, XXXIV, 1939, 121-133.

Link, John W., Jr. "The Theory of the Meantone Temperament," The Piano Technician's Journal, VI (April, 1963), 15-19, 30.

Lloyd, Llewelyn S. "Intonation and the Ear," Music and Letters, XIX (October, 1938), 443-449.

Lloyd, Llewelyn S. "Just Temperament," Music and Letters, XX (October, 1939), 365-373.

Lloyd, Llewelyn S. "The Major Third," Musical Times, MCLXXI (September, 1940), 365-367.

Lloyd, Llewelyn S. "The Myth of Equal Temperament," Music and Letters, XXI (October, 1940), 347-61.

Lloyd, Llewelyn S. "The Perfect Fifth," Musical Times, MCLXIX (July, 1940), 298-300.

Lloyd, Llewelyn S. "The Musical Scale," Musical Quarterly, XXVIII (October, 1942), 205.

McHose, Allen I. "Harmonic Foundation for String Playing," Music Journal, VII (September-October, 1949), 8-9.

Moran, H. and Pratt, C. C. "Variability of Judgments on Musical Intervals," Journal of Experimental Psychology, IX, 1926, 492-500.

Mursell, James. "Psychology and the Problem of the Scales," Musical Quarterly, XXXII (October, 1946), 564-573.

Nickerson, James F. "Comparing Intonation of Solo and Ensemble Performances," Music Journal, VII (March-April, 1950), 21, 30-31.

Norden, N. Lindsay. "A New Theory of Untempered Music," The Musical Quarterly, XXII (April, 1936), 221-233.

Pierce, Edwin H. "A Colossal Experiment in Just Intonation," Musical Quarterly, X (July, 1924), 326-332.

Poole, Henry Ward. "On Perfect Harmony in Music," Sillman's American Journal of Science and Arts, Second Series, XLIX, 1867, 1-22.

Schoen, Max. "Pitch and Vibrato in Artistic Singing," The Musical Quarterly, XII (April, 1926), 275-290.

Scully, F. E. "A Scientific Approach to Better Intonation," Violins and Violinists, XIX (November, 1957), 267-269, XX (January, 1958), 22, 23, XX (March, 1958), 60-62.

Unpublished Material

Gustin, Molly. "Tonality." Unpublished doctoral dissertation, University of Indiana, 1960. (Typed.)

Isted, Leslie. "A Study of Violin Pitch Intonation." Unpublished Master's thesis, University of Indiana, 1946. (Typed.)

Johnson, Hugh B. "An Investigation of the Tuning Preferences of a Select Group of Singers with Reference to Just Intonation, Pythagorean Tuning, and Equal Temperament." Unpublished doctoral dissertation, University of Indiana, 1963. (Typed.)

McQuerry, Laurence H. "The Improvement of Sensitivity to Interval Intonation Through Training with a Mechanical Apparatus, an Exploratory Study." Unpublished doctoral dissertation, University of Indiana, 1957. (Typed.)

Nickerson, James F. "A Comparison of the Same Melody Played in Solo and in Ensemble with Reference to Equitempered, Just, and Pythagorean Intonation." Unpublished doctoral dissertation, University of Minnesota at Minneapolis, 1948. (Typed.)

Richardson, Louis S. "The Effect of Certain Harmonic Configurations upon Tuning Preferences for the Major Third." Unpublished doctoral dissertation, University of Indiana, 1962. (Typed.)

Shackford, Charles R. "Intonation in Ensemble String Performance, an Objective Study." Unpublished doctoral dissertation, Harvard University at Cambridge, Massachusetts, 1954. (Typed.)

Thomson, William E. "A Clarification of the Tonality Concept." Unpublished doctoral dissertation, University of Indiana, 1952. (Typed.)

Other Sources

Stegeman, W. J. *Application Manual for the Johnson Intonation Trainer*. Waseca, Minnesota: E. F. Johnson Company, 1965.

Young, Robert W. *A Table Relating Frequency to Cents*. Elkhart, Indiana: C. G. Conn Limited, 1952.

APPENDIX A

PITCH PREFERENCE DETERMINATION

APPENDIX A

PITCH PREFERENCE DETERMINATION

General Information

Name____________________Major____________________________
Voice, instrument or theory

1. How many years have you studied piano? _________________

2. Have you ever performed in an ensemble such as band, orchestra, a cappella choir, string quartet or any other organization which does not use the piano accompaniment? _____ If yes, specify which. _________________

3. Have you had extensive work in groups which do not use the piano accompaniment? _____ If yes, specify which.
____

4. Have you ever tuned or attempted to tune a piano? ______

5. Are you familiar with the different tuning systems such as just, mean tone, equal temperament, and pythagorean?
____

6. If you have had experience as a conductor of a musical organization, do you approach intonation by elimination of acoustical beats? ______________________________

7. Do you use either the Strobo-Conn or Strobo-Tuner?______

8. Are you the director of, or a performing member in a regularly organized string quartet, trombone quartet, or a cappella vocal group?_________________________________

9. Do you have absolute pitch?______________________________

Instructions

This is not a test of your ability.

The examples that you will hear are based upon three different tunings. You are to show your preference by selecting the example in each group which sounds in tune. Indicate your selection numerically as follows:

1. First choice
2. Second choice
3. Third choice, where applicable

If you do not have a preference, this should be indicated by giving each example the numerical rating 1.

If two of a group of three are equally acceptable and the third is not acceptable, indicate this by giving the comparable examples an equal rating and the objectionable example a lower rating.

Each example will be played twice. For example: 1,a. will sound twice, then 1,b., etc. Each example will be identified on the tape.

In instances where there are three examples, do not reach a hurried decision. Wait until all three examples have been played.

If you are having trouble reaching a decision, the proper answer would probably be to give each an identical rating.

If none of the examples is acceptable, indicate this by giving each a 3 rating.

Perfect fifths played melodically

1,a._____ 1,b._____

Perfect fifths played harmonically

2,a._____ 2,b._____

Perfect fifths played harmonically with vibrato

3,a._____ 3,b._____

Major thirds played melodically

4,a._____ 4,b._____ 4,c._____

Major thirds played harmonically

5,a._____ 5,b._____ 5,c._____

Major thirds, played harmonically with a change of timbre

6,a._____ 6,b._____ 6,c._____

Minor thirds played melodically

7,a._____ 7,b._____

Minor thirds played harmonically

8,a._____ 8,b._____

Major triads played melodically

9,a._____ 9,b._____ 9,c._____

Major triads played harmonically

10,a._____ 10,b._____ 10,c._____

Major triads played harmonically with vibrato

11,a._____ 11,b._____ 11,c._____

Minor triads played melodically

12,a._____ 12,b._____

Minor triads played harmonically

13,a._____ 13,b._____

Minor triads played harmonically with vibrato

14,a._____ 14,b._____

Dominant seventh chords played melodically

15,a._____ 15,b._____ 15,c._____

Dominant seventh chords played harmonically

16,a._____ 16,b._____ 16,c._____

Major seventh chords played melodically

17,a._____ 17,b._____ 17,c._____

Major seventh chords played harmonically

18,a._____ 18,b,_____ 18,c._____

Cadence chords played harmonically

19,a._____ 19,b._____ 19,c._____

The major scale ascending and descending (each example played only once)

20,a._____ 20,b._____ 20,c._____

APPENDIX B

PITCH PREFERENCE MUSICAL EXAMPLES

APPENDIX B

PITCH PREFERENCE MUSICAL EXAMPLES

Perfect Fifths Played Melodically

1a. J. 1b. T. Each example played two times.

Perfect Fifths Played Harmonically

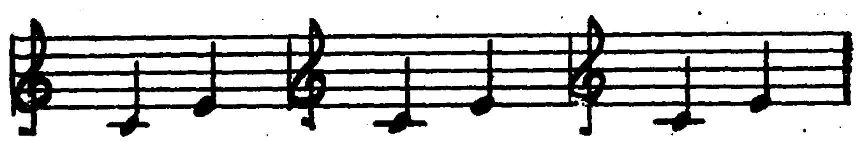
2a. J. 2b. T. Each example played two times.

Perfect Fifths Played Harmonically With Vibrato

3a. J. 3b. T. Each example played two times.

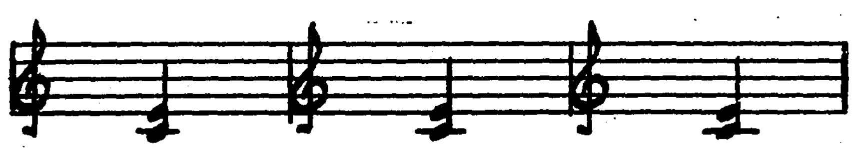
Major Thirds Played Melodically

4a. J. 4b. T. 4c. P. Each example played twice.



Major Thirds Played Harmonically

5a. J. 5b. T. 5c. P. Each example played twice.



Major Thirds Played Harmonically With Change Of Timbre

6a. J. 6b. T. 6c. P. Each example played twice.

Minor Thirds Played Melodically

7a. J. 7b. T. Each example played twice.

Minor Thirds Played Harmonically

8a. J. 8b. T. Each example played twice.

Major Triads Played Melodically

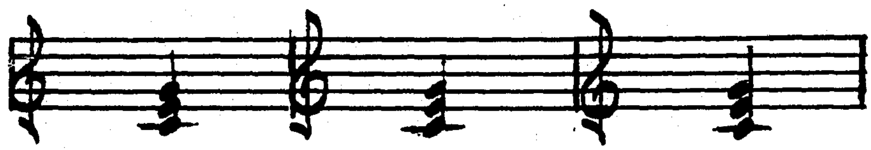
9a. J. 9b. T. 9c. P. Each example played twice.

Major Triads Played Harmonically

10a. J. 10b. T. 10c. P. Each example played twice.

Major Triads Played Harmonically With Vibrato

11a. J. 11b. T. 11c. P. Each example played twice.



Minor Triads Played Melodically

12a. J. 12b. T. 12c. P. Each example played twice.

Minor Triads Played Harmonically

13a. J. 13b. T. 13c. P. Each example played twice.

Minor Triads Played Harmonically With Vibrato

14a. J. 14b. T. 14c. P. Each example played twice.

Dominant Seventh Chord Played Melodically

15a. J. 15b. T. 15c. P. Each example played twice.

Dominant Seventh Chords Played Harmonically

16a. J. 16b. T. 16c. P.

Each example played twice.

Major Seventh Chord Played Melodically

17a. J. 17b. T. 17c. P.

Each example played twice.

Major Seventh Chord Played Harmonically

18a. J. 18b. T. 18c. P.

Each example played twice.

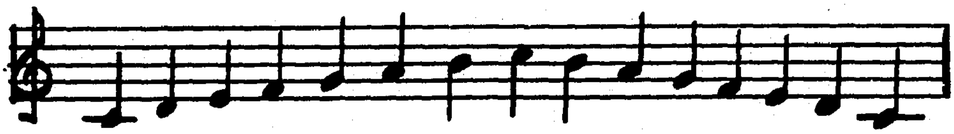
Cadence Chords Played Harmonically

19a. T. 19b. T. 19c. P.

Each example played twice.

Major Scale Ascending and Descending

20a. J.



20b. T.

20c. P.

Each example played once only.

APPENDIX C

RESPONSES ACCORDING TO MAJOR AREAS

APPENDIX C

PITCH PREFERENCE SELECTIONS FOR PERFECT FIFTHS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	J&T
Band Directors	35	17 (46.8%)	15 (42.9)	3 (8.5)
Vocal Directors	18	7 (38.9)	11 (72.2)	0 (0)
Voice Majors	18	10 (55.6)	1 (5.6)	7 (38.9)
Pianists	46	20 (43.5)	13 (28.3)	13 (28.3)
String Instrumentalists	20	10 (50.0)	10 (50.0)	0 (0)
Winds and Percussion	86	33 (38.4)	35 (40.7)	18 (20.9)
Total Tested Population	223	97 (43.5)	85 (38.1)	41 (18.4)

*Just tuning

**Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR PERFECT FIFTHS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	J&T
Band Directors	35	20 (57.1%)	14 (40.0)	1 (2.9)
Vocal Directors	18	5 (27.8)	13 (72.2)	0 (0)
Voice Majors	18	8 (44.4)	6 (33.3)	4 (22.2)
Pianists	46	18 (39.1)	27 (58.7)	1 (2.2)
String Instrumentalists	20	11 (55.0)	8 (40.0)	1 (5.0)
Winds and Percussion	86	42 (48.8)	36 (41.9)	8 (9.3)
Total Tested Population	223	104 (46.6)	104 (46.6)	15 (6.8)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR PERFECT FIFTHS PLAYED HARMONICALLY WITH VIBRATO

Classification	Number Tested	J*	T**	J&T
Band Directors	35	20 (57.1%)	8 (22.8)	7 (20.1)
Vocal Directors	18	5 (27.8)	12 (66.7)	1 (5.6)
Voice Majors	18	9 (50.0)	6 (33.3)	3 (16.7)
Pianists	46	16 (34.8)	20 (43.5)	10 (21.7)
String Instrumentalists	20	9 (45.0)	10 (50.0)	1 (5.0)
Winds and Percussion	86	39 (45.3)	34 (39.5)	13 (15.1)
Total Tested Population	223	98 (43.9)	90 (40.4)	35 (15.7)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR THIRDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	8 (22.8%)	16 (45.7)	8 (22.8)	1 (2.9)	0 (0)	1 (2.9)	1 (2.9)
Vocal Directors	18	0 (0)	12 (66.7)	2 (11.1)	0 (0)	0 (0)	1 (5.6)	3 (16.7)
Voice Major	18	3 (16.7)	5 (27.8)	5 (27.8	0 (0)	0 (0)	0 (0)	5 (27.8)
Pianists	46	9 (19.6)	16 (34.8)	15 (32.6)	0 (0)	2 (4.3)	1 (2.2)	3 (6.5)
String Instrumentalists	20	6 (30.0)	6 (30.0)	7 (35.0)	0 (0)	0 (0)	0 (0)	1 (5.0)
Winds and Percussion	86	17 (19.8)	27 (31.3)	18 (20.8)	3 (3.5)	6 (7.0)	3 (3.5)	12 (14.0)
Total Tested Population	223	43 (19.3)	82 (36.8)	55 (24.7)	4 (1.3)	9 (4.0)	5 (2.7)	25 (11.2)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR THIRDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	13 (37.1%)	6 (17.1)	10 (28.6)	1 (2.9)	2 (5.7)	1 (2.9)	2 (5.7)
Vocal Directors	18	2 (11.1)	5 (27.8)	8 (44.4)	0 (0)	1 (5.6)	0 (0)	2 (11.1)
Voice Majors	18	7 (38.9)	4 (22.2)	5 (27.8)	1 (5.6)	1 (5.6)	0 (0)	0 (0)
Pianists	46	14 (30.4)	13 (28.3)	11 (23.9)	0 (0)	4 (8.7)	1 (2.2)	3 (6.5)
String Instrumentalists	20	10 (50.0)	5 (25.0)	5 (25.0)	0 (0)	0 (0)	0 (0)	0 (0)
Winds and Percussion	86	34 (39.5)	14 (16.3)	18 (20.9)	9 (10.5)	2 (2.3)	4 (4.7)	5 (5.8)
Total Tested Population	223	80 (35.9)	47 (21.1)	57 (25.6)	11 (4.9)	9 (4.0)	7 (3.1)	12 (5.4)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR THIRDS PLAYED HARMONICALLY WITH CHANGE OF TIMBRE

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	24 (68.6%)	5 (14.3)	2 (5.7)	1 (2.9)	2 (5.7)	0 (0)	1 (2.9)
Vocal Directors	18	5 (27.8)	10 (55.6)	3 (16.7)	0 (0)	0 (0)	0 (0)	0 (0)
Voice Majors	18	7 (38.9)	7 (38.9)	2 (11.1)	0 (0)	0 (0)	0 (0)	2 (11.1)
Pianists	46	12 (26.1)	21 (45.6)	7 (15.2)	1 (2.2)	3 (6.5)	1 (2.2)	1 (2.2)
String Instrumentalists	20	15 (75.0)	3 (15.0)	2 (10.0)	0 (0)	0 (0)	0 (0)	0 (0)
Winds and Percussion	86	40 (46.5)	19 (22.1)	15 (17.4)	5 (5.8)	2 (2.3)	3 (3.5)	2 (2.3)
Total Tested Population	223	103 (46.2)	65 (29.1)	31 (13.9)	7 (3.1)	7 (3.1)	4 (1.8)	6 (2.7)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MINOR THIRDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	J&T
Band Directors	35	15 (42.9%)	18 (51.4)	2 (5.7)
Vocal Directors	18	8 (44.4)	10 (55.6)	0 (0)
Voice Majors	18	6 (33.3)	10 (55.6)	2 (11.1)
Pianists	46	13 (28.3)	27 (58.7)	6 (13.0)
String Instrumentalists	20	8 (40.0)	10 (50.0)	2 (10.0)
Winds and Percussion	86	29 (33.7)	48 (55.8)	9 (10.5)
Total Tested Population	223	79 (35.4)	123 (55.1)	21 (9.4)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MINOR THIRDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	J&T
Band Directors	35	15 (42.9%)	12 (34.3)	8 (22.8)
Vocal Directors	18	6 (33.3)	12 (66.7)	0 (0)
Voice Majors	18	6 (33.3)	10 (55.6)	2 (11.1)
Pianists	46	22 (47.8)	18 (39.1)	6 (13.0)
String Instrumentalists	20	12 (60.0)	7 (35.0)	1 (5.0)
Winds and Percussion	86	44 (51.2)	33 (38.4)	9 (10.5)
Total Tested Population	223	105 (47.1)	92 (41.3)	26 (11.6)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR TRIADS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	2 (5.7%)	17 (48.6)	8 (22.8)	2 (5.7)	0 (0)	0 (0)	6 (17.1)
Vocal Directors	18	0 (0)	8 (44.4)	5 (27.8)	0 (0)	0 (0)	0 (0)	5 (27.8)
Voice Majors	18	1 (5.6)	5 (27.8)	5 (27.8)	0 (0)	3 (16.7)	0 (0)	4 (22.2)
Pianists	46	7 (15.2)	12 (26.1)	17 (36.9)	1 (2.2)	6 (13.0)	1 (2.2)	2 (4.3)
String Instrumentalists	20	3 (15.0)	8 (40.0)	6 (30.0)	0 (0)	0 (0)	0 (0)	3 (15.0)
Winds and Percussion	86	13 (15.1)	24 (27.9)	24 (27.9)	6 (7.0)	7 (8.1)	5 (5.8)	7 (8.1)
Total Tested Population	223	26 (11.6)	74 (33.2)	65 (29.1)	9 (4.0)	16 (7.2)	6 (2.7)	27 (12.1)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR TRIADS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	28 (80.0%)	4 (11.4)	1 (2.9)	0 (0)	2 (5.7)	0 (0)	0 (0)
Vocal Directors	18	5 (27.8)	8 (44.4)	4 (22.2)	1 (5.6)	0 (0)	0 (0)	0 (0)
Voice Major	18	6 (33.3)	8 (44.4)	2 (11.1)	0 (0)	0 (0)	0 (0)	2 (11.1)
Pianists	46	19 (41.3)	18 (39.1)	3 (6.5)	0 (0)	2 (4.3)	2 (4.3)	2 (4.3)
String Instrumentalists	20	10 (50.0)	10 (50.0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Winds and Percussion	86	67 (77.9)	14 (16.3)	1 (1.2)	2 (2.3)	1 (1.2)	0 (0)	1 (1.2)
Total Tested Population	223	135 (60.5)	62 (27.8)	11 (4.9)	3 (1.3)	5 (2.2)	2 (.9)	5 (2.2)

*Just tuning   **Equal tempered tuning   ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR TRIADS PLAYED HARMONICALLY WITH VIBRATO

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	25 (71.4%)	2 (5.7)	5 (14.3)	1 (2.9)	1 (2.9)	1 (2.9)	0 (0)
Vocal Directors	18	3 (16.7)	7 (38.9)	4 (22.2)	0 (0)	0 (0)	1 (5.6)	3 (16.7)
Voice Majors	18	5 (27.8)	10 (55.6)	2 (11.1)	0 (0)	0 (0)	1 (5.6)	0 (0)
Pianists	46	14 (30.4)	17 (36.9)	6 (13.0)	2 (4.5)	5 (10.9)	0 (0)	2 (4.3)
String Instrumentalists	20	12 (60.0)	6 (30.0)	0 (0)	1 (5.0)	1 (5.0)	0 (0)	0 (0)
Wind and Percussion	86	53 (61.6)	11 (12.8)	11 (12.8)	5 (5.8)	4 (4.7)	2 (2.3)	0 (0)
Total Tested Population	223	112 (50.2)	53 (23.8)	28 (12.6)	9 (4.0)	11 (4.9)	5 (2.2)	5 (2.2)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MINOR TRIADS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	J&T
Band Directors	35	9 (25.7%)	23 (65.7)	3 (8.6)
Vocal Directors	18	2 (11.1)	16 (88.9)	0 (0)
Voice Majors	18	4 (22.7)	14 (77.8)	0 (0)
Pianists	46	9 (19.6)	33 (71.7)	4 (8.7)
String Instrumentalists	20	11 (55.0)	9 (45.0)	0 (0)
Winds and Percussion	86	18 (20.9)	54 (62.8)	14 (16.3)
Total Tested Population	223	53 (23.8)	149 (66.8)	21 (9.4)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MINOR TRIADS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	J&T
Band Directors	35	19 (54.3%)	14 (40.0)	2 (5.7)
Vocal Directors	18	7 (38.9)	9 (50.0)	2 (11.1)
Voice Majors	18	6 (33.3)	10 (55.6)	2 (11.1)
Pianists	46	15 (32.6)	24 (58.7)	7 (8.7)
String Instrumentalists	20	9 (45.0)	11 (55.0)	0 (0)
Winds and Percussion	86	32 (37.2)	43 (50.0)	11 (12.8)
Total Tested Population	223	88 (39.5)	111 (49.8)	24 (10.3)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MINOR TRIADS PLAYED HARMONICALLY WITH VIBRATO

Classification	Number Tested	J*	T**	J&T
Band Directors	35	19 (54.3%)	11 (31.4)	5 (14.5)
Vocal Directors	18	4 (22.2)	13 (72.2)	1 (5.6)
Voice Majors	18	5 (27.8)	9 (50.0)	4 (22.2)
Pianists	46	15 (32.6)	27 (58.7)	4 (8.7)
String Instrumentalists	20	11 (55.0)	9 (45.0)	0 (0)
Winds and Percussion	86	40 (46.5)	33 (38.4)	13 (15.1)
Total Tested Population	223	94 (42.2)	102 (45.1)	27 (12.1)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR DOMINANT SEVENTH CHORDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	2 (5.7%)	10 (28.6)	12 (34.3)	2 (5.7)	1 (2.9)	1 (2.9)	7 (20.1)
Vocal Directors	18	2 (11.1)	8 (44.4)	6 (33.3)	0 (0)	1 (5.6)	0 (0)	1 (5.6)
Voice Majors	18	1 (5.6)	5 (27.8)	9 (50.0)	1 (5.6)	2 (11.1)	0 (0)	0 (0)
Pianists	46	8 (17.4)	18 (39.1)	14 (30.4)	0 (0)	0 (0)	3 (6.5)	3 (6.5)
String Instrumentalists	20	6 (30.0)	4 (20.0)	9 (45.0)	0 (0)	0 (0)	0 (0)	1 (5.0)
Winds and Percussion	86	12 (13.9)	25 (29.1)	31 (36.0)	1 (1.2)	3 (3.5)	4 (4.7)	10 (11.6)
Total Tested Population	223	31 (13.9)	70 (31.4)	81 (36.3)	4 (1.8)	7 (3.1)	8 (3.6)	22 (9.9)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR DOMINANT SEVENTH CHORDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	23 (65.7%)	2 (5.7)	8 (22.9)	2 (5.7)	0 (0)	0 (0)	0 (0)
Vocal Directors	18	2 (11.1)	7 (38.9)	8 (44.4)	0 (0)	0 (0)	0 (0)	1 (5.6)
Voice Majors	18	3 (16.7)	5 (27.8)	9 (50.0)	1 (5.6)	0 (0)	0 (0)	0 (0)
Pianists	46	16 (34.8)	8 (17.4)	15 (32.6)	0 (0)	2 (4.3)	2 (4.3)	3 (6.5)
String Instrumentalists	20	15 (75.0)	2 (10.0)	3 (15.0)	0 (0)	0 (0)	0 (0)	0 (0)
Winds and Percussion	86	49 (57.0)	16 (18.6)	13 (15.1)	1 (1.2)	2 (2.3)	2 (2.3)	3 (3.5)
Total Tested Population	223	108 (48.4)	40 (17.9)	56 (25.1)	4 (1.8)	4 (1.8)	4 (1.8)	7 (3.1)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR SEVENTH CHORDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	2 (5.7%)	12 (34.3)	9 (25.7)	0 (0)	7 (20.0)	1 (2.9)	4 (11.4)
Vocal Directors	18	0 (0)	8 (44.4)	7 (38.9)	0 (0)	0 (0)	2 (11.1)	1 (5.6)
Voice Majors	18	0 (0)	6 (33.3)	8 (44.4)	0 (0)	0 (0)	0 (0)	4 (22.2)
Pianists	46	3 (6.5)	10 (21.7)	22 (47.8)	1 (2.2)	3 (6.5)	1 (2.2)	6 (13.0)
String Instrumentalists	20	2 (10.0)	4 (20.0)	12 (60.0)	0 (0)	0 (0)	1 (5.0)	1 (5.0)
Winds and Percussion	86	5 (5.8)	23 (26.7)	27 (31.4)	7 (8.1)	6 (7.0)	2 (2.3)	16 (18.6)
Total Tested Population	223	12 (5.4)	63 (28.3)	85 (38.1)	8 (3.6)	16 (7.2)	7 (3.1)	32 (14.3)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR SEVENTH CHORDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	15 (42.9%)	7 (20.1)	9 (25.9)	1 (2.9)	1 (2.9)	0 (0)	2 (5.7)
Vocal Directors	18	2 (11.1)	7 (38.9)	8 (44.4)	0 (0)	0 (0)	0 (0)	1 (5.6)
Voice Majors	18	3 (16.7)	10 (55.6)	3 (16.7)	0 (0)	1 (5.6)	0 (0)	1 (5.6)
Pianists	46	9 (19.6)	26 (56.5)	6 (13.0)	0 (0)	3 (6.5)	1 (2.2)	1 (2.2)
String Instrumentalists	20	10 (50.0)	7 (35.0)	3 (15.0)	0 (0)	0 (0)	0 (0)	0 (0)
Winds and Percussion	86	33 (38.4)	35 (40.7)	10 (11.6)	1 (1.2)	3 (3.5)	1 (1.2)	3 (3.5)
Total Tested Population	223	72 (32.3)	92 (41.2)	39 (17.5)	2 (.9)	8 (3.6)	2 (.9)	8 (3.6)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR CADENCE CHORDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	29 (82.9%)	4 (11.4)	0 (0)	1 (2.9)	0 (0)	1 (2.9)	0 (0)
Vocal Directors	18	1 (5.6)	12 (66.7)	4 (22.2)	0 (0)	0 (0)	1 (5.6)	0 (0)
Voice Majors	18	9 (50.0)	7 (38.9)	1 (5.6)	0 (0)	0 (0)	0 (0)	1 (5.6)
Pianists	46	18 (39.1)	22 (47.8)	3 (6.5)	3 (6.5)	0 (0)	0 (0)	0 (0)
String Instrumentalists	20	11 (55.0)	5 (25.0)	1 (5.0)	3 (15.0)	0 (0)	0 (0)	0 (0)
Winds and Percussion	86	51 (59.3)	26 (30.2)	6 (7.0)	2 (2.3)	0 (0)	0 (0)	1 (1.2)
Total Tested Population	223	119 (53.4)	76 (34.1)	15 (6.7)	9 (4.0)	0 (0)	2 (.9)	2 (.9)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR THE MAJOR SCALE ASCENDING AND DESCENDING

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Band Directors	35	0 (0%)	18 (51.4)	8 (22.9)	2 (5.7)	0 (0)	1 (2.9)	6 (17.1)
Vocal Directors	18	1 (5.6)	10 (55.6)	5 (27.8)	1 (5.6)	0 (0)	0 (0)	1 (5.6)
Voice Majors	18	1 (5.6)	12 (66.7)	3 (16.7)	0 (0)	0 (0)	0 (0)	2 (11.1)
Pianists	46	1 (2.2)	13 (28.3)	22 (47.8)	2 (4.3)	2 (4.3)	0 (0)	6 (13.0)
String Instrumentalists	20	1 (5.0)	6 (30.0)	12 (60.0)	0 (0)	0 (0)	0 (0)	1 (5.0)
Winds and Percussion	86	5 (5.8)	36 (41.9)	25 (29.0)	1 (1.2)	10 (11.6)	0 (0)	9 (10.5)
Total Tested Population	223	9 (4.0)	95 (42.6)	75 (33.6)	6 (2.7)	12 (5.4)	1 (.5)	25 (11.2)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

APPENDIX D

RESPONSES OF WIND INSTRUMENTALISTS BY GROUPS

APPENDIX D

PITCH PREFERENCE SELECTIONS FOR PERFECT FIFTHS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	6	8	5
Woodwind Group II	23	10	9	4
Brass Group I	22	7	10	5
Brass Group II	7	4	1	2
Brass Group III	11	6	3	2
Percussion	4	0	4	0
Total Tested Population	86	33 (38.4%)	35 (40.7)	18 (20.9)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR PERFECT FIFTHS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	6	12	1
Woodwind Group II	23	13	6	4
Brass Group I	22	14	7	1
Brass Group II	7	4	3	0
Brass Group III	11	5	4	2
Percussion	4	0	4	0
Total Tested Population	86	42 (48.8%)	36 (41.9)	8 (9.3)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR PERFECT FIFTHS PLAYED HARMONICALLY WITH VIBRATO

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	6	11	2
Woodwind Group II	23	14	6	3
Brass Group I	22	10	10	2
Brass Group II	7	4	0	3
Brass Group III	11	5	4	2
Percussion	4	0	3	1
Total Tested Population	86	39 (45.3%)	34 (39.5)	13 (15.1)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR THIRDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	1	9	4	0	0	1	4
Woodwind Group II	23	6	8	4	1	2	0	2
Brass Group I	22	3	5	5	0	4	1	4
Brass Group II	7	2	2	1	1	0	1	0
Brass Group III	11	5	2	1	1	0	0	2
Percussion	4	0	1	3	0	0	0	0
Total Tested Population	86	17 (19.9%)	27 (31.3)	18 (20.8)	3 (3.5)	6 (7.0)	3 (3.5)	12 (14.0)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR THIRDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	9	1	2	3	0	2	2
Woodwind Group II	23	14	2	5	0	1	0	1
Brass Group I	22	5	4	7	4	1	1	0
Brass Group II	7	4	1	1	0	0	1	0
Brass Group III	11	1	6	1	1	0	0	2
Percussion	4	1	0	2	1	0	0	0
Total Tested Population	86	34 (39.4%)	14 (16.3)	18 (20.9)	9 (10.5)	2 (2.3)	4 (4.7)	5 (5.8)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR THIRDS PLAYED HARMONICALLY WITH CHANGE OF TIMBRE

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	7	7	3	0	0	1	1
Woodwind Group II	23	14	4	3	1	1	0	0
Brass Group I	22	9	2	6	2	0	2	1
Brass Group II	7	5	1	1	0	0	0	0
Brass Group III	11	4	3	2	1	1	0	0
Percussion	4	1	2	0	1	0	0	0
Total Tested Population	86	40 (46.5%)	19 (22.1)	15 (17.4)	5 (5.8)	2 (2.3)	3 (3.5)	2 (2.3)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MINOR THIRDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	7	10	2
Woodwind Group II	23	7	15	1
Brass Group I	22	9	10	3
Brass Group II	7	2	4	1
Brass Group III	11	4	6	1
Percussion	4	0	3	1
Total Tested Population	86	29 (33.7%)	48 (55.8)	9 (10.5)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MINOR THIRDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	8	9	2
Woodwind Group II	23	12	9	2
Brass Group I	22	9	10	3
Brass Group II	7	6	0	1
Brass Group III	11	8	2	1
Percussion	4	1	3	0
Total Tested Population	86	44 (51.2%)	33 (38.4)	9 (10.5)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR TRIADS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	3	2	4	1	3	1	5
Woodwind Group II	23	3	8	8	0	2	2	0
Brass Group I	22	2	7	4	5	2	1	1
Brass Group II	7	2	4	1	0	0	0	0
Brass Group III	11	3	0	6	0	0	1	1
Percussion	4	0	3	1	0	0	0	0
Total Tested Population	86	13 (15.1%)	24 (27.9)	24 (27.9)	6 (7.0)	7 (8.1)	5 (5.8)	7 (8.1)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR TRIADS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	14	4	0	1	0	0	0
Woodwind Group II	23	18	3	1	0	0	0	1
Brass Group I	22	17	3	0	1	1	0	0
Brass Group II	7	6	1	0	0	0	0	0
Brass Group III	11	10	1	0	0	0	0	0
Percussion	4	2	2	0	0	0	0	0
Total Tested Population	86	67 (77.9%)	14 (16.2)	1 (1.2)	2 (2.3)	1 (1.2)	0 (0)	1 (1.2)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR TRIADS PLAYED HARMONICALLY WITH VIBRATO

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	J&P
Woodwind Group I	19	11	4	3	1	0	0	0
Woodwind Group II	23	15	2	5	0	0	1	0
Brass Group I	22	11	2	2	3	3	1	0
Brass Group II	7	6	0	0	0	1	0	0
Brass Group III	11	8	2	0	1	0	0	0
Percussion	4	2	1	1	0	0	0	0
Total Tested Population	86	53 (61.6%)	11 (12.8)	11 (12.8)	5 (5.8)	4 (4.7)	2 (2.3)	0 (0)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MINOR TRIADS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	1	14	4
Woodwind Group II	23	9	10	4
Brass Group I	22	3	16	3
Brass Group II	7	3	2	2
Brass Group III	11	2	9	0
Percussion	4	0	3	1
Total Tested Population	86	18 (20.9%)	54 (62.8)	14 (16.3)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MINOR TRIADS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	5	11	3
Woodwind Group II	23	10	11	2
Brass Group I	22	9	10	3
Brass Group II	7	3	3	1
Brass Group III	11	4	5	2
Percussion	4	1	3	0
Total Tested Population	86	32 (39.5%)	43 (49.8)	11 (10.3)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR MINOR TRIADS PLAYED HARMONICALLY WITH VIBRATO

Classification	Number Tested	J*	T**	J&T
Woodwind Group I	19	6	11	2
Woodwind Group II	23	11	9	3
Brass Group I	22	11	7	4
Brass Group II	7	5	2	0
Brass Group III	11	6	2	3
Percussion	4	1	2	1
Total Tested Population	86	40 (46.5%)	33 (38.4)	13 (15.1)

*Just tuning **Equal tempered tuning

PITCH PREFERENCE SELECTIONS FOR DOMINANT SEVENTH CHORDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	2	3	8	1	1	1	3
Woodwind Group II	23	7	4	9	0	0	1	2
Brass Group I	22	2	7	7	0	1	1	4
Brass Group II	7	1	2	3	0	1	0	0
Brass Group III	11	0	5	4	0	0	1	1
Percussion	4	0	4	0	0	0	0	0
Total Tested Population	86	12 (13.9%)	25 (29.1)	31 (36.0)	1 (1.2)	3 (3.5)	4 (4.7)	10 (11.6)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR DOMINANT SEVENTH CHORDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	11	1	5	0	0	1	1
Woodwind Group II	23	13	5	3	1	0	0	1
Brass Group I	22	11	4	4	0	1	1	1
Brass Group II	7	4	2	0	0	1	0	0
Brass Group III	11	8	2	1	0	0	0	0
Percussion	4	2	2	0	0	0	0	0
Total Tested Population	86	49 (57.0%)	16 (18.6)	13 (15.1)	1 (1.2)	2 (2.3)	2 (2.3)	3 (3.5)

*Just tuning   **Equal tempered tuning   ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR SEVENTH CHORDS PLAYED MELODICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	1	5	7	1	2	0	3
Woodwind Group II	23	3	9	4	1	1	1	4
Brass Group I	22	0	5	8	1	1	1	6
Brass Group II	7	0	0	3	3	0	0	1
Brass Group III	11	1	4	3	1	1	0	1
Percussion	4	0	0	2	0	1	0	1
Total Tested Population	86	5 (5.8%)	23 (26.7)	27 (31.4)	7 (8.1)	6 (7.0)	2 (2.3)	16 (18.6)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR MAJOR SEVENTH CHORDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	4	12	3	0	0	0	0
Woodwind Group II	23	10	8	3	1	1	0	0
Brass Group I	22	9	8	1	0	1	1	2
Brass Group II	7	5	2	0	0	0	0	0
Brass Group III	11	4	4	2	0	0	0	1
Percussion	4	1	1	1	0	1	0	0
Total Tested Population	86	33 (38.4%)	35 (40.7)	10 (11.6)	1 (1.2)	3 (3.5)	1 (1.2)	3 (3.5)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR CADENCE CHORDS PLAYED HARMONICALLY

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	10	9	0	0	0	0	0
Woodwind Group II	23	14	5	2	1	0	0	1
Brass Group I	22	10	9	2	1	0	0	0
Brass Group II	7	6	1	0	0	0	0	0
Brass Group III	11	9	1	1	0	0	0	0
Percussion	4	2	1	1	0	0	0	0
Total Tested Population	86	51 (59.3%)	26 (30.2)	6 (7.0)	2 (2.3)	0 (0)	0 (0)	1 (1.2)

*Just tuning **Equal tempered tuning ***Pythagorean tuning

PITCH PREFERENCE SELECTIONS FOR THE MAJOR SCALE ASCENDING AND DESCENDING

Classification	Number Tested	J*	T**	P***	J&T	J,T,&P	J&P	T&P
Woodwind Group I	19	1	7	7	0	2	0	2
Woodwind Group II	23	2	8	8	1	3	0	1
Brass Group I	22	2	9	6	0	1	0	4
Brass Group II	7	0	3	2	0	2	0	0
Brass Group III	11	0	6	2	0	2	0	1
Percussion	4	0	3	0	0	0	0	1
Total Tested Population	86	5 (5.8%)	36 (41.9)	25 (29.0)	1 (1.2)	10 (11.6)	0 (0)	9 (10.5)

*Just tuning **Equal tempered tuning ***Pythagorean tuning