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ABSTRACT

During the 1975-76 academic year student response data were saved for a group of 17 freshman music majors as they worked through 15 units of harmonic dictation exercises delivered on the University of Delaware's Graded Units for Interactive Dictation Operation (GUIDO) system. Analysis of the student data base led to the identification of seven confusion tendencies that affect the perception of harmonies: bass line confusions, confusions by inversion, confusions by chord function, confusions by chord quality, unperceived sevenths, unperceived roots, and favorite response confusions. The level of student achievement on individual harmonies was found to be highly correlated with the percentage of times these harmonies are asked in the curriculum. (Author)

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# Computer-Based Recognition of Perceptual Patterns in Harmonic Dictation Exercises

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# Computer-Based Recognition of Perceptual Patterns in Harmonic Dictation Exercises

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-- Abstract -

During the 1975-76 academic year student response data was saved for a group of seventeen freshman music majors as they worked through fifteen units of harmonic dictation exercises delivered on the University of Delaware's GUIDO system. Analysis of the student data base led to the identification of seven confusion tendencies which affect the perception of harmonies: bass line confusions, confusions by inversion, confusions by chord function, confusions by chord quality, unperceived sevenths, unperceived roots, and favorite response confusions. The level of student achievement on individual harmonies was found to be highly correlated with the percentage of times these harmonies are asked in the curriculum.

## - Introduction -

During the 1974-75 academic year a computer-based dictation system called GUIDO was developed at the University of Delaware. GUIDO is an acronym for Graded Units for Interactive Dictation Operation, named after Guido d'Arezzo, the eleventh century musician and music educator who invented the staff and established the principles of solmization. The learning stations in this system consist of digital synthesizers through which the computer plays dictation exercises, and high-speed graphics terminals which display musical notation, ask questions, and record student responses.

It has previously been reported how an experiment was run to determine the impact of this system on student achievement in harmonic dictation (Hofstetter, 1975). The experiment was conducted with a freshman ear-training class during the 1974-75 academic year. During the first semester, all 33 students received the same course of instruction in ear-training, with all drill-and-practice done in the tape laboratory. At the beginning of the second semester, the class was randomly split into two groups; 17 students were assigned to an experimental GUIDO group which practiced ear-training at the computer terminals, and 16 students were assigned to a control TAPE group which practiced in the tape laboratory. At the end of the first semester (before the implementation of GUIDO), the mean harmonic dictation scores of the GUIDO and TAPE groups were 77 percent and 76 percent, respectively. At the end of the experiment the mean scores were 86 percent for the GUIDO group and 75 percent for the TAPE group. The results of a t-test applied to the GUIDO and TAPE scores at the end of the experiment indicate that the difference between the two groups is significant at the .05 level.

The second phase of this project has been to use the record-keeping features of the GUIDO system to identify perceptual patterns in harmonic dictation exercises. As the students work through the dictation units, GUIDO collects information on how the students respond to each individual item in the dication exercises. During the 1975-76 academic year, records were saved for a class of seventeen freshman majors at the University of Delaware. The dictation exercises were taken from the Benward (1969) Workbook in Ear-Training. The resulting student records constitute a complete data base of student responses given during the course of Benward's harmonic dictation exercises. It is the purpose of the present study to analyze the data base and to report the patterns of student learning which can be discerned therein.

## - Procedures -

The experiment was conducted in the context of the activities normally associated with freshman ear-training courses. The students met in class for two hours each week with the instructor, and they practiced dictation exercises on their own time for an additional two hours each week. The seventeen students participating in this experiment did the additional practice at the computer terminals. The GUIDO system normally allows the students to select the units of dictation exercises which they want to practice. In this study the choice of dictation units was controlled so that all students received the same sequence of harmonic dictation exercises. The sequence is given in Table 1, which shows the unit numbers and content of the harmonic dictation units. In order that the student response data could be interpreted in a single key with respect to one tonic, this experiment was limited to non-modulating dictation exercises.

Table 1

Harmonic Dictation Units Included in the Experiment

| Sequence Number | Benward Harmonic Unit Number | Content |
|---|---|---|
| 1 | 3A | I and V |
| 2 | 4B | I, V, and $VII^6$ |
| 3 | 4E | I, V, and $VII^6$ |
| 4 | 5B | I, IV, V, and $VII^6$ |
| 5 | 5D | I, IV, V, and $VII^6$ |
| 6 | 6A | I, IV, V, and $VII^6$ |
| 7 | 6B | I, IV, V, and $VII^6$ |
| 8 | 6D | I, IV, V, and $VII^6$ |
| 9 | 7C | I, II, IV, V, and $VII^6$ |
| 10 | 8B | I, II, IV, V, and $VII^6$ |
| 11 | 8D | I, II, IV, V, and $VII^6$ |
| 12 | 9D | I, II, IV, V, $V^7$, and $VII^6$ |
| 13 | 10A | I, II, IV, V, $V^7$, and $VII^6$ |
| 14 | 11A | I, II, IV, V, $V^7$, VI, and $VII^6$ |
| 15 | 12D | I, II, III, IV, V, $V^7$, VI, and $VII^6$ |

The GUIDO system also normally allows the students to select the order in which they answer harmonic dictation questions. In this study the order was controlled so that all students were required to answer Roman numerals first, then soprano and bass lines. The GUIDO system saved all student responses to each harmony played in the dictation exercises. If the students got a harmony wrong, they were allowed to continue working until they got it right. In this study only the first response to each harmony was considered for analysis.

## - Results -

In order to determine the overall pattern of student responses to the harmonic dictation exercises, cross tabulations were made for each harmonic dictation unit and for the complete set of all 15 units. By studying the cross tabulations for each individual unit a summary of student achievement was obtained for each harmony in the dictation exercises. Given in Table 2, this summary shows the units in which each harmony was asked, the units in which students showed mastery in the identification of individual harmonies, and the units in which students consistently gave the same wrong answer to a given harmony. Harmonies were considered to be mastered if the students answered correctly at least 70% of the time on the first try. 70% was the grand mean for all students on all exercises in the curriculum. Consistent wrong answers were defined to be those which were given at least 20% of the time. At the bottom of the table are given the mean scores for each unit. The range is from a low of 59 in unit 2 to a high of 82 in units 6 and 14.

Several response patterns can be seen in Table 2. First, there are those harmonies which are quickly mastered at the beginning of the curriculum and are not subsequently confused with other harmonies. These are I, i, V, and $vii^{o}_{6}$. Second, there are harmonies which after their initial mastery are subsequently confused with other harmonies. These are $I^{6}$ which is confused with I in unit 13; $i^{6}$ which is confused with i in unit 7; IV which is confused with $ii^{6}$ in unit 9; $IV^{6}$ which is confused with $iv^{6}$ in unit 12 and with vi in unit 15; iv which is confused with IV in unit 8 and $ii^{o}_{6}$ in unit 9; and $V^{6}$ which is confused with $vii^{6}$ in units 7, 8, 10, 11, and 12 and with $V^{7}$ in unit 13. Third, there are those harmonies which are mastered after some initial difficulty and are not subsequently confused with other harmonies. These are $I^{6}_{4}$ and $iv^{6}$. Fourth, there are those harmonies which are never mastered. These are $i^{6}_{4}$ which is consistently confused with V; ii which is confused with $vii^{o}_{6}$ and IV; $ii^{6}$ which is confused with IV; and $ii^{o}_{6}$ which is confused with IV and iv; $iii^{6}$ which is confused with V; $V^{7}$ which is confused with V; $V^{6}_{5}$ which is confused with $V^{6}$; $V^{4}_{3}$ which is confused with $vii^{o}_{6}$; and $V^{4}_{2}$ which is confused with $ii^{o}_{6}$ and ii. Finally there are the harmonies iii and vi which are not presented until the end of the curriculum but which are nevertheless immediately mastered.

Table 2

Summary of Student Achievement in Harmonic Dictation Exercises.

| Roman Numeral | Harmonic Dictation Units | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| I | V | – | * | * | * | * | – | * | * | * | * | * | * | * | * |
| $I^6$ | – | – | I | $i^6$ | I | * | – | * | * | * | * | * | I | * | * |
| $I^6_4$ | – | – | – | – | – | – | – | – | – | V | V | – | * | – | – |
| i | – | I | I | * | * | * | * | * | * | * | * | * | * | – | – |
| $i^6$ | – | – | $I^6$ | i | i | * | i | * | * | * | – | * | * | – | – |
| $i^6_4$ | – | – | – | – | – | – | – | V | V | – | – | V | V | – | – |
| ii | – | – | – | $vii^o_6$ | – | – | – | $vii^o_6$ | – | $vii^o_6$ | IV | IV | $vii^o_6$ | $vii^o_6$ | IV |
| $ii^6$ | – | – | – | – | – | – | – | – | IV | IV | IV | IV | IV | IV | IV |
| $ii^o_6$ | – | – | – | – | – | – | – | IV | iv | – | iv | IV | IV | – | – |
| iii | – | – | – | – | – | – | – | – | – | – | – | – | – | – | * |
| $iii^6$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | V |
| IV | – | – | – | * | * | * | – | * | $ii^6$ | * | * | * | * | * | * |
| $IV^6$ | – | – | – | – | – | V | – | $iv^6$ | IV | * | * | $iv^6$ | * | – | vi |
| iv | – | – | – | IV | V | * | * | IV | $ii^o_6$ | * | – | – | * | – | – |
| $iv^6$ | – | – | – | iv | – | – | iv | * | – | – | * | * | * | – | – |
| V | I | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| $V^6$ | – | – | $vii^o_6$ | $vii^o_6$ | V | * | $vii^o_6$ | $vii^o_6$ | – | $vii^o_6$ | $vii^o_6$ | $vii^o_6$ | $V^7$ | – | – |
| $V^7$ | – | – | – | – | – | – | – | – | – | – | – | V | V | – | V |
| $V^6_5$ | – | – | – | – | – | – | – | – | – | – | – | – | $V^6$ | $V^6$ | – |
| $V^4_3$ | – | – | – | – | – | – | – | – | – | – | – | – | – | $vii^o_6$ | – |
| $V^4_2$ | – | – | – | – | – | – | – | – | – | – | – | – | $ii^o_6$ | ii | – |
| vi | – | – | – | – | – | – | – | – | – | – | – | – | – | * | * |
| $vii^o_6$ | – | V | * | * | * | * | * | * | * | * | * | * | * | – | – |
| $\bar{X}$ | .74 | .59 | .64 | .71 | .70 | .82 | .75 | .73 | .68 | .78 | .76 | .61 | .61 | .82 | .71 |
| SD | .44 | .49 | .48 | .45 | .46 | .38 | .43 | .44 | .47 | .41 | .44 | .49 | .49 | .39 | .45 |

Key: " – " means a harmony was not asked in a given unit.
" * " means a harmony was correctly answered more than 70% of the time.
Roman numerals are given when they are confused with the correct answer more than 20% of the time.

Table 3 contains a cross tabulation of correct answers and student responses for all of the harmonic dictation units. Examination of this table leads to the identification of seven principles of chord confusion which account for all of the student errors which occur at least 10% of the time. Errors occurring less than 10% of the time are not discussed in this paper. The percentages of times the students gave correct answers are found on the diagonal line drawn on the table. The other numbers in the table indicate the percentages of the times wrong answers were given. These are categorized by seven symbols drawn around the numbers corresponding to the seven principles of chord confusion which are described as follows:

Principle One: Bass Line Confusions. The most common confusion tendency involves chords which have the same bass notes. The percentages of confusions according to this principle have been circled in Table 3. $I_4^6$ is often confused with $iii^6$, while $i_4^6$ is confused with V. It has been generally believed that tonic six-four chords are often confused with dominant chords. The data in Table 3 indicates that this is much more true of the minor $i_4^6$ than it is of the major $I_4^6$, which is actually confused more often with $iii^6$ than it is with V.

ii is confused with $vii_6^o$, a chord with the same bass note but with a different harmonic function. $ii^6$ is confused with IV, and $ii_6^o$ is confused with iv. These pairs of chords share the same bass notes, and they have the same subdominant harmonic function. iii is confused with $I^6$ and $iii^6$ with $I_4^6$. These pairs of chords share two common notes, although they have dissimilar harmonic functions. $iii^6$ is also confused with V, supporting the theory that it can function as a dominant substitute.

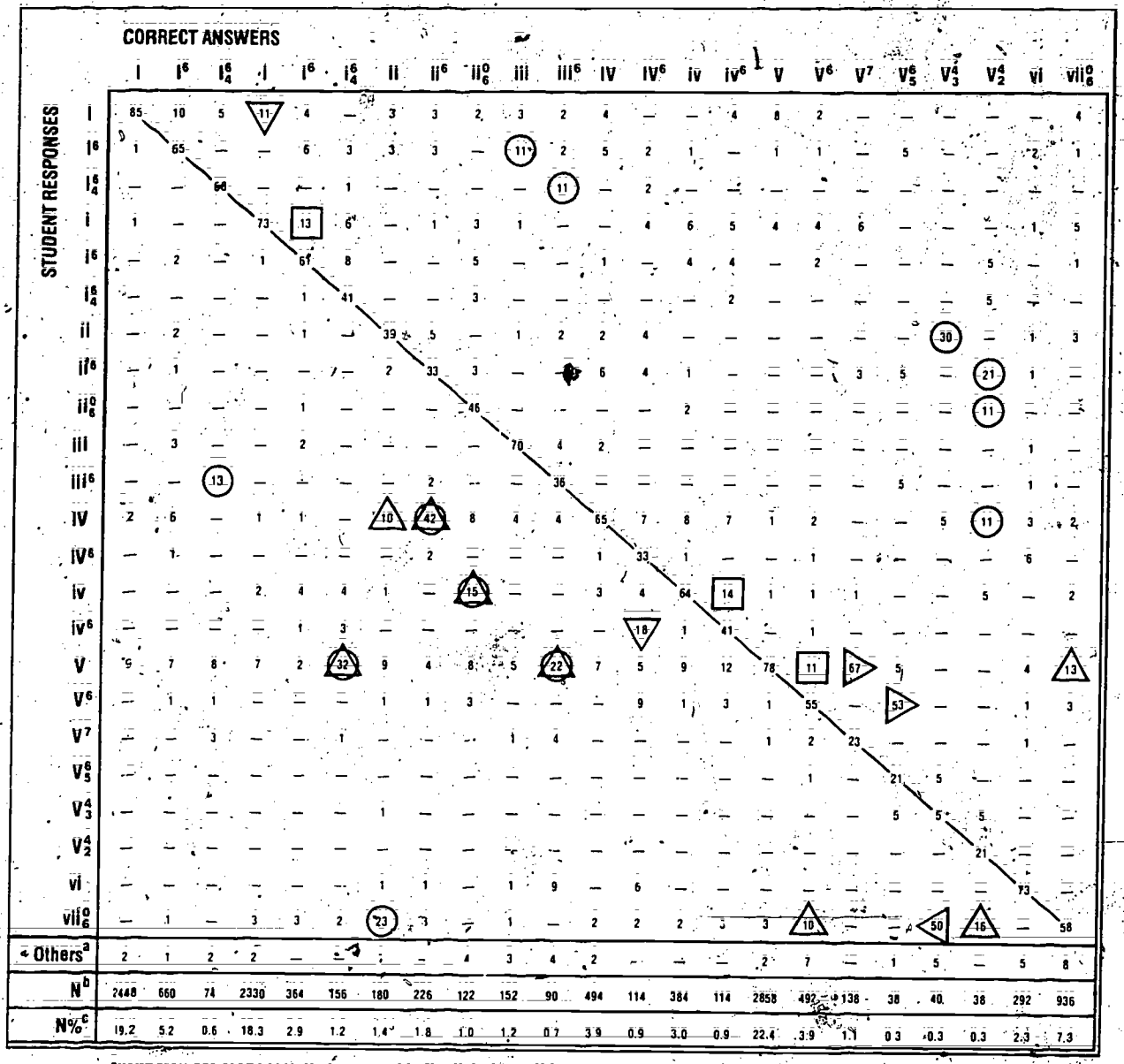
$V_3^4$ is confused with ii, a chord with the same bass note but with a much different harmonic function. $V_2^4$ is similarly confused with $ii^6$ and $ii_6^o$, and also with IV, chords with the same bass notes and with subdominant functions.

Principle Two: Confusions by Inversion. Only three chord confusions occurred under this principle whereby the correct Roman numeral is answered with the wrong inversion. $i^6$ was confused with i, $iv^6$ with iv, and $V^6$ with V. A square has been drawn around the percentages of these confusions in Table 3. It has generally been believed that confusions of this type can occur on any degree of the scale, and in any mode. The data in Table 3 show that this principle affects only $i^6$, $iv^6$, and $V^6$.

Principle Three: Confusions by Chord Function. Four of the confusions discussed under principle one, bass line confusions, can also be classified under principle three as confusions by chord function, namely, $i_4^6$ and V (dominant), $ii^6$ and IV (subdominant), $ii_6^o$ and iv (subdominant), and $iii^6$ and V (dominant). Confusions under principle three have been marked with a "$\Delta$" in Table 3. Noticeably absent from the list of confusions under this principle is the chord substitute vi for I.

## TABLE 3

Cross Tabulation of Correct Answers and Student Responses for All Harmonic Dictation Units; Numbers Given in the Matrix are Percentages of the times the Student Responses were Given




[a] "Others" are responses that were not in the list of possible answers.
[b] "N" is the number of times the chord was asked.
[c] "N%" is the percentage of times the chord was asked.

○ = Bass Line Confusions
□ = Confusions by Inversion
△ = Confusions by chord function
▽ = Confusions of chord quality
▷ = Unperceived seventh
◁ = Unperceived root

Principle Four: Confusions of Chord Quality. Only two examples of the confusion of chord quality were found, namely, the confusion of $IV^6$ and $iv^6$, and of i and I. These have been marked with a " $\nabla$ " in Table 3.

Principle Five: Unperceived Seventh. In the perception of the $V^7$ chord and its first inversion a common problem was that students did not recognize the presence of the seventh. They confused $V^7$ with V, and $V^6_5$ with $V^6$. These confusions have been identified by a " $\triangleright$ " in Table 3.

Principle Six: Unperceived Root. 50% of the time students confused $V^4_3$ with $vii^0_6$, the spelling of which is identical to a $V^4_3$ minus the root. This confusion has been marked with a " $\triangleleft$ " in Table 3.

Principle Seven: Favorite Response. The six principles given above account for all of the percentages in Table 3 greater than 10% except for one, namely, the confusion of $iv^6$ and V. These two harmonies have no notes in common, and their functions are most dissimilar. The only explanation for this confusion is that V was the most frequently used wrong response in the data base, and if students did not have any idea what to name a harmony, their most frequent guess was V.

The last two rows of Table 3 give the number of times each harmony was asked throughout the curriculum, and the percentage of times each harmony was asked, respectively. A wide variation exists in the percentages which range from .3% for inversions of $V^7$ to 19% for the tonic triad. This variation led to the question of whether the number of times a harmony is asked is related to the percentage of times that harmony is answered correctly. A product moment correlation was done for each unit and for the whole population based on the percentage of times each chord was asked and the percentage of times each chord was correctly answered. Table 4 contains the resulting correlation coefficients. The high correlations found in most units indicate that students do better on harmonies which are asked a lot. It stands to reason that harmonies which are asked more and therfore practiced more will be learned better than those which are asked less frequently. Therefore, one way of increasing student achievement of the difficult harmonies may be to increase the percentage of times they are asked.

Table 4

Pearson Correlation Coefficients for the Percentage of Correct Answers for Each Harmony with the Percentage of Times Each Harmony Was Asked in Each Unit and in the Whole Population.

| Unit | Correlation Coefficient | Content |
|---|---|---|
| 1 | .99 | I and V |
| 2 | .95 | I, V, and $VII^6$ |
| 3 | .57 | I, V, and $VII^6$ |
| 4 | .60 | I, IV, V, and $VII^6$ |
| 5 | .66 | I, IV, V, and $VII^6$ |
| 6 | .35 | I, IV, V, and $VII^6$ |
| 7 | .44 | I, IV, V, and $VII^6$ |
| 8 | .76 | I, IV, V, and $VII^6$ |
| 9 | .36 | I, II, IV, V, and $VII^6$ |
| 10 | .51 | I, II, IV, V, and $VII^6$ |
| 11 | .66 | I, II, IV, V, and $VII^6$ |
| 12 | .79 | I, II, IV, V, $V^7$, and $VII^6$ |
| 13 | .52 | I, II, IV, V, $V^7$, and $VII^6$ |
| 14 | .66 | I, II, IV, V, $V^7$, VI, and $VII^6$ |
| 15 | .86 | I, II, III, IV, V, $V^7$, VI, and $VII^6$ |
| All 15 Units | .65 | All Harmonies |

## Discussion

Considering the data included in this study five observations can be made about the design of Benward's harmonic dictation exercises. First, the average score for all seventeen students in all fifteen units is 70%. The means of the individual units range from 59% to 82%. The level of difficulty is fairly consistent throughout the curriculum.

Second, especially noteworthy is the immediate mastery of the harmonies iii and vi, which are not introduced until the end of the curriculum. Benward has done an exceptional job in designing the curriculum in such a way that these harmonies are learned so quickly.

Third, a weakness in the curriculum concerns those harmonies which are never mastered. These are $i^6_4$, ii, $ii^6$, $ii^6_5$, $V^7$, and the inversions of $V^7$. The product moment correlations indicate that one way of improving student performance of these chords may be to increase the frequency of their occurence in the curriculum.

Fourth, there is no one confusion pattern which affects all of the harmonies; on the contrary, the confusion patterns are selective. Bass line confusions affect the perception of the tonic six-four chords, the first inversions of the supertonic chords, both root positions and first inversions of the mediant chords, and the second and third inversions of the dominant seventh chord. Confusions by inversion affect the perception of only three chords, namely, $i^6$, $iv^6$, and $V^6$. Confusions by chord function affect the perception of tonic six-fours, supertonic, mediant, and dominant chords; they do not occur in subdominant, submediant, and leading-tone chords. Confusions of chord quality affect the perception of root position tonic triads and first inversion subdominant triads. Inversions of the dominant seventh chords are affected by unperceived roots and unperceived sevenths. The instructor's manual of the Benward text includes sections in which teaching techniques are discussed. It may be helpful to include in these sections information regarding the confusion patterns detected in this study so that instructors can watch for them and warn their students about them. Additional units could be specifically designed to give more practice in the confusion areas.

The continuation of this study will seek to determine not only the perceptual patterns discernible in existing harmonic dictation series, but also the best way of organizing dictation exercises. This will be pursued through the gradual cycle of design, evaluation, and redesign which has begun in the University of Delaware's GUIDO project. The perception of intervals, melodies, chord qualities, and rhythms are also under investigation in an attempt to realize what Allvin (1971) identified as a very important goal of computer-based education, namely, "to define the optimal sequential ordering of material within concept modules."

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