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ABSTRACT

Computer Assisted Synthesizer System (CASS), a portable music synthesizer system which can produce tones from ordinary paper and pencil graphs, was developed and its usefulness for music instruction evaluated in this study. After completion of a pilot study to determine the feasibility of developing CASS and to run a trail test period, 28 fifth and eighth grade students were randomly selected to be given instruction utilizing the system. Subjects received six weeks of instruction, and at the end of this period, they were compared with random samples of instrumental music students and with general music students from the same school. The results indicated that the CASS training was as effective as the study of conventional musical instruments. Because of some unexpected results with the general music students, it is considered that another variable, such as motivation, may be of importance in predicting the differential response to the three treatments. (The technical aspects of CASS are described in an appendix.) (Author/SH)

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GRAPHIC REPRESENTATION OF MUSICAL CONCEPTS:

A COMPUTER ASSISTED INSTRUCTIONAL SYSTEM

Jack J. Heller
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SUMMARY

The purposes of the research project were to 1) develop a unique portable music synthesizer system which could produce tones from ordinary paper and pencil graphs, and 2) to test the usefulness of the new system for teaching music notation and performance skills.

The experimental portion of the project was limited to determining the effect of six weeks instruction with the new system when compared to traditional instrumental music study and to normal classroom music activities. The specific hypothesis tested was that classes utilizing the Computer Assisted Synthesizer System (CASS) would develop a performance capability at least equal to that of a conventional musical instrument studied for the same length of time.

In order to assess the effectiveness of training with the CASS, twenty-eight subjects were randomly chosen (from 5th and 8th grade classes) and were given instruction utilizing the system. These subjects were compared to random samples of instrumental music students (n=28) and to general music students (n=28) from the same school. Two other factors included in the analysis were grade level (5th and 8th) and musical aptitude (Seashore, Measures of Musical Talents). These variables were included so that differential effects (interaction) due to grade level or musical aptitude could be determined. Thus, a 3x2x2 analysis of variance was computed for two dependent measures (a written test of discrimination of aural stimuli from normal notation, and a performance of three musical phrases).

The results indicated that the CASS training was as effective as the study of conventional musical instruments. However, for the 5th grade, the general music groups scored higher on the performance test than either of the other two groups, while for the 8th grade, the general music group scored lower than either of the other groups. Because of the low 8th grade general music scores, (due, in part, to refusal of seven subjects to sing for the test) it is considered that another variable, such as motivation, may be of importance in predicting the differential response to the three treatments.

This project has provided for the development and testing of a unique, portable music synthesizer system, which produces tones from regular paper and pencil graphs. The experiment provides evidence that this unique system is useful for music training in a public school. In view of the limited experience in devising training methods using the CASS, the results appear particularly encouraging. It is expected that further technical development of the system, and improved training methods will provide the means to deal with a variety of persistent educational problems in music. The system has the potential for use in: 1) teaching the relationship between traditional notation and the performance concepts implicit in the notation, 2) reducing the length of time necessary to develop performance skills, and 3) eliminating inability to actively participate in musical composition and performance by those persons physically or psychologically incapable of traditional performance.

I. INTRODUCTION

A. Rationale

The music student typically has two major hurdles to overcome before he can engage creatively in the composition and performance of traditional music: 1) he must master a complex, highly stylized, and limited musical notation, and 2) he must develop a technique on some musical instrument sufficient to provide a medium for his own creative thoughts. With the advent of electronic music, and the recent proliferation of sound synthesizers, the possibility arises to circumvent these problems.

This research was designed to develop a unique system of tone generation from paper and pencil graphs and to test its feasibility for application to the teaching of music. The primary goal was to determine whether this system is a useful device for teaching musical performance skills, which are necessary for the demonstration of covert musical concepts.

Three premises are stated as reasonable expectations for this system:

1) It will provide a performance capability equal to that of a conventional musical instrument studied for the same length of time.

2) It will enable some students to actively participate in musical composition and performance who were previously barred from such activity by physical or psychological inadequacies.

3) The combined effects of a visual analog of a musical performance and the ability of the student to actively participate in manipulating the visual analog (and to produce corresponding changes in the auditory dimension) will provide an effective way of teaching musical concepts.

The experiment described in this report is a first step in the evaluation of these premises. The scope of this experiment provides evidence relative to the first premise, and suggests implications for the second and third premises even though they were not tested directly.

B. Problem Statement

The purpose of the experimental portion of the research was to determine the effect of six weeks training in music under three conditions: 1) Classes with the newly developed Computer Assisted Synthesizer System (CASS), 2) General Music Classes, and 3) Instrumental Music Classes, upon a written test of auditory recognition of musical notation and upon a musical performance test.

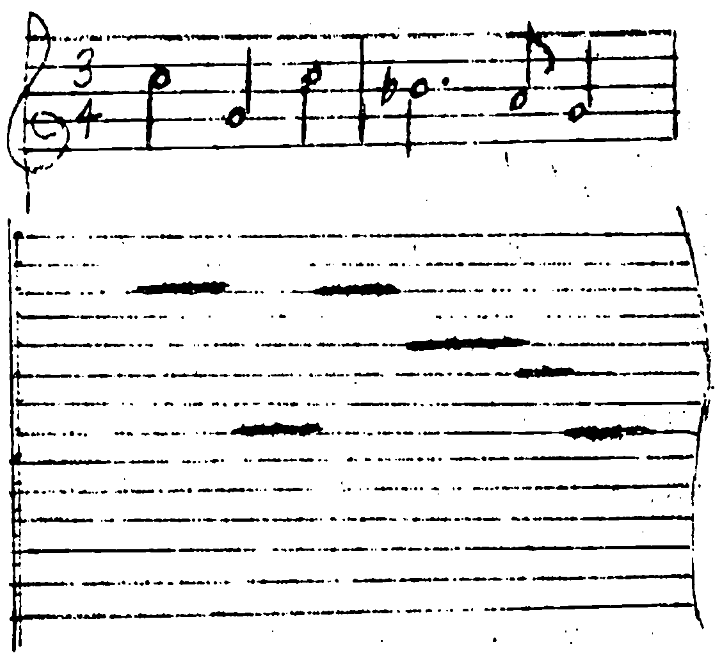
C. Background and Significance

For those students who do not elect to study traditional instruments, the system and application suggested here may provide a means of active participation in composition and performance otherwise unavailable to them. For those able to read and perform traditionally, the CASS can be used to illustrate graphically, as well as demonstrate aurally, advanced concepts, such as vibrato, portamento, intonation subtleties, etc.

Figure 1 shows a musical phrase in traditional notation with the corresponding graph notation below it.

FIGURE 1

TRADITIONAL AND GRAPH NOTATION



In order to produce the above traditional notation as a performance, a certain amount of knowledge in music must be assumed. First, the performer must understand the different signals which appear in the traditional notation. Second, he must be able to manipulate an instrument in order to transform these instructions into sound. If voice is the performing instrument, the performer must have sufficient auditory skills ("ear-training") before the appropriate tones can be produced. On an instrument where keys, valves, strings, etc. are manipulated, the performer may be able to produce the tones with reasonable success without the auditory

skills (i.e., when a particular signal is seen in the notation, a physical response of a particular kind is made). Nevertheless, for either group of performers (vocalists or instrumentalists) a great deal of prior study must take place before even the simplest musical phrase can be produced from directions given in the notation (i.e., sight reading rather than rote singing or playing).

In order to perform or compose with the Computer Assisted Synthesizer System (CASS), the necessity of prior study of an instrument or "ear-training" is eliminated. The only equipment needed by the student is paper and a pencil. Knowledge of conventional music notation is also not necessary for performance.

With the use of the CASS, the student has a visual as well as an auditory record of his performance. It is possible to see and hear his performance simultaneously. There is no permanent visual record available from a performance with conventional instruments. Once the selection has been played in the traditional manner, the mistakes cannot be corrected unless another performance is undertaken. With the CASS it becomes possible to revise, alter, or correct the performance record. Since the student can study the non-real time visual record, this procedure may be useful as an effective teaching device. The student can see immediately where he has "played" an incorrect note or where his rhythm is not as he would like it. He is able to equate such nebulous performance terms such as "flat" and "sharp" with the visual analog.

This system (CASS) could develop interest in creative composition and also allow for the immediate performance of student compositions. Since the CASS reads markings of any shape or size from the paper many possibilities for composition arise. One need not be limited by notation of a specific type. Any picture or design could be transformed into musical sound.

This research does not propose the elimination of traditional instrumental music training or notation study. The authors believe that the new means provided by technology to teach musical concepts and to allow for the demonstration of the development of these concepts, should be made available for use in the public schools. This study has developed a new system and provided evidence regarding its educational usefulness. The remainder of this report describes the pilot study, the formal experiment, and the statistical results and conclusions. The Appendices give detailed descriptions of the portable Computer Assisted Synthesizer System, the pilot system using the PDP-9 Computer, the training sequence, and tests utilized (dependent measures) for the experiment.

II. PRELIMINARY OBSERVATION OF THE SYSTEM (A Pilot Study)

A pilot study was undertaken during the 1970 spring semester to determine the feasibility of developing a portable unit for use in the public

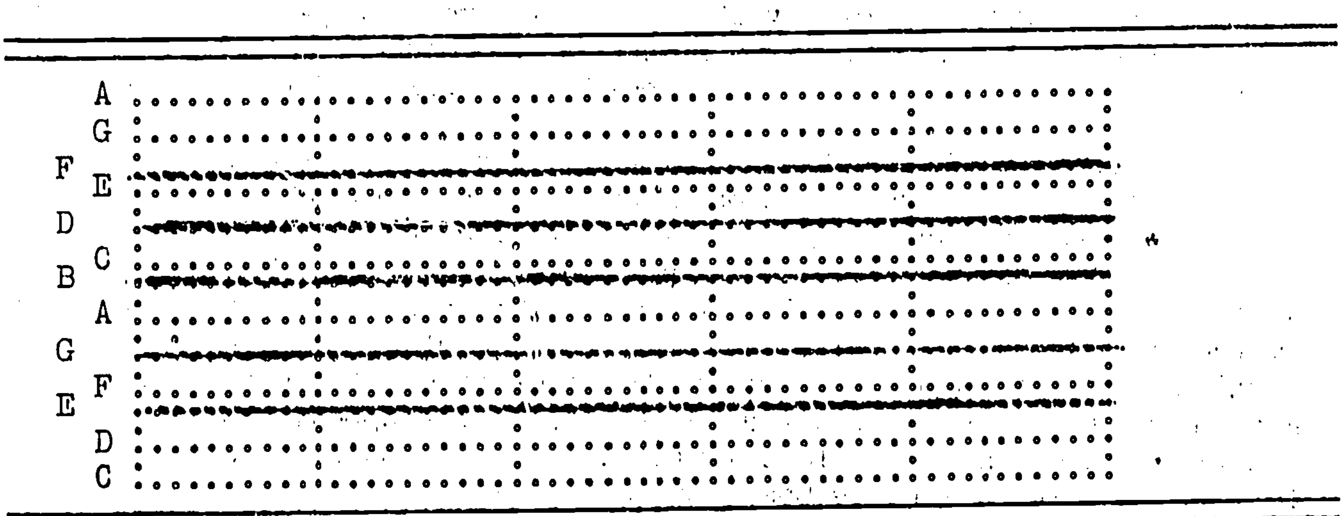
schools and to run a trial test period on the first premise stated for the project.

Twelve volunteer college students from the instrumental music education classes at the University of Connecticut participated in the pilot study. As part of regular course work, each of the students was required to study a traditional musical instrument for one semester. The instrument studied is one with which the students had no previous experience. For the pilot study, a comparison was made between performance capability on these instruments and the computer system to determine the possible effects of the experimental treatment.

The following is a general description of the pilot system and training sequence. Appendix A describes the technical aspects of the system. A PDP-9 computer was programmed so the pitches produced by an attached Moog Synthesizer were representative of the voltages produced by the computer. Three groups consisting of four Ss each followed a one-hour training sequence for four weeks at the Digital Systems Laboratory in the School of Engineering. Each student was seated before a Cathode Ray Tube (a screen similar to that of a television set). He used a light pen, attached to the console, to track a line of music across the screen. The computer was programmed to display a grid on the screen similar to Figure 2:

FIGURE 2

DISPLAY OF SCREEN IN PILOT STUDY

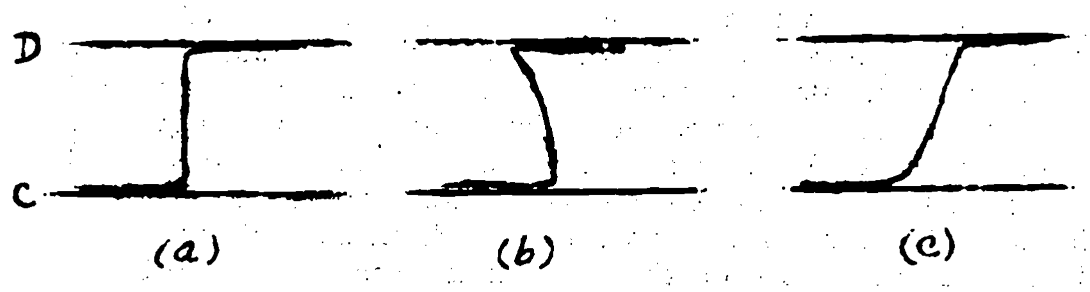


The lines which corresponded to each pitch were lit and those representing the treble staff had a greater light intensity (darker lines). The vertical lines were used to determine time relationships. These lines could represent various time periods.

The length of the line drawn determined the time value for each note. In order to change pitch, it was necessary to trace a vertical line from a particular pitch to another or to back-track slightly in a vertical movement. In the first two examples below (Figure 3, a and b) the pitch is maintained aurally until horizontal movement is reached again for the note D.

FIGURE 3

TRACING A TONE LINE ON THE CATHODE RAY TUBE



However, any forward non-horizontal movement of the light pen caused an aural glissando effect, as in example (c) above.

In tracking a line of music, it was not necessary to draw a line in real-time. The length of the line governed the time values and not the time involved in tracing the line. The speed at which the students completed a frame of music was dependent upon his agility with the light pen. However, agility did not necessarily indicate accuracy.

While tracing the tone line across the screen, there was an immediate audio and video display, although the video portion faded slowly. Upon completion of the written phrase, the student could call back the faded portion by pressing a button. At this point, the total written phrase could be seen and heard in real-time. Several different audio playback speeds were available.

During the lessons, musical excerpts in normal notation were placed above the top of the screen and the students were told to position the tracking square to the starting note. The tracking square consisted of four dots of illumination located closely together . . . . It was the light pen coming into optical contact with this square that allowed a line of light to be drawn across the screen. Each of the students were asked to play the excerpts and the errors were discussed by the class after each playback. All students in the three classes appeared inter-

ested and enthusiastic. In the beginning, the major common problem was the initial positioning of the tracking square. There was also the problem of maintaining contact with the square during the tracing for some students.

The response to this computer system seemed to generate a high level of enthusiasm. The subjects talked to the screen, expressed frustration and excitement at their accomplishments. They remained interested in conquering their individual mechanical problems in manipulation. Suggestions were freely given concerning system improvement. Two of the ones stated most frequently were 1) a desire for a correction device so that individual note changes could be made after the aural playback and 2) a horizontal placement of the screen to facilitate the manipulation of the light pen and alleviate arm fatigue. These two suggestions were incorporated in the portable system that was subsequently developed.

For the pilot study, a six-week instructional period was planned, with testing at the end for statistical comparisons. However, because of the campus unrest and numerous student strikes, this goal was not realized. As a post-test, each subject who completed four weeks of training (n=7) was asked to draw two musical phrases on the screen (Cathode Ray Tube). Each phrase was taped for a permanent record. Each of the seven students then played the same phrases on the instruments which were studied in secondary instrumental classes over the same time span. The pilot study was useful in determining the problems that occurred in the initial student-machine interaction, and to help in planning the procedures for the formal experiment. A subjective analysis of the post-tests showed that the computer performances were superior to the performances on the traditional instruments in demonstrating pitch and rhythmic skills.

III PROCEDURES FOR THE EXPERIMENT

A. Selection of Subjects

For the experimental portion of this investigation, subjects were randomly chosen from classes of the R. J. O'Brien School, East Hartford, Connecticut. This school, one of twenty-two in the town, was considered typical in terms of student characteristics and had a large number of students in the specific age levels desired for the experiment. The school administration indicated great interest in participating in the experiment and cooperated in every way possible. A room was provided for the experimental treatment. The experiment was able to be carried on with a minimum disruption of normal school functioning.

Since students normally begin the study of instrumental music in the fifth grade, this grade level was chosen to participate in the experiment. The authors were interested in the comparison between performance ability of beginning instrumentalists and beginners in the Computer Assisted Synthesizer System (CASS). (See Appendix B for a description of the CASS.)

In order to study the differential effects and usefulness of the CASS on different age levels, the eighth grade was also selected to participate in the experiment. Both grade levels were equally represented in the analysis for the three following treatments:

A_1 Experimental - those students participating in the CASS Treatment (fifth grade, n=14, eighth grade, n=14; Total n=28).

A_2 General music - the students remaining in the regular music classes and having no other school music experience (fifth grade, n=14, eighth grade, n=14; Total n=28).

A_3 Instrumental music - students studying an instrument through the school music program (fifth grade, n=14, eighth grade, n=14; Total n=28).

Since the student-machine interaction was of particular interest, it was decided to have small classes so that more exposure with the CASS would be possible. Each of the experimental classes consisted of seven students.

Every student in the classes from which the Ss were chosen was given the Pitch, Rhythm and Time tests from the Seashore Measures of Musical Talents. The manual accompanying the tests states that the reliability of these measures was estimated by means of internal consistency coefficients (Kuder-Richardson formula 21). These coefficients are presented in Table 1 for those grades and measures chosen.

TABLE 1

C. A. Seashore, Measures of Musical Talents:

COEFFICIENTS OF RELIABILITY

	Grade 5	Grade 8
Pitch	.82	.84
Rhythm	.67	.69
Time	.72	.63

The Seashore Measures were not used as a pre-test, but rather as a means for blocking in the final analysis. This blocking of high and low Seashore test scores provided additional information in the evaluation of

the effects of the main treatments. Interaction between treatment and musical aptitude could thus be determined.

Instead of participating in general music classes twice a week for forty-five minutes each period, the experimental treatment group reported to the classroom specifically allocated for the experiment for six consecutive weeks and were given lessons with the CASS. The second treatment group (general music, n=28) remained in the scheduled music classes twice a week and did not receive any further music instruction either within or outside school. The third group (n=28) consisted of those students, within the pre-determined grade categories, who were studying an instrument in school. These students continued to have general music classes twice a week in addition to their regularly scheduled instrumental lessons once a week.

B. Experimental Treatment

A portion of a standard size classroom was used for the experimental treatment and the desks and chairs were organized into a semi-circle. Each subject was able to hear and see the CASS, which had been placed in the center. At the beginning of each class period Ss were provided with paper containing 24 parallel lines $\frac{1}{4}$ inch apart. Each S was responsible for labeling the lines with the pitch names from normal notation. Most of the subjects also drew the treble staff at the bottom of their papers and labeled these notes for reference. A copy of each musical phrase to be studied during the class period was given to each subject.

The beginning of each period consisted of verbal explanations of pitch and rhythmic notation, and aural demonstrations of these concepts with the CASS. The blackboard was used to illustrate further the musical examples of each lesson. The board usually had an example of the traditional staff and the staff used with the CASS notation. Subjects were required to compare the relationships between both staffs. Appendix C contains a copy of all lesson plans.

Time was allowed during the second class period each week for individual composition. During this period, the students could compose their own music or draw designs to be played. Several subjects enjoyed joint efforts in compositions and designs.

Halfway through the experiment, five subjects from one of the eighth grade classes indicated that they wished to return to their regularly scheduled music class. The subjects probably became uncomfortable because of the individual exposure inherent in the small class size (experimental classes of seven each as opposed to the more typical size of twenty-five). They stated that they "wished to go back to see and talk to their friends." As stated earlier, fourteen eighth grade and fourteen fifth grade Ss were utilized for analysis. The original number of eighth grade experimental subjects was twenty-one. Since five of these Ss drop-

ped the experimental treatment and one subject did not complete the tests (due to illness) this reduced the experimental eighth grade group to fifteen. In order to utilize an appropriate analysis of variance model, one S from this group was randomly eliminated. This reduced the size of the eighth grade experimental group to fourteen (equal to the comparable fifth grade experimental group). This subject mortality should be considered when interpreting the data.

C. Testing Procedures

Near the termination of the experimental treatment classes, the instrumental teachers (string and brass/woodwind) were consulted to determine what musical examples they would expect students to play at the end of the first six weeks of study. Three eight measure phrases were chosen (see Appendix D). All experimental subjects were asked to "draw" these phrases. The tempo was indicated by a line drawn at the bottom of the page to represent the length of a quarter note. The Ss were expected to complete these phrases in one class meeting. The instrumentalists were required to play these selections on their respective instruments. The tempo was indicated verbally to each subject and the performances were taped. The third group of subjects, from the regularly scheduled general music classes, were required to sing the music on the "ah" vowel. Their performances were likewise taped.

A written test was given to all Ss to determine ability to correlate sight and sound (see Appendix E). Each subject was asked to identify the correct notation (multiple choice answers) for an auditory sample, for both pitch and rhythm.

D. Scoring of the Performance Test

Scoring of the performance was accomplished by setting limits of $\pm$ 25 cents ($\frac{1}{4}$ semi-tone) from the normal pitch, and $\pm$ the duration of half the value of the given note relative to the initial rhythm established by the subject. A score of + 1 was assigned for each note (for both pitch and rhythm) within these limits, and -1 for each note exceeding these limits.

The CASS performance tests consisted of a visual record of pitch and rhythm. Since these records were already in a graph form, they were used for scoring. The instrumental performance tests were transferred to frequency graphs via a special purpose system consisting of an FM discriminator and strip chart recorder. These graphs were used in scoring the instrumental performances. Due to the extremely poor quality of the vocal performances for both grade levels, it was not possible to produce readable graphs for this group. Consequently, scores were obtained by listening to the performance tapes and applying the same scoring criteria used with the other two groups.

IV. RESULTS AND INTERPRETATIONS

For the statistical analysis a 3x2x2 analysis of variance (equal n design), fixed model, was chosen. The three factors were A: Treatment (CASS, General Music Classes, Instrumental Music Classes), B: Grade Level (Fifth and Eighth Grades) and C: Musical Aptitute (High and Low).

Two separate analyses were completed for the two dependent measures (written test and performance test). Table 2 indicates the means and standard deviations for the results of the written test. The highest possible score on this test was twenty.

No significant difference was found for the separate treatments on the written test (discrimination of aural stimuli from normal notation). The small differences between the means (11.67, 12.68, and 12.47) are simply due to sampling variability. The difference between the means of the two grade levels was found to be significant at the .01 level. As a group, the eighth grade subjects scored higher (Mean = 13.30) than the fifth grade subjects (Mean = 11.24) on the written test. The other statistically significant result on the written test was obtained for factor C - Musical Aptitude ($p < .001$). This was not surprising since it is to be expected that musically perceptive persons will execute a test dealing with discrimination in music in a superior manner. That is, Ss who scored above the 50th percentile on the Seashore measures scored higher on the written notation test (Mean = 13.66) than the low Seashore test subjects scored on the written test (Mean = 10.88). The difference between the means (2.78) was not due to sampling variability. Table 3 is the summary table of the analysis of variance for the written test.

The three types of training examined in the experiment showed no differences in student ability on the music discrimination test developed for this experiment. However, the data support the hypothesis that 8th graders score higher than 5th graders on this test. Further, students whose senses of pitch and rhythm are above average (Seashore's Measures) also score higher on the written test than students whose sensory discrimination ability are below average.

TABLE 2

MEANS AND STANDARD DEVIATIONS FOR THE WRITTEN TEST

(The Standard Deviation of each cell and for each of the totals is indicated by the number in the parenthesis. The number in the upper left corner indicates the number of subjects in that particular cell.)

	A_1 C_1	A_1 C_2	A_2 C_1	A_2 C_2	A_3 C_1	A_3 C_2	Totals
B_1	[7] 11.57 (3.64)	[7] 8.42 (3.55)	[7] 13.57 (2.54)	[7] 12.00 (2.44)	[7] 13.00 (3.21)	[7] 8.86 (4.29)	[42] 11.24 (3.72)
B_2	[7] 15.71 (3.03)	[7] 11.00 (3.46)	[7] 13.14 (4.22)	[7] 12.00 (2.64)	[7] 15.00 (4.50)	[7] 13.00 (4.93)	[42] 13.30 (3.99)
Totals	[28] 11.67 (4.18)		[28] 12.68 (3.01)		[28] 12.47 (4.66)		

	A_1	A_2	A_3	Totals
B_1	[14] 10.00 (3.68)	[14] 12.78 (2.54)	[14] 10.93 (4.28)	[42] 11.24 (3.72)
B_2	[14] 13.35 (4.01)	[14] 12.57 (3.43)	[14] 14.00 (4.65)	[42] 13.30 (3.99)
Totals	[28] 11.67 (4.18)	[28] 12.68 (3.01)	[28] 12.47 (4.66)	

TABLE 2 (Con't.)

	A_1	A_2	A_3	Totals
C_1	[14] 13.64 (3.87)	[14] 13.35 (3.36)	[14] 14.00 (3.96)	[42] 13.66 (3.65)
C_2	[14] 9.71 (3.62)	[14] 12.00 (2.44)	[14] 10.93 (4.93)	[42] 10.88 (3.83)
Totals	[28] 11.67 (4.18)	[28] 12.68 (3.01)	[28] 12.47 (4.66)	

	B_1	B_2	Totals
C_1	[21] 12.71 (3.17)	[21] 14.61 (3.92)	[42] 13.66 (3.65)
C_2	[21] 9.76 (3.71)	[21] 12.00 (3.70)	[42] 10.88 (3.83)
Totals	[42] 11.24 (3.72)	[42] 13.30 (3.99)	

A_1 - CASS
A_2 - General Music
A_3 - Instrumental Music
B_1 - 5th Grade
B_2 - 8th Grade
C_1 - High Music Aptitude
C_2 - Low Music Aptitude

TABLE 3

SUMMARY TABLE (ANOVA) WRITTEN TEST

Source	d.f.	S.S.	M.S.	F
Total	84	1314.71		
A (Treatment)	2	15.13	7.57	.57
B (Grade)	1	90.11	90.11	6.89 *
C (Musical Aptitude)	1	162.97	162.97	12.46 **
AB	2	55.14	27.57	2.10
AC	2	23.99	11.99	.91
BC	1	.58	.58	.04
ABC	2	12.50	6.25	.47
S/ABC	73	954.29	13.07	

* Significant beyond .01.
** Significant beyond .001.

Tables 4 and 5 present the means and standard deviations and summary table of the analysis of variance for the performance test scores. The highest possible score for this test was 158.

Table 5 indicates that the A and B factors and the AB interaction were statistically significant.

Before discussing the significant main effects, A and B, and the first order interaction, AB (see Figure 4), it may be useful for interpretation to examine the vocal means for the fifth and eighth grade students separately, since these means may have produced the significance levels. The mean score of 94.35 obtained by the fifth grade general music group was higher than either the CASS fifth graders (Mean = 54.42) or the instrumental fifth graders (Mean = 58.28). However, for the subjects in the eighth grade, the mean score for the general music group was 46.64, while the CASS group had a mean of 140.92 and the instrumentalists a mean of 130.07. This result for the eighth grade general music group may be due to several circumstances. Seven of the fourteen subjects in this group refused to perform vocally, although they had taken the written test willingly. The subjects who executed the performance showed great difficulty in singing from the given notation. In order to explain this performance difficulty, an examination of the emphasis placed on dif-

TABLE 4

MEANS AND STANDARD DEVIATIONS FOR THE PERFORMANCE TEST

(The standard deviation for each cell and for the totals is indicated by the number in the parenthesis. The number in the upper left corner indicates the number of subjects in that particular cell.)

	A_1		A_2		A_3		Totals
	C_1	C_2	C_1	C_2	C_1	C_2	
B_1	[7] 58.85 (35.20)	[7] 50.00 (43.22)	[7] 90.00 (31.46)	[7] 98.71 (23.94)	[7] 76.14 (72.19)	[7] 40.42 (23.44)	[42] 69.02 (47.93)
B_2	[7] 148.71 (11.10)	[7] 133.14 (23.08)	[7] 53.85 (62.56)	[7] 39.42 (35.81)	[7] 125.85 (21.70)	[7] 134.28 (13.69)	[42] 105.88 (54.41)
Totals	[28] 97.67 (53.86)		[28] 70.50 (48.18)		[28] 94.17 (58/69)		

	A_1	A_2	A_3	Totals
B_1	[14] 54.42 (38.14)	[14] 94.35 (27.74)	[14] 58.28 (63.29)	[42] 69.02 (47.93)
B_2	[14] 140.92 (20.46)	[14] 46.64 (53.42)	[14] 130.07 (19.33)	[42] 105.88 (54.41)
Totals	[28] 97.67 (53.86)	[28] 70.50 (48.18)	[28] 94.17 (58.69)	

TABLE 4 (Con't.)

	A_1	A_2	A_3	Totals
C_1	[14] 103.78 (53.02)	[14] 71.92 (54.00)	[14] 101.00 (57.65)	[42] 92.24 (55.52)
C_2	[14] 91.57 (54.86)	[14] 69.07 (43.60)	[14] 87.35 (61.07)	[42] 82.66 (53.27)
Totals	[28] 97.67 (53.86)	[28] 70.50 (48.18)	[28] 94.17 (58.69)	

	B_1	B_2	Totals
C_1	[21] 75.00 (48.50)	[21] 109.47 (57.38)	[42] 92.24 (55.52)
C_2	[21] 63.04 (47.26)	[21] 102.28 (52.68)	[42] 82.66 (53.27)
Totals	[42] 69.02 (47.93)	[42] 105.88 (54.41)	

A_1 - CASS Treatment
A_2 - General Music Classes
A_3 - Instrumental Music Classes
B_1 - 5th Grade
B_2 - 8th Grade
C_1 - High Music Aptitude
C_2 - Low Music Aptitude

ferent aspects of music studied in these eighth grade classes was undertaken. Singing was only one activity in these general music classes. Much time was devoted to learning about various aspects of music rather than using the voice to demonstrate knowledge and skill. Conversely, singing played a large role in the music program for the fifth grade classes. The students in the fifth grade seemed to be less inhibited in performing vocally. However, the actual reasons for deterioration in the vocal scores of the eighth graders, when compared to the fifth graders, cannot be assessed within the scope of this experiment.

The "A" effect was found to be significant at the .05 level in favor of the CASS and Instrumental treatments. In view of the difficulty inherent in explaining the decrease in the mean for the eighth grade general music group, this significant F-value may be misleading. It is assumed here that the experimental group 8th grade mean was affected by variables (e. g., motivation) not considered in this experiment. A conservative interpretation of these results would indicate that the CASS was at least as effective as six weeks <u>or more</u> instrumental study. While the instrumental and CASS classes were specifically oriented toward sight-reading skills, the general music classes did not necessarily have the same instructional objectives. On the other hand, while half of the instrumental subjects were beginners, many had been studying for more than two years and all had opportunities for outside practice. All the CASS subjects were beginners and yet they were able to bridge the time gap and achieve a comparable performance rating. This ability was due in part to the non-real time aspect of the CASS, and should not be considered as a disadvantage for the instrumentalists but rather as a unique quality inherent in the CASS.

The effect of grade level was shown to be highly significant ($p<.001$). This points out that, as a whole, the eighth graders performed these phrases better than the fifth graders. But, again, this significant F-value may be misleading for the same reasons given for the interpretation of the "A" main effect.

The C effect (Musical Aptitude) was not significant for the performance test. That is, when subjects were grouped according to musical aptitude there was not enough difference in performance skills to generalize the results. However, it may be of interest to note that this factor was highly significant ($p<.001$) for the written test. One explanation of the observed difference between the two dependent measures may be that the discrimination required for the performance tasks is not as strongly related to the Seashore <u>Measures</u> as the discrimination required for the written test.

The significant AB interaction ($p<.001$) indicates that the differences among the means of the treatments change as a function of grade level. Figure 4 shows this effect. This disordinal (crossed lines) interaction, which occurred through the vocal treatment, should be considered with respect to the earlier discussion about the eighth grade general mu-

TABLE 5

SUMMARY TABLE (ANOVA) PERFORMANCE TEST

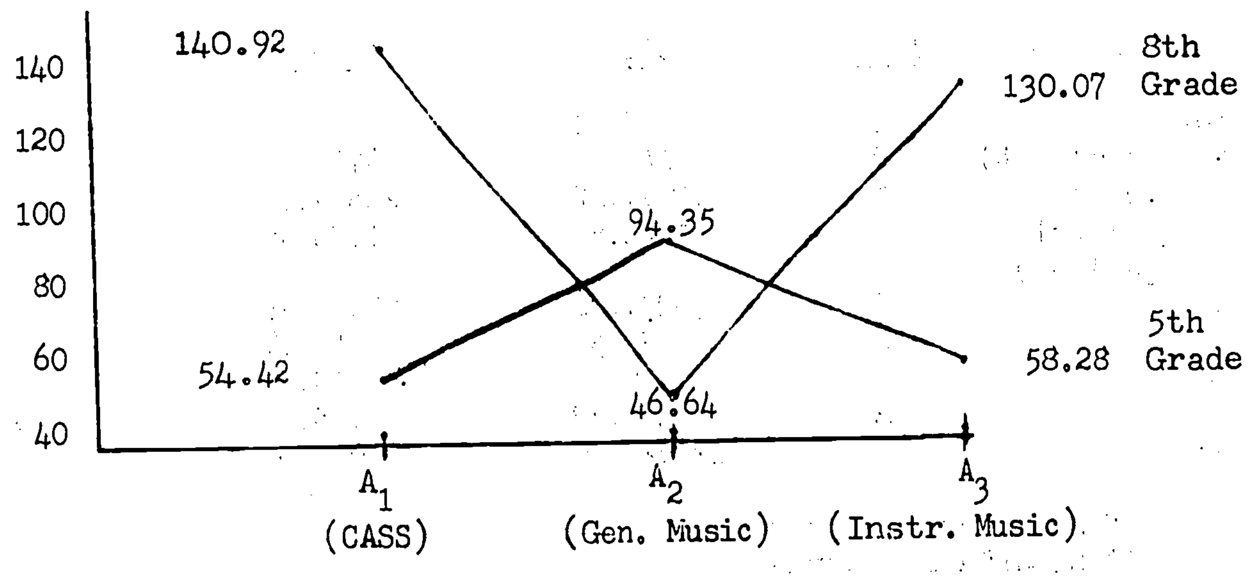
Source	d.f.	S.S.	M.S.	F
Total	84	244678.81		
A (Treatment)	2	12441.59	6120.80	3.68 *
B (Grade)	1	28527.42	28527.42	17.17 **
C (Musical Aptitude)	1	1923.85	1923.85	1.15
AB	2	75857.22	37978.61	22.87 **
AC	2	480.51	240.26	.14
BC	1	119.06	119.06	.07
ABC	2	4311.22	2155.61	1.29
S/ABC	73	121220.00	1660.54	

* Significant beyond .05.
** Significant beyond .001.

sic subjects. It is readily apparent from Figure 4 that the eighth grade level of performance is greater for both instrumentalists and the CASS. These two groups were significantly better than the general music group. This difference for the eighth grade instrumentalists is understandable considering their extended experience with their instruments (mean number of years studied = 2.3). The subjects in the CASS parallel this performance ability although their training lasted only six weeks. At the eighth grade level, all three treatment groups were able to complete the performance of the musical phrases, with the exception of the seven vocalists who simply refused to sing. These seven Ss received scores of zero. A conservative statement regarding the high mean performance score for the CASS eighth graders is that they are at least as good in demonstrating a performance skill from normal notation as eighth graders who have studied instruments for a longer average time period.

FIGURE 4

INTERACTION OF TREATMENT BY GRADE LEVEL



In the fifth grade group of instrumentalists, seven of the fourteen Ss were unable to play the selected musical phrases even though these phrases were chosen by the instrumental music instructors as representative of the expected performance ability for beginners. The vocal Ss in this grade level all performed the chosen phrases. The mean score of 94.35 for this group may be explained by viewing the musical activities in this grade level. They were requested to perform using their voices. They had been involved in this musical activity since kindergarten and were accustomed to singing. The fifth grade subjects in the other two groups (Instrumental and CASS) were performing using an instrument which was relatively new to them. This may account for the lower mean scores for the CASS and instrumental groups ($p < .01$). All except one of the fourteen CASS subjects (fifth grade) were unable to finish all three phrases because of the time allotment.

While the analysis of the three types of training examined in this experiment showed a statistical significance on the performance test, the conservative interpretation given (due to the unexpected low scores in the eighth grade general music group) is that the CASS treatment is at least as good as instrumental training for both fifth and eighth grades. From these data no conclusion should be drawn about the main effect relationship between the CASS and the general music classes.

While the data support the hypothesis that eighth graders score higher than fifth graders on the performance test, the grade by treatment (AB) interaction limits the conclusions that may be drawn. At the fifth grade level, the general music group scored higher than either of the other groups, while at the eighth grade level the general music group scored lower than either of the other groups, and, in fact, scored lower than any of the fifth grade groups.

Since motivation is an important aspect of performance the comparison between the instrumentalists and the CASS group, both consisting of subjects motivated to perform, provides a reasonable estimate of the effects of the experimental treatment. The mortality in the CASS group is thus taken into account. Because the experimental group could not demonstrate any performance skill on the CASS before the treatment was administered, no performance pre-test was given.

V. CONCLUSIONS AND RECOMMENDATIONS

The portable Computer Assisted Synthesizer System (CASS) developed as part of this project has been shown to be as effective in providing a musical performance capability as the study of conventional musical instruments. The null hypothesis, implicit in premise one, has been accepted. In view of the limited experience in devising training methods using the CASS, the results appear particularly encouraging. It is expected that further technical development of the System, and improved training methods will provide the means to test premises two and three.

It is recommended that future investigations deal with the following questions:

1) For what range of grade level and musical achievement is the CASS appropriate?

2) Can motivation account for the differences between the fifth and eighth grade vocal performance scores?

3) Can the CASS be used in the absence of prior exposure to musical notation for teaching and demonstrating musically acceptable performance skills?

Appendix A

The PDP - 9 System (Pilot Study)

Introduction

A computer-assisted instructional program has been written which enables an operator to generate, on a cathode ray tube, a visual image representing a line of music, and use it to control an on line tone generator. The program provides a method for the operator to "draw" a music line on the CRT using a photosensitive device, called a light-pen. The contours of this music line are detected by the computer, which simultaneously stores this data, and feeds it to a tone generator via a digital-to-analog-voltage converter (D/A). Three loudness settings are available, (loud, soft, and off) enabling the operator to play his composition with varied interpretation, including staccato. A playback mode is also provided, so that the operator may play back his composition at any time.

The equipment used for this segment of the project is part of the research facility located in the Digital Systems Laboratory of the Department of Electrical Engineering at the University of Connecticut, Storrs, Connecticut. This facility includes a Digital Equipment Corporation PDP-9 stored program digital computer with 8192, 18 bit, core memory words, along with a type 339 buffered display. In addition, a tone synthesizer was constructed using several modules generic to the Moog Synthesizer. These modules included a voltage controlled amplifier, and a voltage controlled oscillator, connected to an amplifier and speaker.

The light pen is a photoelectric detector sensitive to the presence of light. When it is placed near a specific location on the CRT screen, it triggers a pulsed output signal whenever that location is reenergized by the electron beam. A subroutine uses the coincidence of the light pen pulse and electron beam position of the light pen as core data.

One method of "drawing" images on a CRT screen provides a "tracking-square" for the light-pen to detect. A tracking-square is essentially a series of illuminated dots which form a figure shaped like box or, alternatively, the four points of a compass. The figure below shows two forms of tracking-squares. Note that each dot is illuminated in sequence, not simultaneously.

```
* * * *               *
*     *            *     *
*     *
* * * *               *
```

Tracking-Squares

When the light-pen is held over an illuminated dot, the pulse output signal from the light-pen can be used to determine the dot that caused the pulse. Under program control, the relative position of the figure can be moved in the direction of the dot which is sensed by the light-pen.

This is the method used to "draw" lines of music on the CRT.

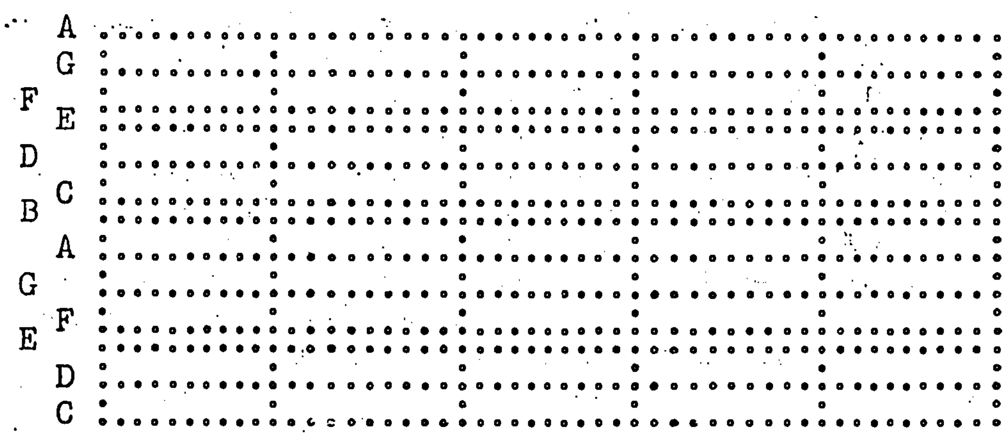
A subroutine was written so that the "movement" of the tracking-square in the X/Y plane could be displayed on the face of the CRT screen. This is accomplished by detecting and illuminating the relative position of the tracking-square whenever a pulse is received from the light-pen. In order to conserve memory space and subroutine timing, the horizontal resolution of the CRT screen was reduced from 2000 points to 200 segments of 10 points each along the X axis. Whenever the tracking-square is moved into a new segment, the subroutine was programmed to display a short vector from the terminus of the previous vector position to the entry position of the new segment.

Another subroutine was programmed to store the transitions of the tracking-square along the Y axis. The available vertical resolution was 256 points (8 bits). These transitions are stored in core, starting at memory location 2001. Each new data position is concatonated to this list. Thus, since the CRT screen has a total of 2000 points along the X axis, and new data is received every 10 points, a frame (one complete CRT scan) of data has 200 eight bit entries. With the present memory size of the PDP-9 computer, the program will store 56 frames of data.

The subroutine which provides playback was programmed to be used in conjunction with the storied data. In this subroutine, a counter is set with the number of data positions recorded, starting at memory location 2001. Then each data word is fed into a D/A converter for a predetermined time (using the time delay subroutine) so that the operator may hear his composition up to the current data entry. When the operator has heard enough, he may wipe out the previous data and start again, or continue to draw additional music lines on the CRT.

The time delay subroutine is simple counter which reads the status of the switches on the control panel of the PDP-9, converts this status to a digital word, complements and then increments this word until it equals zero. Since the memory cycle time of the computer is one micro-second (10^{-6} sec) and there are up to 2^{18} possible increments, a wide range of playback speeds is available (200 microseconds to 52 seconds per frame).

To align the relative Y axis positions with corresponding tones on the synthesizer, a raster display was programmed. This display gives the operator the relative positions of the notes of the C-major scale on the CRT screen. The figure on the next page illustrates the display.



C-Major Scale, as displayed on the CRT

The vertical lines were added to aid the operator in timing his composition, and have no other significance in the program. Since the vertical resolution is 256 points and 21 semitones are displayed, the pitch resolution available from the system is 8.2 cents (approximately one-twelfth semitone). Within this restriction, the operator can produce tones anywhere between the whole-tones and semitones displayed, producing, for example, vibrato or portamento effects.

A final subroutine allows the operator to choose one of three loudness levels (including off) via a switch on the display panel. The main program checks the status of the switch setting once in each subroutine cycle, to determine which loudness level is desired. This information determines the input voltage to the voltage-controlled amplifier of the tone synthesizer using a channel of the D/A converter. In addition, this loudness control data is packed into the Y-position data word, so that in the playback mode the desired loudness for a given note may be reproduced. Furthermore, when there is no sound desired, the music line on the CRT is blanked, so that the operator perceives a break in the visual continuity.

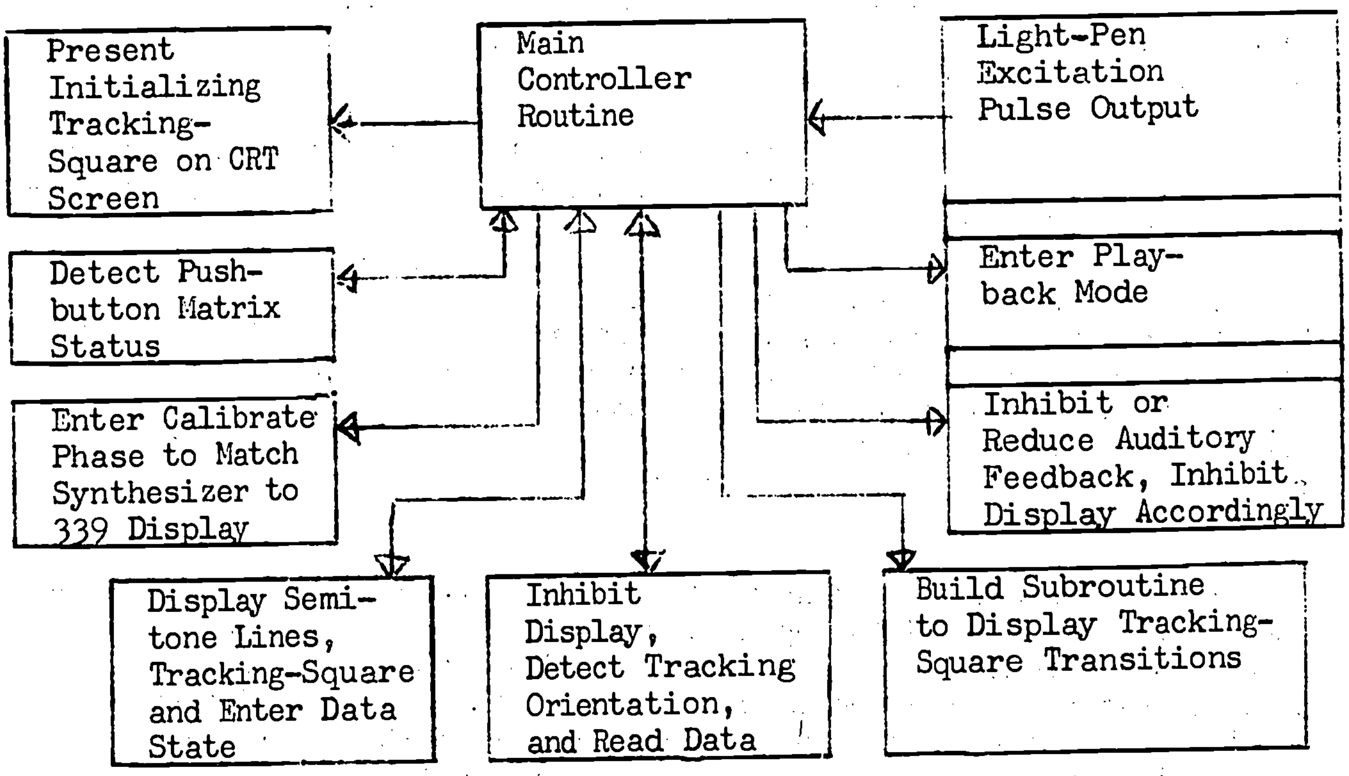
The programming philosophy of this effort has been essentially modular, as indicated in the block diagram on the following page.

Summary

A computer-assisted instructional program has been written which allows the operator to "draw" (with a light-pen) music lines on the face of a CRT screen, and simultaneously, to hear a tone. The pitch of the tone corresponds to the vertical position of the last indicated point of the music line. Major subroutines allow the operator to calibrate the system to the on-line tone synthesizer, detect and record data from the movement of a light-pen across the CRT screen, and play back the data which has been recorded. The temporal tone sequence corresponds to the left to right sequence of the graphical representation "drawn" by the operator.

Although the program works quite well, and probably represents one of the few attempts of this type, it lacks a suitable editing capability. An operator may err in his "drawing" of a given music line and may wish to change portions of it without starting over. At present he may only clear

those locations in core memory used to store his data, and start over again. An editing function would increase the usefulness of this program.



Program Block Diagram

Appendix B

The Computer Assisted Synthesizer System (CASS)

CASS was designed to read a graphical input and to convert it to a corresponding auditory output. The system accepts hand-drawn charts representing pitch contours, and converts them to sound by providing a voltage input to a voltage controlled synthesizer.

The system consists of three parts: (1) an optical scanner or "chart reader." (2) a "sample and hold" electronic interface unit. (3) a voltage controlled tone synthesizer.

1. The optical scanner is a modified document transmitter built by Graphic Transmission Systems, Inc., Hanover, New Jersey. This device provides a constant speed paper feed of one inch per second for paper up to $8\frac{1}{2}$ inches in width. An optical-mechanical scanner reads across the paper, transverse to the direction of motion. Sixty scans are made each second, and a two-level signal indicates the presence or absence of a line on the paper.

2. The "sample and hold" unit, designed by Earnest Guignon, converts the two level output of the optical scanner to a signal voltage proportional to the relative position of a line drawn on the paper chart. A voltage "ramp" is generated in synchronism with each optical scan, and is sampled when a line-indicating pulse appears from the optical scanner. The sampled voltage is held until the next pulse arrives from the scanner.

A very fast sample and hold unit is required because of the pitch tolerances demanded for musically acceptable reproduction of the intended music line. The pitch scale presently used on the input graph is $\frac{1}{4}$ inch per semitone. Since 8.5 inches is scanned in 0.0167 second (. 1/60 sec), a semitone is scanned in approximately 100 microseconds. If acceptable pitch tolerance limits are set at $\pm$ 4 cents ($\pm$ 1/25 semitone), sample and hold tolerances must be smaller than $\pm$ 4 microseconds. A Philbric-Nexus sample and hold module provides the necessary speed and accuracy.

3. The synthesizer used with this system consisted of modules purchased from R. A. Moog Inc., Trumansberg, New York. However, any voltage controlled oscillator, for which the output pitch is linear with changes in input voltage, could be used.

Appendix C

Outline of Lesson Plans For CASS

WEEK ONE

Lesson One:

1. A short description of the CASS was given, indicating the three component parts to the system: the optical scanner, the Mini-Moog Synthesizer and the amplification system. It was explained that the scanner "read" the markings on a sheet of paper, transformed them into voltage units which were then read as frequencies and amplified through the speakers as the perceived pitches. Any markings put on a sheet of paper were changed into musical sound.

2. Each subject was asked to write or print his name on a sheet of paper given him.

3. A demonstration name was played by the experimenter.

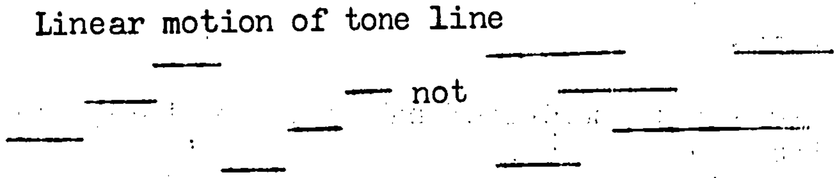
4. Names of each individual were played.

5. Each subject was given paper to "draw" notes. They could place their linear notes any place on the scanner staff.

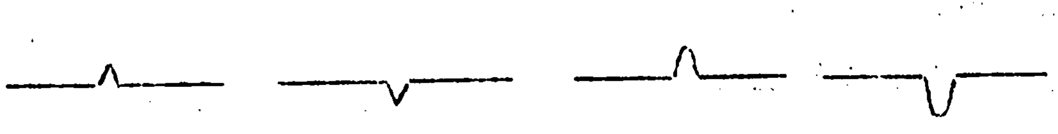
Lesson Two:

1. New Material:

a. Explanation of whole and half notes. Length of each note was demonstrated by CASS.
b. Linear motion of tone line



c. Technique used in graphic notation for repeated notes. Some break or interruption must occur in the tone line or the sound will be continuous.



2. Composition

a. Mystery melody (Subjects do not know what the composition is) Formula was given as follows for a version of Twinkle, twinkle little star;
1. Starting on the seventh line from the bottom, draw a half note
2. Repeat this note (half note)
3. Four lines up - draw another half note
4. Repeat this note (half note also)
5. Three lines up again - draw a half note
6. Repeat this half note
7. Three lines down - draw a half note
8. One line up - half note
9. Repeat this last note

WEEK TWO

Lesson Three:

1. Review material

a. Whole and half notes
b. Linear motion of tone line
c. Technique employed for repeated notes

2. New material

a. Explanation of half and whole steps. Paper used in class is divided into half steps. A series of whole and half steps were demonstrated using the CASS.
b. Organization of the major scale - eight notes arranged in whole and half steps.

3. Compositions

a. Subjects wrote series of half and whole steps in their own rhythms.
b. Subjects wrote a scale starting on any line.
c. Mystery melody of London Bridge. Instructions to subjects were arranged in whole and half step combinations.

Lesson Four:

1. Review material

a. Whole and half steps. Drew comparisons between graphic and traditional notation both of which were illustrated on the blackboard.
b. Linear motion of tone line. Several examples of incorrect use were illustrated on the blackboard.

2. New material

a. Explanation of treble staff. Comparisons were made between both types of notation systems (traditional and graphic).

3. Compositions

a. Completed mystery melody from Lesson II.
b. Wrote original compositions utilizing lines to represent notes or designs.

WEEK THREE

Lesson Five: (after a school vacation of 10 days)

1. Review material

a. Linear motion of tone line
b. Repeated notes in graphic notation
c. Whole and half steps
d. Whole and half notes
e. Formula for the major scale

2. New material

a. 4/4 time signature
b. Explanation of quarter and eighth notes. Relationships were drawn among whole, half, quarter and eighth notes.

3. Compositions

a. Given a line representing the time value of a quarter note, subjects were asked to compose four measures using the four different types of notes covered that day (whole, half, quarter and eighth notes).
b. Mystery melody (This Land is Your Land).

Lesson Six:

1. Review material

a. 4/4 time signature
b. Quarter and eighth notes

2. New material

a. Pitch names for the lines and spaces of traditional treble staff.
b. Explanation of a key signature. Key of F.
c. Technique in drawing tied notes in graphic notation. Length of the "drawn" note represents the total value of the tied notes.

3. Compositions

a. Subjects drew examples of tied notes.
b. Mystery melody illustrated eighth notes, half notes and tied quarter notes in the Key of F major.
c. Original compositions written by the subjects.

WEEK FOUR

Lesson Seven:

1. Review material

a. Key signature - F major
b. Tied notes

2. New material

a. Time signature 3/4
b. Explanation of the dotted half note
c. Explanation of the #
d. Key signature of G major

3. Compositions

a. Sound of Music read from traditional notation illustrating G major, tied notes, quarter and eighth notes.
b. O How Lovely is the Evening illustrating 3/4 time signature and the dotted half (read from traditional notation)

Lesson Eight:

1. Review material

a. Time signature 3/4
b. Dotted half note
c. Explanation of #
d. Key of G major

2. New material

a. Explanation of legato in traditional notation and adaptation for use with the CASS.
b. Explanation of natural sign (♮).

3. Compositions

a. Returned performances of Sound of Music. Subjects were requested to connect certain parts in a legato manner according to their individual preferences.
b. Original compositions by subjects.

WEEK FIVE

Lesson Nine:

1. Review material

   a. Time signatures 4/4 and 3/4
   b. Keys of C, F and G major
   c. Techniques necessary in CASS notation - repeated and tied notes, legato markings.

2. New material

   a. An explanation of how to compute the correct time value for any dotted note.
   b. Demonstrations of the sixteenth note with the CASS. The blackboard was used to illustrate the sixteenth note in traditional and graphic notation.

3. Compositions

   a. Love is Blue. This composition involved skills of drawing half, quarter, eighth, dotted quarter and dotted eighth notes as well as legato phrasing.

Lesson Ten:

1. Review material

   a. Dotted notes
   b. Sixteenth notes

2. New material

   a. The trill

3. Compositions

   a. Subjects were requested to write original composition using a trill somewhere in their composition.
   b. The Impossible Dream from traditional notation.

WEEK SIX

Lesson Eleven:

This session consisted of a general review of all skills covered during the previous ten lessons. Each student wrote short examples to illustrate the material presented in these lessons.

Lesson Twelve:

This session consisted of individual help. Some subjects wished to write music from traditional notation, others wished to create new compositions while others asked questions about traditional or graphic notation.

Appendix D

Musical Performance Test

1.

2.

3.

WRITTEN TEST

RHYTHMIC ELEMENTS

WRITTEN TEST

MELODIC SECTION

KEY A B C D

11. B
12. D
13. C
14. A
15 C
16. A
17. D
18. A
19. B
20. C

Appendix F

RAW SCORES FOR THE WRITTEN AND PERFORMANCE TESTS

A_1 (Experimental treatment)
CASS

B_1 (Fifth Grade)		B_2 (Eighth Grade)	
C_1 (High Musical Aptitude)	C_2 (Low Musical Aptitude)	C_1 (High Musical Aptitude)	C_2 (Low Musical Aptitude)
1. 9 - 61	8. 8 - 42	15. 20 - 157	22. 13 - 156
2. 16 - 48	9. 10 - 0	16. 19 - 150	23. 12 - 127
3. 14 - 43	10. 13 - 114	17. 16 - 153	24. 7 - 130
4. 11 - 93	11. 8 - 95	18. 15 - 155	25. 6 - 146
5. 13 - 46	12. 4 - 0	19. 15 - 152	26. 12 - 83
6. 5 - 7	13. 4 - 46	20. 14 - 152	27. 16 - 155
7. 13 - 114	14. 12 - 53	21. 11 - 122	28. 11 - 135
Written Test - Performance Test	Written Test - Performance Test	Written Test - Performance Test	Written Test - Performance Test

Total score possible on written test = 20

Total score possible on performance test = 158

Appendix F
(continued)

A_2 (General music)

B_1 (Fifth Grade)		B_2 (Eighth Grade)	
C_1 (High Musical Aptitude)	C_2 (Low Musical Aptitude)	C_1 (High Musical Aptitude)	C_2 (Low musical Aptitude)
29. 17 - 120	26. 17 - 115	43. 19 - 0	50. 16 - 0
30. 16 - 82	37. 12 - 138	44. 16 - 134	51. 10 - 66
31. 13 - 118	38. 13 - 106	45. 14 - 111	52. 9 - 0
32. 15 - 32	39. 11 - 75	46. 6 - 0	53. 14 - 0
33. 10 - 76	40. 10 - 76	47. 11 - 0	54. 14 - 61
34. 13 - 87	41. 11 - 77	48. 15 - 0	55. 11 - 56
35. 11 - 115	42. 10 - 104	49. 11 - 132	56. 10 - 93
Written Test - Performance Test	Written Test - Performance Test	Written Test - Performance Test	Written Test - Performance Test

Appendix F
(continued)

A_3 (Instrumental music)

B_1 (Fifth Grade)		B_2 (Eighth Grade)	
C_1 (High Musical Aptitude)	C_2 (Low Musical Aptitude)	C_1 (High Musical Aptitude)	C_2 (Low Musical Aptitude)
57. 13 - 126	64. 9 - 0	71. 19 - 125	78. 12 - 124
58. 14 - 0	65. 6 - 69	72. 9 - 89	79. 8 - 139
59. 19 - 155	66. 12 - 0	73. 16 - 151	80. 12 - 107
60. 14 - 116	67. 2 - 0	74. 19 - 129	81. 18 - 151
61. 11 - 0	68. 11 - 115	75. 19 - 145	82. 19 - 145
62. 12 - 136	69. 15 - 0	76. 9 - 142	83. 16 - 133
63. 8 - 0	70. 7 - 99	77. 14 - 100	84. 6 - 141
Written Test - Performance Test	Written Test - Performance Test	Written Test - Performance Test	Written Test - Performance Test