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RESEARCH APPLICATIONS IN MUSIC CAI

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INTRODUCTION

Computer-assisted instruction (CAI) in music involves a variety of research applications. Development of a viable system requires extensive research in theory pedagogy, computer hardware and software, and listening skills. Any CAI system must undergo extensive research and testing to reach maximum effectiveness for student users.[1] Once the system is in use, continuing research is necessary to measure its educational value to students and to determine areas where the system needs to be improved or expanded. A CAI system provides the means through which much additional research, such as investigations of auditory pattern perception and development of new pedagogical techniques, can be accomplished. In short, ongoing research is essential in many content areas and from multiple viewpoints to produce effective CAI.

Before implementing a CAI system, the limits of content to be presented as well as the appropriate pedagogical stance must be determined, and a detailed outline of curriculum must be planned. A complete curriculum outline requires considerable research, but is essential if student answer formats are to be clear, discrete, and non-contradictory. These factors will also play a crucial role in the necessary research

into appropriate hardware and software. A profile of the potential student population should be prepared, so that formats for student interaction may be planned. To illustrate: complex responses on an alphanumeric keyboard should not be planned if a large proportion of the student body does not know to type!

RESEARCH IN MODELING THE STUDENT

Modeling an image of the student user is probably the most important preliminary research activity.[2] Design of curriculum, choice of hardware and software, and study of student data are all dependent on the establishment of accurate delineation of students for whom the CAI system is intended. Modeling the student image continues throughout the development and use of any CAI system.

The effectiveness of any instructional strategy is dependent on development of a clear and accurate model of the learner. For music CAI this model should include physiological as well as psychological attributes. Unfortunately, a number of music educators have tended to rely upon intuitive notions concerning the nature of these attributes; however, some areas of student image have been researched, forming the basis for good quality music CAI.

Music CAI facilities provide laboratories for the investigation of the music student's learning processes. The use of CAI for research activities includes the following advantages:

1. Computer use requires a clear specification of the question (programming allows little tolerance for thinking processes which are poorly defined).

2. A stimulus is precisely and infinitely repeatable, insuring the protection of results from an experimenter's bias or fatigue.
3. Results may be efficiently collected, retrieved, and tabulated.

A functional model of the music student should include specifics of hearing, learning, and environment. Research by audiologists has established the structure and function of the auditory system and neural network to and from the brain. The music educator needs to know the effects of values of frequency, duration, amplitude, and timbre upon accuracy in perception and identification. Will certain values for these parameters aid the learner's development? Where are errors in perception likely to occur? Are any of these errors physiologically based? Music researchers need to explore all of these questions.

Psychological questions in need of exploration are numerous; a few important ones are listed here. The first questions relate closely to those above, concerning theories of perception. The highly specific nature of music notation (a shorthand for discrete pitch, duration, and temporal information) provides a tool for further investigation. Collaborations between musicians and psychologists can help verify and enlarge existing theories.

Concepts of memory, attention, and motivation are other relevant areas of pursuit.[3] Musicians understand and distinguish between hearing and listening. The latter implies a focus of attention, and the exercise of cognitive powers. Can listening skills be taught and improved upon? The intuitive answer is yes, and yet the psychological mechanism of attention is only crudely understood. Clearly, further evolution of music CAI requires study in this area.

Additional areas of research have been suggested regarding peripheral factors such as time of day, or barometric pressure. If a morning class is used as the experimental group, and an afternoon class as the control group, will the results be valid and replicable at any time of day? These questions cannot be ignored.

Environmental factors constitute a final area to be considered in modeling the learner. These factors include the sum of all the sociological, educational, and cultural situations which make a student population unique. CAI strategies for an urban university will differ from those for a rural community college. Each individual student population may be described by an equation which includes such factors as socio-economic status, previous education, level of motivation, and attitude.[4]

Currently, research is being done to model the student's creative processes. Paul E. Dworak, under a grant from the National Institute of Education, is developing a microcomputer-based CAI system employing a dynamic memory model of creativity.[5] This system will aid the student in composing melodies by reflecting decisions of the student in the selection of his melodic materials. This example of direct computer application to modeling the student image is a concept expandable to all levels of research.

RESEARCH IN CURRICULUM DESIGN

Research plays an integral role in the design and subsequent evaluation of curriculum for music CAI.

In preparation for aural courseware development, review of current literature concerning auditory perception, learning psychology and music theory is important. Consideration of fundamental pedagogical philosophy is inherent in curriculum development, and is easy to overlook. However, one of the preliminary goals of curriculum design should be an examination of alternative teaching strategies. Although a number of valid theoretical approaches may present themselves, the adoption of a central point of view will be helpful, for the sake of consistency within a set of lessons. Questions such as the following should be considered:

1. Is the overriding philosophy that of Schenker? Hindemith? Comprehensive Musicianship? "Traditional" theorists?
2. Is the approach melodic or harmonic?
3. Will scale step numbers or solfege be used?
   a. Moveable or fixed DO?
4. What is the role of keyboard in theory instruction?
5. Should the sound source vary in timbre for dictation?
6. In melodic dictation, are pitch and rhythm equally important?
   b. Which one should the student write first?
7. In harmonic dictation:
   a. Are all four voices equally important or are outer voices more important?
   b. How important is Roman numeral identification, as opposed to harmonic function (tonic-dominant-subdominant)?
8. Is the emphasis on student speed or accuracy?
9. What are acceptable competency levels?

Ultimately, the form and substance of each lesson will reflect the nature of the developer's answers to these and other questions. After these choices are made, the content of each semester should be outlined in detail.

During the early planning stages, the role of CAI within the learning environment must be considered. Do not assume that the computer is a replacement for classroom instruction, nor that it is merely another dispensable option. CAI encompasses a variety of teaching and learning strategies, including competitive manipulation (gaming), simulation of the learning environment, presentation of new material in a tutorial format, and drill and practice of concepts already presented in the classroom.

When the role of the computer has been defined, lessons may be tailored to meet the needs of the music program for which CAI is being designed. Much of lesson format is determined by functional considerations. A lesson which substitutes for classroom experience (e.g., to "make up" a class absence) required a more lengthy tutorial than one which serves to supplement or reinforce. Be sure that answer formats reinforce valid relationships. Consider carefully how many elements are to be tested at a time and how students are to enter them into the machine. Text should be consistent in style and should include a clear explanation of answer format, lesson purpose, sample questions and answers, and appropriate response cues. Avoid succumbing to the temptation to be cute or clever. This approach rarely holds up under long-term use.

The effectiveness of curriculum is dependent upon careful study before lessons are designed and after they are in use. CAI is an ongoing

process in which planning, design, testing, use, reevaluation and rewriting must take place. Research is the tool which illuminates this process and is the means by which the most efficient learning occurs.[6]

RESEARCH IN HARDWARE AND SOFTWARE

If the designer of a CAI system has a firm idea of what the system ought to do, he or she may theoretically implement it on almost any commercially-available computer system. Realistically, not any computer can be used for CAI. Very large machines may be overcommitted in large university settings, and may not be able to allocate enough processor time to drive the sound-generating hardware which is needed for ear training. On the other hand, very small, dedicated processors may have insufficient memory and disk storage for storing lessons, running lessons, and compiling statistics.

In the selection of hardware for CAI, much research must be devoted to how or why the particular configuration works. Most hardware configurations are not designed by musicians, and only fit a small set of specifications. Because CAI systems must support research in teaching and learning, the total system must allow for expansion and upgrading.

Hardware for an ear training CAI system must have two components: a processor, with its operating system, software, and disk storage; and sound-generation hardware. The processor must meet the following specifications:

1. It must allow interactive computing. Therefore, large computers that run jobs from punched cards in batch mode are useless for CAI.

2. It must have adequate storage for lesson files and statistics files. If only twenty students use the system, a microprocessor may prove adequate. However, if several hundred students use the computer, a large minicomputer with at least ten megabytes of disk storage is essential.
3. It must allow real-time control of digital hardware that generates sound. Of course, the choice of digital hardware influences the choice of processor. If the sound generation is largely controlled by software, the lessons must be run on a dedicated, single-user microprocessor of minicomputer in order to preserve the real-time nature of the sound. On the other hand, if the processor needs only to load the score periodically, several sets of hardware can be driven by a single processor.

The choice of sound-generating hardware requires extensive research. Very little machine-independent hardware is available. Machine-dependent hardware cannot be implemented on an incompatible machine by a musician without a hardware background. The greatest disaster that can befall a CAI developer is that which comes from scrounging around for any available components, without a thorough understanding of how they will interface with one another.

The problem is compounded when a particular computer is already in place at the institution and none of the available hardware is compatible with it. When this problem arises, some institutions choose to design their own hardware. This may be disastrous if the musician has not learned to specify his hardware needs in the succinct language of the engineer and designer. Musicians tend to think in generalities and

engineers, in details; good engineers prefer to have little or nothing left to their imagination about what the hardware should do. They prefer to devote their creativity to elegant realizations of specified design.

Research is necessary into all available sound-generating hardware and the computers with which it will run. Three sources are particularly helpful for preliminary research:

1. technical journals;
2. computer dealers can specify what hardware is compatible with their machines; (and be careful! hardware supplied without complete software support is totally useless!)
3. sales seminars sponsored by electronic and computer retailers and minicourses which deal with applications of microprocessors. Much free literature can be obtained from retailers. Reading this literature allows the musician to become competent in asking the right questions of salespersons and of other educators who have used particular hardware configurations.

Of course, the CAI developer must be concerned about the quality of sound generated by the hardware. Many grotesque schemes for pulling square waves off the computer bus exist; these sounds are particularly dreadful when each pitch has a square wave with a different duty cycle and thus a different timbre. Instruments which allow the summation of harmonics of a complex tone and the shaping of a note with envelope control are more desirable and more expensive. One must remember that the sound generator is a musical instrument, to which serious investigation of quality must be given. In other words, would theory teachers be willing to substitute a quartet of kazoos for a piano in playing examples of

four-part harmony in class? Details of an additive synthesis system and the effects of variable envelopes are reported in the literature.[7,8]

Once research has determined the appropriate hardware and software configuration to support curriculum designed for a specified student population, careful consideration needs to be given to data saving and analysis.

RESEARCH IN DATA SAVING AND ANALYSIS

The nature of CAI allows for extensive accumulation of data. Statistics can be saved which will generate research in areas such as auditory perception, memory, learning psychology, and the creative process. Information saved will make an essential contribution to the reevaluation of a system's effectiveness. Changes indicated by these data may involve lessons to be inserted, question or answer format, speed and/or timbre of musical examples, number of repetitions allowed, effectiveness of individual lessons or groups of lessons, revision of instructions, etc. At the inception of a CAI system, an orderly approach to gathering and evaluating statistics should be devised.[9]

One of the most important tasks in music CAI research applications is the gathering of data. The results of a statistical analysis of these data can show the strengths and weaknesses of current curricula and their presentation. These results determine how the curricula will be modified for future use. The statistics on student use of the NTSU ear training CAI Lab indicate peak Lab use and help in planning Lab and monitor schedules.

At North Texas State University, the ear training CAI system is implemented on a Hewlett-Packard 2000 Timeshared computer.[10] Approximately

400 music students enrolled on the system in the spring semester of 1980. They registered during the first week of classes by entering their names, student identification number, ear training class and section, sex, and primary instrument on the CRT terminals. This information was saved in an Index file for future reference and data processing.

The system software updates a Statistics file with each individual lesson use, storing such information as student identification number, lesson name, date, beginning and ending time of lesson use, total number of questions asked, number of correct answers on first trial, number of correct answers by final trial, and number of replays of musical examples requested by students. Another file, containing individual student responses, is kept. As can well be imagined, much space is consumed storing these files. Even more computer space is required to conduct statistical analyses of the data. Due to the space requirements, these data files are moved annually from the Hewlett-Packard to NTSU's National Advanced System 5000 computer, which has a four megabyte capacity. Through software packages such as SPSS (Statistical Package for the Social Sciences) and SAS (Statistical Analysis System) statistical research is carried out.

Statistics indicate that out of nearly 5,000 lesson uses during the spring semester of 1980, mid-morning and mid-afternoon hours were preferred, with 33% of all lessons taken during the 10-11 a.m. and 3-4 p.m. hours. These data assist in lab management and planning.

Statistical analysis also indicates that, except for the anticipated increase of student usage prior to final exams, a fairly constant access of the lessons occurred throughout the semester, with mean use of 337 lessons per week. Research investigating student competence vs. time

of day, sex, primary instrument, and other significant factors is in process; results should prove to be enlightening for further development of CAI in music.

SUMMARY AND CONCLUSIONS

To conclude: research is an integral part of effective music CAI. Extensive research must be conducted prior to and during system development. The research areas of modeling the students' musical processes, instructional design, system configuration, and data saving and analysis are all basic to CAI. Once a system is operational, continued research is needed to evaluate the system's effectiveness and to plan future modification and expansion. Finally, music CAI supports a variety of research applications to inquiries which have long engaged musicians.

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