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ABSTRACT

This paper forms part of a preliminary survey for work on the application of artificial intelligence theories and techniques to the learning of music composition skills. The paper deals with present day applications of computers to the teaching of music and speculations about how artificial intelligence might be used to foster music composition in the future. The field of music composition makes use of computer aided instruction in the areas of music theory, music history, and aural testing. Music Logo, the use of the programming language, Logo, to create music, is another application of computer technology to music. Computerized musical instruments allow students to compose and play music at their own level; to listen and adapt these compositions; and to analyze existing music for pitch, note intervals and values, and pattern recognition. Interactive videogames provide untrained students with opportunities to compose music and hear it immediately and to teach musical transformations through simple visual manipulation of music. In the future, artificial intelligence may make modest contributions to support the learning of music composition in the areas of intelligent tutors that focus on music theory, aural training, harmonization, and some highly formalized and artificial styles of composition. Intelligent tools in the form of editors, instruments, and analytical aids along with educational games also could help students learn about music composition. The document contains 16 figures. (DB)

How computers are used in the teaching of music and speculations about how artificial intelligence could be applied to radically improve the learning of composition skills.

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1 INTRODUCTION

This paper forms part of a preliminary survey for work on the application of artificial intelligence theories and techniques to support the learning of composition skills. The paper falls naturally into two halves; present day applications of computers to the teaching of music, and speculations about how artificial Intelligence might be used to foster music composition in the future.

2 HOW COMPUTERS ARE USED IN THE TEACHING OF MUSIC

2.0 Preliminaries

2.0.1 Notes on Scope of Discussion

This discussion is not comprehensive. The factual, as opposed to speculative part concentrates mainly on American work reported in journals. It should be bourne in mind that the philosphy of music education prevalent in the United States (this appears to be "back to basics") differs from the philosophy being encouraged in Great Britain (apparently "listen,compose, perform"). No up-to-date survey of commercially available systems is attempted. Given the continuing explosion of new applications of computers to music, this would be a separate and considerable undertaking, one already carried out by the Music Education Centre Micro Technology Unit at Reading University in their "Information Updates".

The first section attempts to pick representative examples of four contrasting approaches. The four approaches are computer assisted programmed learning, music Logo, simple music analysis and interactive graphical games. In practice, applications often display characteristics of all four divisions ; the categories shouldbe not taken too seriously. Straightforward **music editors and computer musical instruments are omitted** because of time limitations.

2.1" Traditional "Computer Based Instruction

2.1.1What is "Traditional" Computer Aided Instruction (CAI)

"Traditional" CAI is here taken to refer to computerised page turning of programmed texts, and computerised multiple choice tests. By "page turning" we mean any system that presents canned text, asks a question, and then on the basis of the answer , and perhaps previous answers, selects a new piece of text to present.

2.1.2 Scope of discussion of traditional CAI in Music

Traditional CAI is used in Music in the following areas; Music Theory, Music History and Aural testing.(This list is drawn in compressed form from Folz and Gross (1980))
Exclusively *text* shuffling CAI systems whose subject matter happens to be music are not discussed here, because there is nothing secifically musical about such systems, and their limitations are well known . (More on these limitations later) This leaves us with aural training and testing, and indeed, published work in journals on CAI seems to centre mainly on aural training. Hofstetter's GUIDO system at the University of Delaware (Hofstetter 1975 and 1981), is a pioneering and paradigmatic example of computer aided instruction in ear training.

2.1 3 GUIDO:- Ear training by computer administered dictation

The GUIDO system (named after the 11th Century music educator Guido d'Arezzo) has a twin purpose; the provision of computer based ear training, and the collection of data for research into the acquisition of aural skills. GUIDO can oversee dictation in five areas; intervals, melody, chords, harmony and rhythym. GUIDO plays musical examples by means of four voice synthesizer, and the student is invited to select from a multiple-choice touch-sensitive display what he thinks he has heard. (Please understand "she" as well as "he" throughout). Example displays from each of the five dictation areas are reproduced in Figs 1 - 4. We will look at each of the drills in a little detail. (The following descriptions of the various drills draw closely on Hofstetter (1981)). For the interval drill (fig. 1), GUIDO plays an interval, and the student touches a box on the screen to indicate what interval was heard. The three columns of boxes in the middle of the screen can be used by the teacher or student to control how the dictation is given. The teacher has the option of "locking" the control boxes or allowing the student to control them. The legends are mostly self explanatory, and all details do not need to be grasped for our purposes, but two non-obvious points are worth mentioning. Firstly, the box marked "intervals" can be used to eliminate from the dication any selected intervals; secondly, the attractive looking keyboard display at the bottom of the screen is used in this program only when fixing the lower or upper note of intervals.

In the melody program (fig 2), GUIDO plays a tune and the student tries to reproduce it by touching the note "boxes". Options are available for the student to input using boxes marked with solfa syllables, or the keyboard shown in fig 1. The students' input is sounded and displayed simultaneously as staff notation. The chord quality program asks the student to indicate the quality and inversion of chords sounded (fig 3). In the harmony program, the student listens to a four part exercise in chorale style, and then indicates what he has heard by touching boxes for Roman numerals and soprano and bass notes. GUIDO displays the replies in staff notation. As in most of the programs, the student can ask to hear the example played again, can control the tempo, and can alter the relative loudness of the different voices. Finally, in the rhythym dictation program (fig. 5), GUIDO plays a rhythm, and the student touches boxes to indicate what was heard. GUIDO displays the reply as it is input.

2.1.4 Discovery learning mode

Although this goes beyond the traditional CAI approach, it should be mentioned that all the GUIDO programs can be used for discovery learning as well as dictation. In discovery learning mode, the touch sensitive displays can be used playfully to "play" GUIDO as a musical instrument.

2.1.6 Advantages of CA aural training

If you want to practise and test aural skills formally, (ignoring arguments about whether this is desirable) then dictation is a useful method. GUIDO's competitors for dictation in undergraduate courses are classroom dictation and tape. The advantages claimed for GUIDO are firstly that speed of dictation, order of presentation and time allowed for answering can be individualised for each student; secondly that the students replies can be recorded, analysed and acted upon instantly. Hofstetter demonstrated experimentally that a group of students using the GUIDO harmony program scored better in subsequent traditional classrooom dictation using a piano than a control group using taped dictation practice (Hofetetter 1975 p.104). The vast majority of students seem to enjoy using GUIDO (Hofstetter 1975).

2.1.7 Limitations of Computer Aided dictation

The criticisms of traditional CAI in most *other* fields can be summarised as follows. The system is neither able to recognise any correct answers that were not catered for explicitly by the author, nor to make educational capital out of slightly wrong answers, or answers that are "wrong for a good reason" that were not forseen . If a student happens to know most of the material in the course, and simply wishes to extract one or two pieces of information, the system is unlikely to be able to help; it can only run through those paths the author allowed for. CAI for Aural dictation seems to avoid most of these charges. Many aural drills only have one right answer, and GUIDO often allows a choice of ways of presenting this answer. It is not always obvious how educational capital could be made out of wrong answers to aural dictation - but we will postpone discussion of that point until the section on intelligent tutoring systems.Certainly, with all the control boxes off, GUIDO gives the student full rein to extract "information" . Aural training seems to be one of the few areas where traditional CAI really is an improvement over the alternatives. (It might be argued that there are better ways of helping someone to learn how to recognise, say, chord qualities; perhaps by presenting a song that the student liked which contained those chord qualities in different important roles - but that is an open question) .Gross (1984) discovered an interesting limitation using an aural dictation system similar to GUIDO.

> ". . their (the students) skill with short problems, that is intervals and chords, improved with additional time spent at the computer, but their ability to suceed with larger scale topics did not correlate significantly with their CAI time ."(Gross 84)

If this finding generalises to all aural training, then in the section dealing with the encouragement of composition skills, we might wonder whether any development of this sort of aural training would be likely to help develop composition skills.

[Footnote to "traditional" Music CAI

At the beginning of this section, a distinction was drawn between exclusively textual CAI whose subject matter happens to be about music, and CAI for elementary aural training. This misses out an entire possible class of applications of CAI to music : namely those that combine texts with music editors or computer based music tools in systems aimed at developing higher level skills. (e.g., melody writing, harmony and orchestration) Unfortunately, no examples of this sort of work were found in the (admittedly rapid) survey of the literature, disqualifying it from being discussed under the heading of "current practice". However, this class of CAI fits no better in the speculative section on the possible applications of AI, since AI is not crucial to this sort of application. For these reasons, we will limit discussion of this sort of application to a single speculative example. Samuel Adler's "The study of orchestration" (not a CAI text) , reviewed in Computer Music Journal (Yavelov 1984), comes with a workbook and eighteen seven inch reels of audio tape. Examples are performed in more than one way to demonstrate different bowing conventions, "subtle timbral variations", typical student pitfalls in piano transcription, doubling and so on. A version of this work linked to a music editor could have similar advantages over a tape-based version as were discussed earlier in relation to simple aural training. Unfortunately, currently available computer musical instruments neither have the timbral subtlety of a symphony orchestra, nor typically the amount of storage that would be required for such an application. However, if costs and capabilities of Computer Musical Instruments continue to follow their respective trends, it is reasonable to expect this sort of application to become practicable soon.]

The subject of the next section, Music Logo, contains elements of a music editor and of a game, but its intellectual parentage and ambitious aims are such that it can reasonably be discussed in a category of its own.

2.2 Music Logo

In concrete terms, music Logo takes the form of such things as the "Tune Blocks" and the "Time Machine.", which we will describe shortly. But Music Logo is an attempt to apply the ideas of Logo to music, so it is fruitful to ask first "What is Logo?".

2.2.1 What is Logo?

Logo is a programming language that tries to embody an educational philosophy of "learning without being taught" (Papert 1980 p.7). Logo is an attempt to link deep and powerful mathematical ideas (e.g. the idea of a function) to a child's intuitions about his own body movement (Papert 1980 viii). Logo draws on many different communities and bodies of work: Piaget, The Artificial Intelligence Community at MIT, Bourbaki, Lisp, Church's lambda calculus and Alan Kay's Dynabook Project (Papert 1980 p.210) . Logo is explicitly intended to appeal to the emotions as well as the intellect (Papert 1980 p.7). Logo's central proponent, Seymour Papert, sees computers as potential tools for exploring how thinking and learning work, and as possessing a double-edged power to change how people think and learn. (Papert 1980 p. 209) Logo has taken many forms, but the best known and best explored version is "turtle geometry" Logo.

Turtle geometry is a computational version of geometry which can be explored by giving commands to a "turtle" which leaves a trace as it moves. (The turtle may be a physical robot or may move about in two dimensions on computer terminal screen.) Commands can be assembled in packages called procedures, which can be re-used, adapted, or used as building blocks for further procedures. (Lest this description makes the reader think that Logo is only a toy for children, it should be stressed that while easy to use, Logo is both theoretically and practically a powerful programming language.) Strong claims are made for Logo by its proponents. Speaking in the context of the way in which the notions underlying differential calculus crop up naturally in Logo when trying to "teach" a turtle to move in a circle or spiral, Papert says that "I have seen elementary school children who understand clearly why differential equations are the natural form of laws of motion." (Papert 1980 p. 221). To attribute this understanding to Logo would be a very strong claim, (and Papert only makes it implicitly) since this is an understanding that escapes many graduate mathematicians, physicists and engineers. The validity of the claims made for Logo are hotly contested. Papert says that the sort of growth he is interested in fostering can take decades to bear fruit, and would not necessarily show up on "pre- and post" tests (Papert 1980 viii). Having taken this detour to consider Logo proper, what light does it cast on Music Logo?

2.2.2 What is Music Logo?

In one sense, any attempt to do, using music, what turtle geometry does using mathematics could be considered as music Logo, But music Logo is usually identified with the particular attempt of Jeanne Bamberger and her colleages , working in association with Seymour Papert, Terry Winograd, Hal Abelson and others at MIT.

(Note that the most up-to-date paper specifically about Music Logo consulted here is the 1975 Progress Report on the Music Logo Project. This includes a program for future work (pages 23-25). There is a now a Music Logo Source Book and a Music Logo set of software (Jeanne Bamburger, personal communication) but it is neither clear whether these are yet available, nor whether they cover ground not covered by the 1975 report .)

Music Logo has equally high aims as Turtle Logo. One aim is to describe music in a way that allows redefining of its elements by the user, and leads to extendable concepts. The representation should have very wide scope, yet be uniform and simple. It should allow any student to create his own tools to explore and create music that makes musical sense to him, whatever that sense may be. Music Logo should not only develop the skills that underly intelligent listening, performance, analysis and composition, but should also encourage non-musical learning and understanding. If Turtle Logo was ambitious, then Music Logo is even more ambitious. Logo could at least draw on a concept developed over twenty centuries that most mathematicians would agree underlies much of mathematics (the function) with a well-developed notation (functional notation) and an existing computational embodiment (Lisp). Where do we find as well-developed equivalents for music? The unlikelihood, some would say absurdity, of any such formalism existing for music does not make Music Logo impossible, but it does suggest that its stated aims will be hard to satisfy - especially the requirements for uniformity and wide scope.

We now describe two experiments by Jeanne Bamberger that make a tentative start of creating a music Logo. (The following draws heavily on Bamberger 1972 and 1974.)

2.2.3 Tune Blocks

This experiment starts with a four voice synthesizer connected to a computer. A simple tune (say a nursery rhyme) has already been broken into motives or perhaps phrases, depending on the precise variant of the game being played. The phrases are labelled, say, b1 to b5, and if you type in b1, then the sythesizer plays the corresponding phrase. In one game, you are simply given a set of phrases, and invited to arrange them, using sequence and repetition, in an order that "makes sense " to you. The game sounds trivial, but strong claims are made for it. First of all, anyone can try it - there are virtually no prerequisites. Secondly, it involves active manipulation of and listening to musically meaningful elements (i.e. phrases or motives as opposed to isolated notes or arbitrary fragments). Thirdly , it promotes "context-dependant" as opposed to isolated listening (e.g. block 1 followed by block 2 may give both blocks a new slant). Listening to what people say as they play the game, Bamberger reports that whereas a phrase is initially perceived in only one way e.g. "went down" or "went faster", as the game procedes, it comes to be perceived in a variety of ways, for example "same downward movement as block 1, but doesn't sound like an ending". Players produce a wide variety of resulting pieces, and comparing other peoples pieces, especially if they come from a different musical culture, is one of the pleasures of the game. Bamberger sees the use of neutral tags like B1, B2 as opposed to more visual representations as a positive advantage to tune blocks, as it means that visual sense cannot be used as a substitute for listening. There is variation of the game in which the player is given a complete piece, programmed in advance, which he can hear at will, and the challenge this time is to recreate the original tune from its constituent phrases. Bamberger points out that in this version, the student is likely to discover - as an effortless by-product of play - the melody's overall structure (e.g. A B A). Players begin to ask themselves leading questions like "Why does B1, B3, B2" seem incomplete, although it sounds as though it has ended?". We will go on to look at the "Time Machine ", and Bamberger's suggestions for further work before trying to compare music Logo with its claims and aims.

2.2.4 The Time machine

Most people can clap along with both the rhythym of a melody and its underlying beat (some can tap both at once using hands and feet). The Time machine attempts to represent the interaction of these two streams of motion in a way at once intuitive and concretely representable. The gadgetry is very simple. The player strikes a drum, which leaves a trace on a VDU screen. Figs 6, 7 and 8 should make clear the relation between what is struck on the drum and what appears on the screen. Pieces can be recorded and played back later with synchronised sound and display. One crucial feature is that the time machine can play a regular beat against which you can input your piece; both the rhythym and the beat will appear on the screen (see fig 9) as you play. Once recorded, the beat trace can be concealed while you listen to both streams of sound at once. Bamberger claims that one activity in particular - trying to picture how they mesh, and then revealing the beat trace to check your guess - can transform how people perceive pieces (Bamburger 1974 p.13). Players often originally perceive "Mary had a little lamb" (American version), both aurally and visually as consisting of three "chunks" - as in fig. 8. Bamburger shows that the single suggestion of *linking visually all the marks that occur during the lifetime of each beat* (fig. 9A) can lead to the recreation of conventional rhythym notation, and can lead to the perception (though some people already perceive this anyway) that the first chunk contains a sub-chunk identical to the second and third chunks. This is the only "game" that Bamberger describes for the Time Machine in the papers consulted.

[Footnote

The use of the time machine links very interestingly with later work by Bamburger in which she analyses different notations (some of them invented spontaneously) used by a cross-section of people - children, novices and trained musicians - to record rhythyms. The notations are classified into two types, figural and metric, and it is claimed that they correspond to two ways of perceiving rhythym. It is also claimed that individuals tend to favour one perception or the other, but that both ways of perceiving must be learned as a pre-requisite for full musicianship.]

2.2.5 Tackling higher level features of music

Given sufficiently extendable representations, musically sensible transformations could be carried out in a Music Logo at various levels of musical structure, and it could be argued that this is an important part of what composers do . Bamberger quotes from Schoenberg:

> Even the writing of simple phrases involves the invention and use of motives, though perhaps unconsciously. . . The motive generally appears in a characteristic and impressive manner at the beginning of a piece. . . Inasmuch as almost every figure within a piece reveals some relationship to it, the basic motive is often considered the "germ" of the idea. . . However, everything depends upon its use. . . everything depends upon its treatment and development. Accordingly variation requires changing some of the less important ones (features). Preservation of rhythmic features effectively produces coherence. For the rest, determining which features are important depends on the compositional objective (Schoenberg in Bamberger (1974)).

Bamberger mentions briefly experiments with slightly more extendable representations ; in particular a language for representing and changing separately the pitch and durational aspects of a melody. But for more complex musical structures, Music Logo needs more extendable representations than those suggested so far, if it is to easily permit musical manipulation. However, the implied claims made for the effects on users' perceptions of using even relatively crude tools like Tool Blocks and the Time Machine are interesting.

Bamburger reports how, for a set of students who had played the two games for several weeks, the experience of listening to Haydn's symphony no. 99 was transformed by a perception of the piece's evolution from a 5-note motive. The new perception, for some, dramatically extended their musical taste.

2.2.6 Where does Music Logo take us?

Green (personal communication) suggests we should distinguish (Turtle) Logo, the system, from Logo the theory of learning. Turtle Logo as a theory of learning and a tool for discovering mathematics makes claims that are hard to falsify. Recent work tends to suggest that discovery learning can benefit from the inclusion of an element of guidance, such as ideas from a tutor or a worksheet (Elsom-Cook 1985).
Logo the programming system attracts more modest claims but ones that would probably command wider agreement. Green itemises some of the good points:-

1/ a moderately compact notation for the objects and operators
2/ a clear visual representation (in the turtle) of what the program did and the order of events
3/ incremental growth of programs
4/ parameterised program fragments
5/ an easy way to compose two program fragments into a bigger one.

Part of the power of Turtle Logo springs from the fact that one of the underlying concepts (the function) makes sense both intuitively and formally of much of Mathematics; to take three large sub-areas of mathematics, it pervades not only algebra, but also order and topology.

In the case of Music Logo , It is not hard to believe that better notations and visual representations can be found than conventional staff notation, and it is imaginable that theories of tonality, rhythym and harmony could be given computational embodiment and recast as discovery learning areas (more on this later); but Music Logo has such high aims that fulfilling them is likely to be very hard.

2.3 Tools for the student

In this category of application of computers to the teaching of music, the computer is being used by the student as a tool to assist in carrying out some task. This contrasts loosely with both traditional CAI in which the student is typically being managed, rather than being a manager, and also with music Logo, which has a stress on free exploration, rather than instrumental use. Three examples of tools are score editors, computer musical instruments and music analysis programs. As has already been mentioned, music editors and computer musical instruments are not included in this discussion; but it is useful to very briefly summarise their most obvious advantages and disadvantages.

On the positive side, computer musical instruments (CMIs) allow students to compose and play pieces virtually unrestricted by their level of manual performing skill; music editors allow students to listen to music scores, and hear the effect of any changes they may wish to make, in a way impossible with textbooks, records or tapes. On the negative side, firstly some music teachers and students find distressing the timbres currently on offer from editors and CMIs, and secondly, the ways of controlling computer musical instruments in musically meaningful ways are sometimes limited. We now move on straight away to analytical tools, remarking in passing only that the timbres are likely to improve, and attempts to extend control methods are touched on in section 3.

The brevity of this section reflects both the apparent rarity in the literature of reports on analytical tools in music education and the poverty of most such tools - the latter is discussed below. The following section draws mainly on work by Blombach (1981).

The most common uses of the computer in music analysis are essentially for event counting, sorting, pattern recognition and statistical analysis. Typical analysis programs can recognise occurences of pitches, note values, intervals and combinations and sequences of these elements. One use of such a tool could be to test the validity of statements by music theorists about the piece being studied. For example, it is possible in studying the Bach chorales to:

> "determine the range of each of the four voices, or the number of times pairs of voices cross and compare the results with standard elementary theory textbook statements. Or they (the students) might use the computer to find occurrences of parallel perfect fifths in the Bach chorales or examine resolutions of tritones. . . . Students find these excercises especially satisfying if they prove the textbook author's discussions inaccurate, imprecise or incomplete" (Blombach 1981).

The principal problem with this sort of analysis is that, as Dorothy Gross says (Gross 84), there are "serious questions regarding the significance of mere counts of events". Such counts may help in establishing, for example, authorship of pieces, but there is no prospect that event counting can distinguish good music from bad. Such analytical tools may help identify places in the great composers where, for example, part-writing rules have been observed or broken, but they do not get us much closer to knowing the significance of these "rules", or when it makes musical sense to break them. Statistical analysis tools are limited in what they can teach because they connect neither with any developed theory nor established practice of music analysis. In section 3, tools for musical analysis that reach a little deeper will be considered, but now we turn to the final section on current practice, about an educational music game with roots a little different from those of Music Logo.

2.4 An interactive graphics music game

Music logo is by no means the only educational music game or the only music discovery learning environment. In this section, we describe an interactive graphical music game presented by Martin Lamb (1982). Although the game has many similarities with music Logo (which Lamb mentions), its modest aims and roots in traditional music notation put it in a different (though not neccessarily inferior) category.

Lamb says that the purpose of the game is:

1/ to provide musically untrained children with a means of inventing their own compositions and hearing them immediately, and

2/ to teach musical transformations (e.g. augmentation, transposition and inversion) by letting children manipulate their visual analogues and immediately hear their effect.

The game is best described using pictures. The student begins with a set of blank staves (Fig 10). The player points to the word "Draw" on the display, using a pointing device, and then, holding down a button on the pointing device, can sketch a freehand curve on the staves (Fig 11). The program immediately plays a line of music with the same shape (pitch for height) as the drawn curve. (Fig 12). The curve then breaks up into discrete triangle shapes, each representing a note (Fig 13) (This diagram fails to show properly that a note can lie on a line or a space, or midway between the conventional positions, to indicate black notes. The length of each triangle is proportional to the length of the note.). Pointing to "transform", a group of notes can be selected by circling them (Fig 14), and an inner circle can be drawn to exclude notes. A copy of the selected notes can then be moved about the screen. Using one of two physical sliders, the selected fragment can be continuously stretched or squashed relative to a horizontal axis (time relations are preserved). The image can be squashed beyond a completely flat position continuously through to its mirror image. When the image reaches exact inversion, it indicates this by glowing more brightly. Similarly, using the other slider, a fragment can be squashed vertically into a chord, beyond simultaneity if desired to its exact retrograde and further (interval relations are preserved). The reaching of the exact retrograde point is indicated when the mirror-image fragment glows more brightly. At any point, the transformation can be played at the pitch at which it is floating, or moved down to a different pitch level. It is possible to move or delete notes, as well as copy them, and there is an undo command.

It appears that more than one voice can be entered onto the screen by sketching more than one curve, and music can also be entered using a keyboard. The display uses a colour coding system. Different voices have different colours, but material derived by transformation from the same material is displayed in a single colour.

This game harmonises four elements ; pitch and time, their clear visual analogue, their gestural analogue and traditional staff notation. Not only pitch and time are represented in this way, but also the musical transformations transposition, augmentation and diminution, and the relations inversion and retrograde. It would be interesting to relate this to a taxonomy (Spiegel 81) of musical transformations, and try to identify gaps in such taxonomies - this is left for further work. This game appears to amply fulfill its modest objectives. What is unclear is how far these objectives go towards developing composition skills.This question is taken up again in section 3.

2.5 Summary of present day applications of computers to music education

To put it crudely, computers are used in music education as administrators of multiple choice questionnaires, as easily used musical instruments, "musical typewriters" and for musical games; they can count and identify simple musical events, and perform simple musical manipulations such as reordering, transposition, and pitch and time transformation. In the next section we discuss what more might be needed to encourage and facilitate composition, and speculate how artificial intelligence might go some way to help provide it.

3 SPECULATIONS ABOUT HOW ARTIFICIAL INTELLIGENCE COULD BE APPLIED TO TO CONTRIBUTE TO THE LEARNING OF COMPOSITION SKILLS

3.0 New opportunities for music composition

Very few people compose music. Until the last decade or so, the rarity of the prerequisites - ability to play instruments, access to musicians to perform works, the ability to read and write music - put all but the most rudimentary music composition skills out of the reach of most people. The advent of cheap electronic and computer musical instruments, tape recorders and music editing software has removed many of these barriers. Ideas can be recorded on tape without knowledge of notation; access to a wide palette of sonorities is much more widely available using comparatively inexpensive FM synthesis and sound sampling techniques. Intricate, many-voiced ideas can be tried out and performed not only by those lacking conventional instrumental skills but even by the severely disabled using sequencers , music editors and computer musical instruments. This technology is likely to get cheaper and more widely available. There is not only a technology-driven revolution, but a revolution in ideas about teaching music (at least in Great Britain). Where the majority were previously expected only to sing and "appreciate" music, composition of simple original music is now considered to be an objective for all school children from age five to sixteen (HMI 1985).It appears that a golden age of access for all to the materials for composition is dawning.But there is more to music composition than simple access to materials. Consider the analogy of creative writing. Literacy and writing implements are now commonplace, but creative writing, or even good writing remains relatively rare. There is a big gap between making sounds and composing music. Knowledgable guides are rare. Some good guides are the mutual help of peers, masterworks (and favourite works) and understanding and perceptive teachers. But in the words of Paynter (1982),

> "Unfortunately, relatively few music school teachers have had any serious compositional training. Most music courses in conservatoires and Colleges of Higher Education tend to emphasise instrumental performance, and the majority of University Music courses are still heavily biased towards musicology. . .
> Opportunities to invent and develop musical ideas are rarely given, except within very narrow stylistic limits"

Some people learn to compose well with little help from teachers, but one suspects that despite the technological and educational changes, personal experience of music composition is likely to remain for many people at a limited level. Let it be stressed that there is no suggestion here that Artificial Intelligence should or could make good the shortage of human guides.The speculations that follow envisage *much* more modest roles for Artificial Intelligence as enabler, tool and occasional catalyst.

Where does AI fit in?

So far the term artificial intelligence has not been defined. AI can be seen as two interweaving strands: one is the "study of ideas that enable computers to be intelligent" (Winston 84), the other is an attempt to understand the principles that make *any* intelligence, human or machine, possible. But music engages the *emotions* more obviously than the intellect. Hofstetter writes:

> Question: Will a computer ever write beautiful music?
> Speculation: Yes but not soon. Music is a language of the emotions, and until programs have emotions as complex as ours, there is no way a program will write anything beautiful. There can

> be "forgeries"- shallow imitations of the syntax of earlier music - but . . . there is much more to musical expression than . . syntactical rules.To think . .(that a music box might). . bring forth from its sterile circuitry pieces which Chopin or Bach might have written had they lived longer is a grotesque and shameful misrepresentation of the depth of the human spirit. (Hofstadter 1979)

Would the truth of this speculation (with which this author is sympathetic) mean that AI is an unsuitable tool for our purposes? No - no more than it makes unsuitable pen and paper and piano strings.However it is a useful reminder of how far artificial intelligence may have to go to get any real understanding of music. Marvin Minsky speculates that understanding how the human mind works may prove easier than - and a necessary prerequisite to - understanding how music works. But, as Minsky points out, science proceeds from surface descriptions to deeper explanations. Generative, transformational and knowledge-based approaches explain more than statistical explanations, and may be replaced in turn by deeper explanations. In the sections that follow, we will try to see how artificial intelligence at its present stage of development offers some tools that might for some purposes be more useful than pen, paper and piano strings.

3.1 Intelligent tutors for aspects of traditional music education?

The first requirement for an intelligent tutoring system (ITS) for any task is that it has to have some ability to perform or at very least discuss articulately the task in hand. *This demands explicit knowledge of the task.* To summarise their two other usual features in a nutshell, intelligent tutoring systems are firstly also expected build up knowledge of what a particular student knows so that opportunities can be seized to get points across in the most appropriate way or to diagnose misconceptions, and secondly an intelligent tutoring system is expected to have explicit knowledge of ways of teaching. The very first requirement, for explicit knowledge of the task, raises the question, "For what areas of music composition do we have explicit knowledge ?". This appears to narrow the possibilities *for this style of AI contribution* down to pitifully few areas, some of which are listed below.(We will see later that other areas are amenable to other treatments.)

1/ Music Theory
2/ Aural training
3/ Harmonisation
4/ Some highly formalised and rather artificial styles of composition, (e.g. perhaps Invertible Counterpoint)

3.1.1&2 Music theory and Aural skills

It seems entirely reasonable to suggest that intelligent tutoring systems might be built for factual aspects of music theory . These would probably not differ all that much from Intelligent Tutoring systems for, say, Geography (Barr and Feigenbaum 83). A more specifically musical application might be an intelligent tutor for aural training, although it is not immediately apparent how the skills of, say, recognising a major seventh could be broken down into subskills. Although a remote possibility, it would be worth finding out whether work by cognitive psychologists or others on the perception of music might suggest subskills or mechanisms involved in musical listening that could be exploited in an intelligent aural training tutor. Equally, taxonomies of students' errors in ear training, if they exist, might be exploited for diagnosis by an intelligent tutor. Indeed, Hofstetter (1981) from his work with GUIDO identifies seven confusion tendencies in harmonic dictation. (Such a system, if feasible, might be compared with the diagnostic aid for errors in arithmetic subtraction, BUGGY. (Burton 83)). Let us leave the rudimentary skills and see what opportunities may be available at higher levels of skill involved in music composition.

3.1.3 Harmonisation

One of the very few areas of composition for which explicit rules of thumb can be found in textbooks is harmonisation.* In principle , there seems no reason why an intelligent tutor for harmonisation should not be built, but a number of cautions should be issued. The essential problem is that the tutor will know nothing about music other than whatever formalisms or rules of thumb we can explicitly give it. If, for example, the tutor spots the student using consecutive fifths, what should the tutor do? Parallel fifths should generally be avoided, but they have been used to good musical effect, at any rate by great composers. A good tutor should not criticise unless he (she or it) can suggest a better way of doing things (Burton & Brown 82); Unfortunately, we have no way of making a machine distinguish good music from bad .Could the tutor be sure that any suggestions it might make are musically better? It might be possible to sidestep the problem by careful selection of case studies (this is, in part, the approach used in GUIDON, the experimental medical tutor for diagnosis and treatment of bacterial infection). Another approach might be for the tutor to make plain its limitations (Evertz, personal communication). In general, provided the student understands the tutor's limitations, limited tutors can be useful.

[*Footnote: It is known that the various sets of rules for harmonisation are inadequate. For example, Rothgeb (80) implemented computational models of Heinichen's and Saint-Lambert's eighteenth century theories for realising unfigured bass. The computational model showed the bodies of rules, not unexpectedly, to be "partially incomplete and to a certain extent inadequate." (Rothgeb 80)]

3.1.4 Highly formalised areas of music

Taking the demand for a highly formalised area of music to its extreme, we might (if we could find people who wanted to learn about it), build a tutor for something like invertible counterpoint. The idea that invertible counterpoint, as described by Taniev (1906) is probably sufficiently formal for a detailed computer model to be implemented is due to Green (1978).The snag is that invertible counterpoint (of which the present author is almost wholly ignorant) appears to be a somewhat artificial area of composition.

If we are determined to keep within the intelligent tutoring system paradigm, which tends to imply that the tutor , if not necessarily in control, may at any rate tend to offer the result of its deliberations from time to time, then either we need to pick our area or case studies very carefully, or we need to make sure the tutor's limitations are understood and accepted. However, if we turn to other paradigms of support for learning, we will see that AI-accessible areas of music composition are potentially much wider.

[Footnote : machine learning and human learning about composition

This note briefly discusses some proposals that have been made about applications of machine learning to human education in music , but it assumes some familiarity with machine learning, and can be skipped if desired.
Roads (1980) reports on a proposal to use Mitchell's version space formalism (for compactly representing generalisations about concepts) as the basis of a program to automatically build up knowledge about style from example pieces. Holland (85) proposed the use of a co-operative man-machine partnership for exploring music composition based on Lenat's machine learning program Eurisko. The proposal was that the human partner would contribute common sense and aesthetic judgement, while the machine partner could bring to bear heuristic manipulation of formalised musical knowledge. At first sight, these proposals look exciting. The Lenat/Eurisko partnership jointly invented a new-to-mankind, useful, 3D VLSI electronic device, won a naval tournament competition three years running and made discoveries in other fields. But current learning programs are limited to syntactic manipulation. In areas where syntax mirrors semantics, these techniques are powerful. In areas where syntax does not mirror semantics, one crucial lack of Eurisko is common sense. Lenat's current work (the CYC program) attempts to remedy this lack. But even if machine learners could draw on organised common sense knowledge, it is not clear that they would be any nearer to aesthetic judgement.Without aesthetic judgement, if every manipulation needs to be referred to the human partner, the" co-operation" has collapsed and the program's status sinks to that of "mere" tool.]

3.2 Tools and Instruments

3.2.1 Intelligent, powerful and simple music editors

Artificial Intelligence may be able to make a more indirect contribution to the learning of composition skills than intelligent tuition by allowing music editors to be more intelligent and responsive. Buxton et al. (1981) give the example of a conductor requesting "play a little more staccato in the lower brass". The request is easily put into words, but to put in the corresponding markings using most present day score editors and hear the result could take many distinct operations. The problem is that most music editors are note-based. They may allow operators (e.g. transpose, delete) to be applied to combinations of, for example, all notes within a given block of time, all notes in particular voice, or all notes lying in a certain pitch range, but they do not allow operators to be applied, except laboriously, to musical objects such as phrases, ostinati and themes . How can an editing program "know" what musical structures underly a score ? Buxton et al. (1981) describe one partial solution using a hierarchical tree structure. Other approaches may be worth exploring, either from the direction of computational formalisms for the results of various kinds of musical analysis (e.g. Smoliar's work on Schenkerian analysis, Lerdhal and Jackendoff's generative theory of tonal music, neither of which are well understood by the present author) or from the direction of general and powerful AI knowledge representation formalisms , e.g. contraint based representations (Levitt, 84) and object based representations (Lisp Machine Manual 1981)

3.2.1.1 Object-based music editors

The only approach we will take further in this section is the object-based approach. In an object-based music editor, completely arbitrary collections of musical events could be designated to be a single object, and operated on as such. Objects could be dismantled, regrouped, and re-operated on at will. Object-based programming is, in one sense, little more than a programming convention that makes this happy freedom possible (although the convention is obvious, if at all, only with hindsight). The benefits of object-based editing can be hard to grasp without actually experiencing them. The author does not know if object-based music editors are already commercially available, but readers with access to Macintosh computers can, if they care to, simulate editors comparable to rudimentary note and object based editors for music. "Macpaint" is a commonly available pixel-based graphics editor, and "Macdraw" is an object-based counterpart. These are not specialised music editors, but either can be used, with a little preparation and effort, to prepare scores. The difference in power of these two editors might be expected to correspond with the difference in power between a note-based and an object-based music editor. (The powerful object-based ideas of property inheritance and defaults are left for a later discussion)

(One interesting further opportunity lies in the design of good graphic interfaces to object-based editors. The object-based convention makes it easy for operations to be pplied to any object or group of objects for which the operation makes sense. This makes it reasonable, in turn, to represent operators as well as objects by single icons (pictures) or gestures. So, for example, there is an object-based database that represents operations on data as tiles or icons (Helix 85). Could musical uses for such a scheme be found?)

3.2.2 Intelligent Instruments and the musician-machine interface

It is reasonable to suggest that interpreting or performing a masterwork, or for different reasons, one's own work, might contribute indirectly to the development of composition skills. We can imagine an abstract space of different dimensions of involvement in interpretation, some points in which might include the "null " example of selecting and listening to a fixed recording of a particular performance, interpreting a single line in an ensemble performance, conducting the ensemble and interpreting all lines using overdubbing. Levitt (Durham 84) and Mathews and Abbott (80) offer suggestions that effectively populate new areas in this space. Levitt, an AI researcher and consultant for Atari, has speculated about consumer music boxes with controls not only for volume, balance and tone, but also tempo, harmony, instrumentation and style (Durham 84). Levitt and Fry have both done work on specifying musical style which might be exploited for this purpose; both are discussed in a little more detail in section 3.2.4. Mathews and Abbott, approaching a closely related area from a different perspective, define three different relationships between musician, score and instrument - two familiar and one relatively new. The relationships can be described pictorially (figs 16 -18). Fig 16 illustrates how:

> ". . with traditional instruments, all the information in the score passes throught the musician, who communicates the information to the instrument via physical gestures. The musician has fast, absolute control over the sound, but he or she must be able to read the score rapidly and make complex gestures quickly and accurately ." (Mathews with Abbott 1980)

The second relationship is that which holds with musique concrete, player pianos and music programming languages (Fig 17). The score completely specifies the performance, and although this can be amended indefinitely off-line, no real-time demands or opportunities fall to the player during performance. Fig 20 shows a third possible relationship. The entire score does not have to be interpreted in real time by the musician, but the musician can in principle reserve any aspects of the music for his interpretation.

> "The score is a partial description of musical event. In general the sequence is ordered by time. The information not contained in the score is supplied by the musician in real-time during the performance. The aspects of the performance that are to be interpreted are generally supplied by the musician.The aspects not subject to interpretation are supplied by the score." (Mathews with Abbott 1980)

This third relationship is of course, the familiar conductor-orchestra relationship, but one where the orchestra is replaced by a machine. No representation and control methods are known at present, needless to say, that could allow a human-machine relationship to approach the subtlety of the orchestra-conductor relationship. However, some special cases of relationship 3 may be very useful despite their relative lack of sophistication. One of the most obvious is to separate rhythmic and pitch information, as was done by Bamberger. Mathew's "sequential drum" can go some way beyond this. The drum is a rectangular surface that can be played by hand or stick, andhas four outputs; hit time, hit strength, and X and Y position on the drum's surface.The four signals can be used to control any synthesizer parameters; loudness, timbre, location of sound, time of occurrence, or perhaps even the tempo of groups of notes. The score might, in a simple case, contain a rhythmless melody, allowing the musician to concentrate on phrasing and accent. At least one composer, Joel Chadabe (Chadabe 83) performs, or "interactively composes" - his term - in much this way, although Chadabe uses two theremin rods rather than sequential drums as controllers.

Some might wonder if this discussion of musician-machine interfaces has much to do with artificial intelligence and learning composition skills. There is a strong argument that it has. Artificial Intelligence and efforts to improve the human machine interface in a wider context have long been inextricably intertwined. Alan Kaye talks about a theory of mind that involves three mentalities: "one concerned with doing and muscular action; one concerned with seeing and images; and. . (a). symbolic mentality which thinks in sentences, formulae and equations." (Kay paraphrased by Durham (85)) We would probably want to add a fourth mentality concerned with listening and sounds ; but the point is that musicians' physical gestures in making music may be an essential element in a description of what music is about, and conversely, musical intelligence may become a useful component in responsive musical instruments.

3.2.3 Tools for non-numerical music analysis

A further source of insight for the learning composer is to study the works of great composers. The following section draws heavily on Smoliar (1980), who comments "Unfortunately, the analysis of tonal music has never been a particularly well-defined task, in spite of the fact that it must be performed by every student of music theory". Bearing in mind Meehan's claim (1980) that Schenker's theory of tonal music is the currently dominant theory, and recalling the poverty of numerical and statistical analysis discussed earlier, it is interesting to discover that symbolic processing, a central idea in artificial intelligence, has proven a valuable tool in

Schenkerian analysis. In order to expand this a little, the author will have to pretend to understand Schenker, and crave the reader's momentary indulgence and subsequent corrections for any inaccuracies. (Thanks to Rahn (80)). Previous to Schenker, analysis failed to distinguish chord grammar from chord significance. (Salzer, quoted in (Smoliar 80)). Schenker pointed out that context can affect the function of chords wherever they occur - not only at cadences. Any context-free grammar of chords that merely "labels each chord and relates it to a different chord centre" will fail to capture the diverse roles which chords can play in a phrase or section. Schenker's inspiration was C.P.E. Bach. In the "Essay on the true art of playing keyboard Instruments" Bach discusses "processes by which a note, chord or brief passage may be replaced by a much more elaborate passage, melodic or contrapuntal, which expresses the same basic content as the original". Extending and abstracting this insight, Schenker postulated how "an entire tonal composition could arise from a series of such elaborations . . . compounded ultimately upon a single note - the "tone " of the compositions tonality." Schenker's formalisms pre-date and parallel Chomsky's transformational theories of language.

It should be stressed that there is no suggestion whatsoever that a program could perform the analysis for a learning human composer: Smoliar's aid to Schenkerian analysis is merely a useful tool to the student or analyst . A student can perform and display visually analyses that would otherwise be hopelessly time-consuming and tedious to explore.

(Schenkerian transformations offer a deeper grammar, but no semantics for music. Minsky (81) mentions one highly speculative theory (Clyne's "Sentics")which suggests that "certain specific temporal sensory patterns" are associated with "certain common emotional states", and James Meehan offers an interesting speculative suggestion for combining the music theorist Narmour's work with an approach similar to Schank's expectation-based conceptual dependancy. What the musical semantic primitives for this theory would be is not clear.)

3.2.4 Analysis and resynthesis

Marvin Minsky is reported as asserting that " a good way to train composers would be to give them the rules of a highly constrained system (such as a Beethovan piano sonata) and let them alter the constraints that produce it."(Roads 81). [Footnote : away from the point, but in interesting relation to it, Minsky is also reported as suggesting that "the study of great masterworks would not advance any cognitive theory of music and that theorists might do better to study childrens' reactions to simple tunes, and find out why they prefer some tunes to others" (Roads 81)] This remains a speculation, of course, because no one yet knows how to specify a Beethovan sonata as a constraint system. In the area of jazz improvisation, however, Levitt (83) has written a program that "negotiates mutual harmonic, melodic and thematic constraints to produce a solo from a chord progression and melody" using the AI techniques of propagating symbolic constraints. (Symbolic constraint propagation is a good example of a technique so widely applicable it could have been discussed under any of the headings; intelligent tutoring systems, powerful editors, intelligent instruments, analysis, or under the next heading, games.) . Christopher Fry's (1984) "Flavours Band" allows the representation of a musical style as a network of "phrase-processors" independently, to some extent, of any particular piece of music. This allows experiments such as playing the melody and chords of "Norwegian Wood" in the "style" of John Coltrane. However, to what extent a Flavours Band network of "phrase -processors" captures a musical style in any principled way is unclear. Given the lack of tools presently capable of implementing

Minsky's suggestion vis-a-vis Beethovan sonatas, what tools we do have might be employed honourably as games, as sketched in the next section.

3.3 Games

Seeing that we know so little about music composition, and that knowledge is so fragmented, games are one way of allowing us to build and pass on memorable experiences out of those few insights that we do possess. The problem is not to find material for games; the psychology of music, branches of music theory and almost any piece of AI that captures some musical knowledge all offer possibilities.The problem is to find or make explicit a principled framework to order the possibilities.

The scholarly literature on games as education has not yet been examined as part of this survey. However, one example of the power of games can be cited, if an example is needed. Illich (1971) writes of

> ". . .educational games which can provide a unique way to penetrate formal systems. Set theory, linguistics, propositional logic, geometry, physics and even chemistry reveal themselves with little effort to certain persons who play these games. A friend of mine went to a Mexican market with a game called 'Wff 'n Proof' which consists of some dice on which twelve logical symbols are imprinted.. He showed children which two or three combinations constituted a well formed sentence, and inductively, within the first hour some onlookers also grasped the principle. Within a few hours of playfully conducting formal logical proofs, some children are capable of introducing to others the fundamental proofs of propositional logic. The others just walk away. . . In fact for some children, such games are a special form of liberating education, since they heighten their awareness of the fact that formal systems are built on changeable axioms and that conceptual operations have a gamelike nature." (Illicn 71)

Illich also mentions some pitfalls which deserve sober thought , but discussion of these is reserved for later.

Games that encourage or assist music composition using aleatoric methods are not new (Gollancz, personal communication, and (Eno, 197?). Random methods have also been used by working composers , perhaps most famously Mozart and Cage. If we imagine a continuum extending from random methods at one extreme , through to (human) creative musical intelligence at the other , AI methods can be viewed at present as encapsulating generative intelligence slightly intelligence-wards of the completely random. (Fig 19).

Similar to the way that improvisers will sometimes ask for a motif from the audience, then develop the fragment into a complete piece, games could begin with the player singing, playing or selecting a fragment. However, given the "intelligent human, dumb machine" situation, instead of the machine going away and coming back with a complete piece, the process would involve much more give and take. The machine might begin with more knowledge about elements, form , grammar, and constraints, but the player would have a virtual monopoly on aesthetic judgements. The player could direct the game when confident, or ask for suggestions when stuck.Other possible starting points include setting a piece of text, film, script or picture to music, or trying to capture the elements of a style as previously discussed.

Some of the sort of games being discussed here have a precedent in creative writing aids. Sharples (1983) had children use games employing context-free grammars and associative networks as modest tools for creative writing ."By specifying first an appropriate vocabulary, then syntactic structure and the agreement of meaning the child can use the computer to generate interesting and increasingly refined sentences, poems and stories"(Sharples 83). Sharples work was based on a cognitive theory of the writing process (Bereiter and Scardamalia 1982; Bruce, Collins, Rubin & Genter 1982).

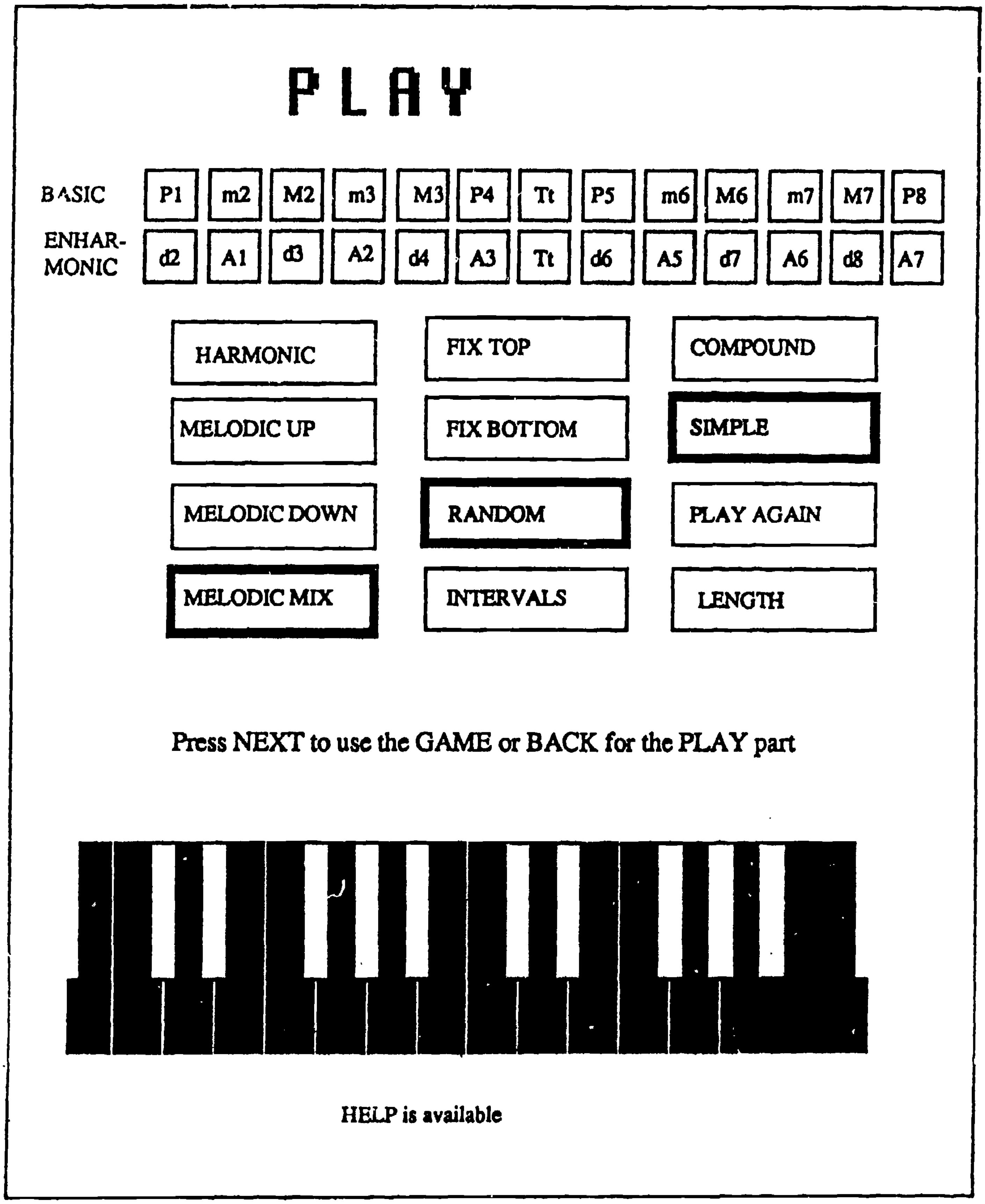
It is proposed to develop in more depth a proposal for a set of educational games to encourage music composition.

4 CONCLUSION

Minsky notes (81) how areas previously considered personal and inaccessible were sytematically explored for the first time earlier this century: Freud and dreams; Piaget and children's play. Since it has not yet happened, it is hard to predict when and to what extent comparable breakthroughs might be made in our understanding of music, and whether artificial intelligence will play a part. However, artificial intelligence already provides the most explicit tools and ideas currently available for modelling and describing mental processes, although the scope and depth of these tools is as yet undeveloped.

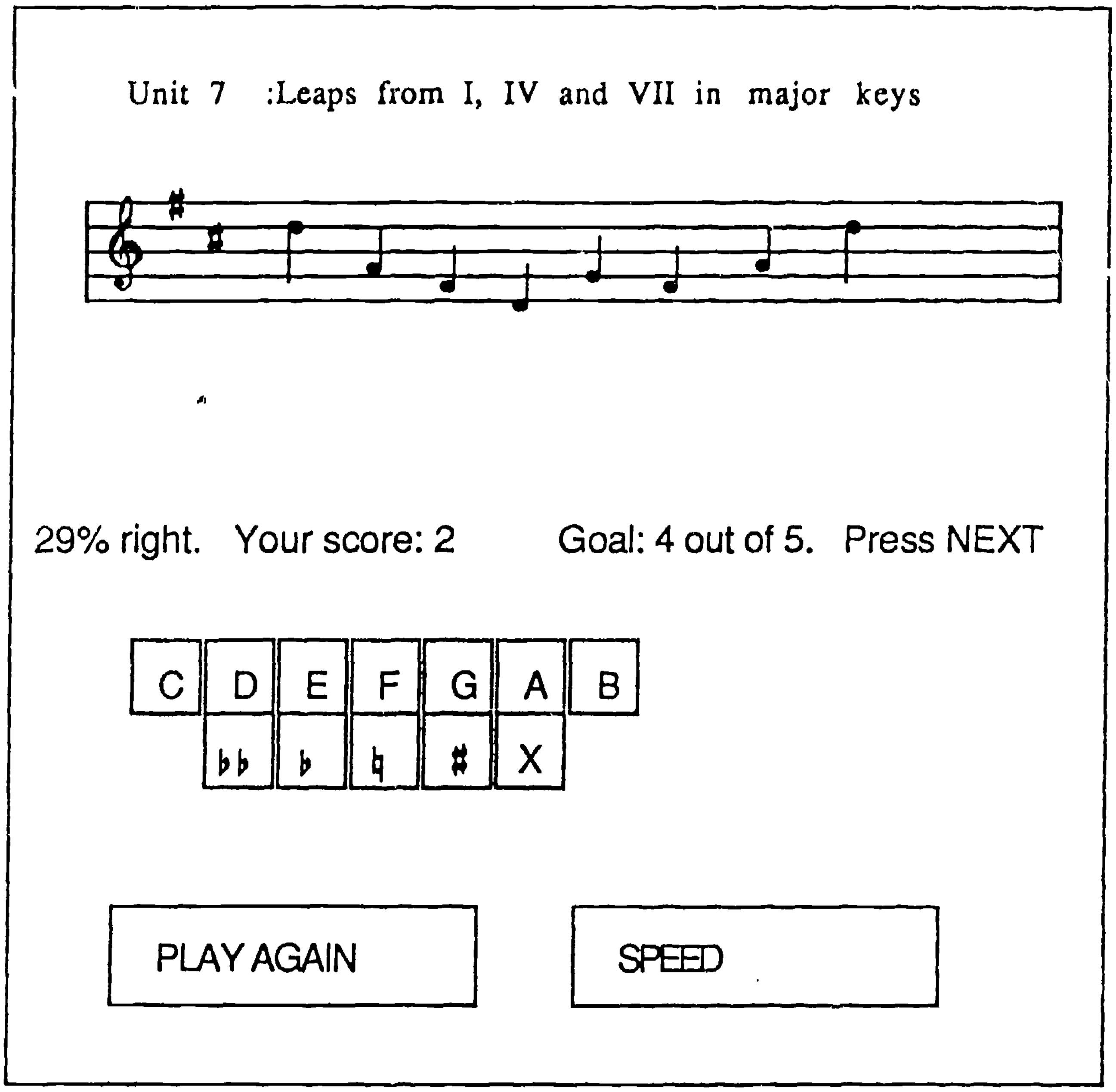
Given due caution, it appears possible that modest contributions may be forthcoming from artificial intelligence to support the learning of music composition in the areas of intelligent tutors, intelligent tools - editors, instruments and aids for analysis - and educational games.

FIG 1: GUIDO INTERVALS PROGRAM



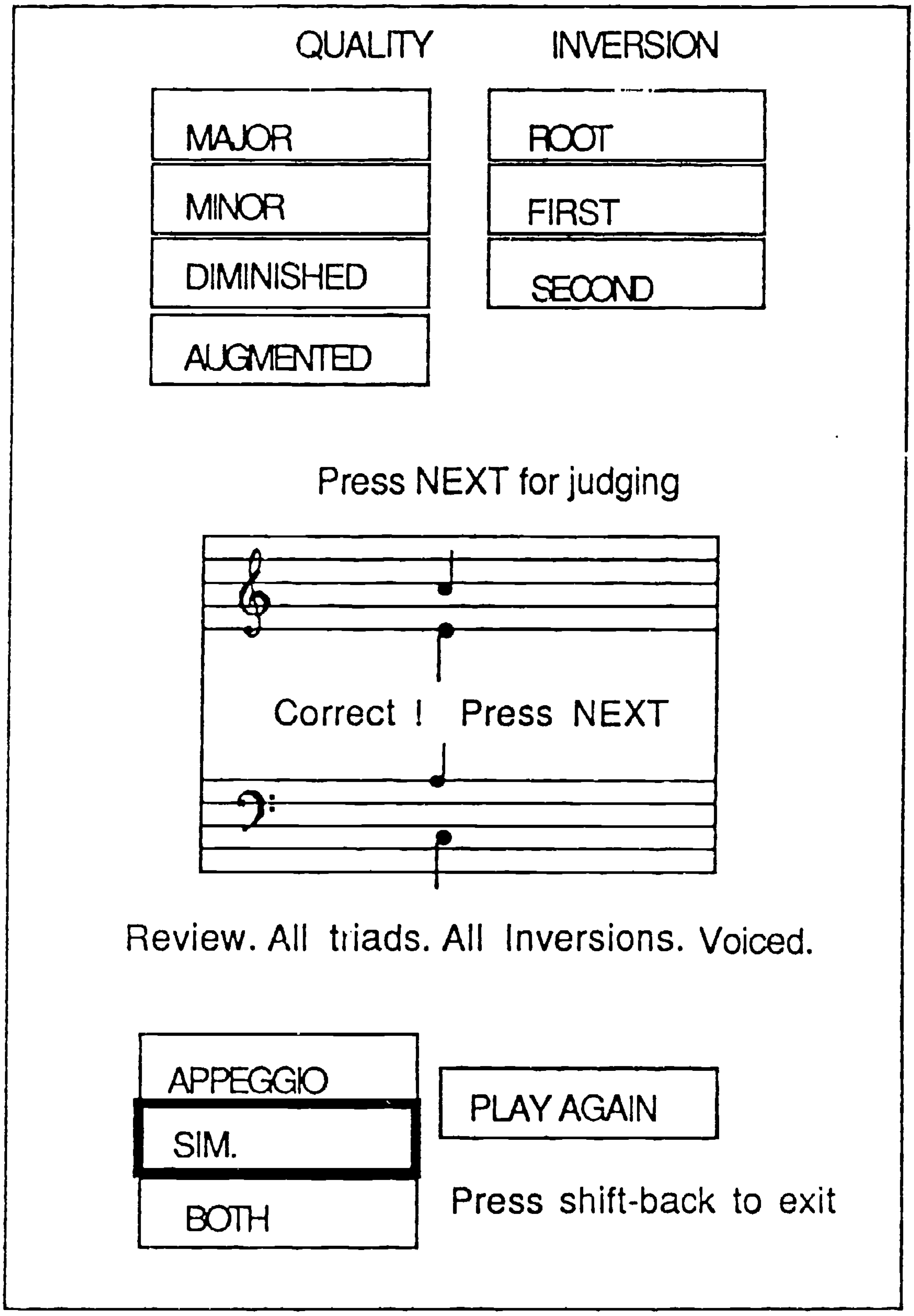
Redrawn from Hofstetter (1981)
(see page 3 for details)

FIG 2: GUIDO MELODY PROGRAM



Redran fro Hofstetter (1981)
(see page 3 for details)

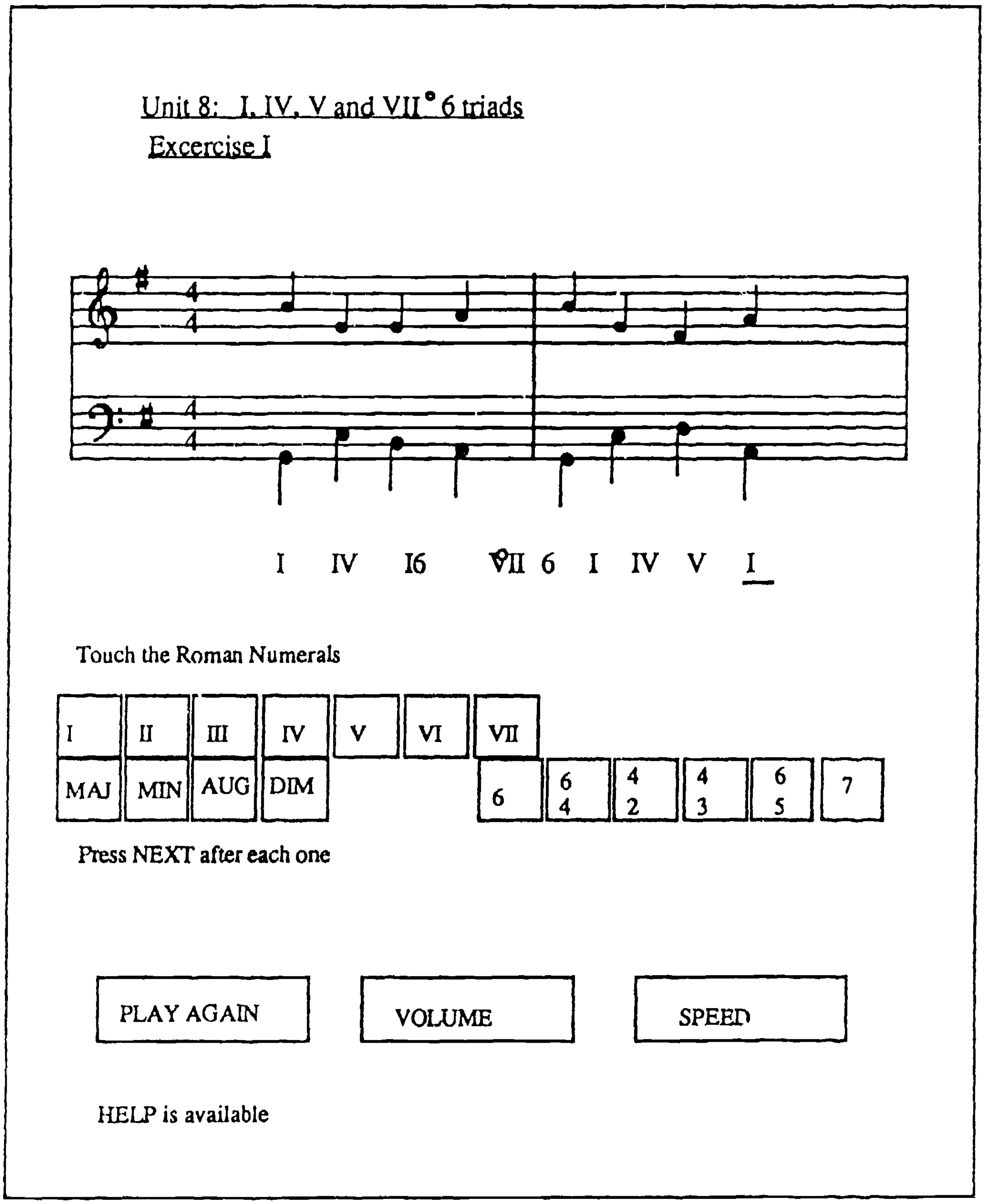
FIG 3: GUIDO CHORD QUALITY PROGRAM



Redrawn from Hofstetter (1981) p. 86

See page 3 for details

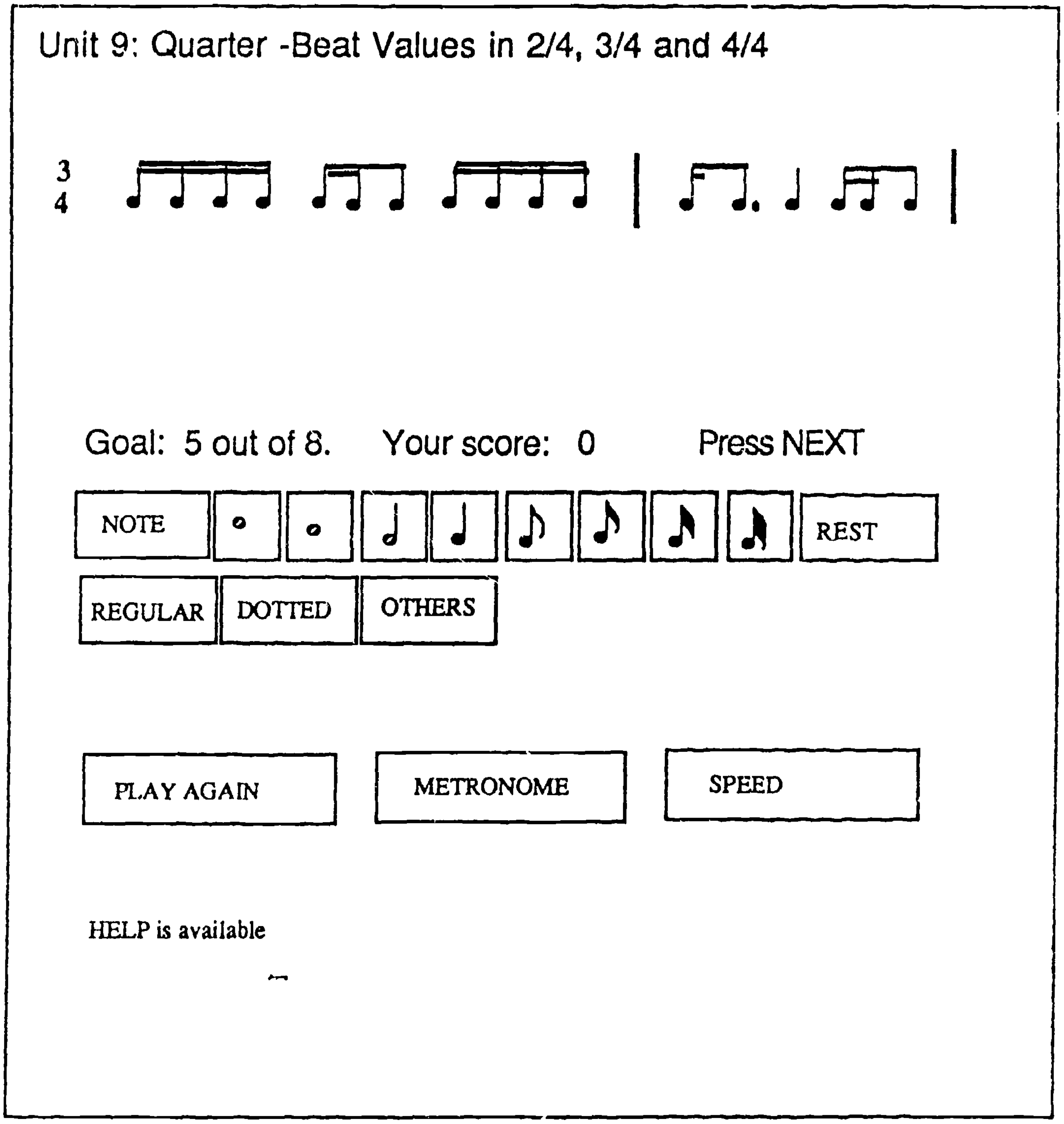
FIG 4: GUIDO HARMONY PROGRAM



Redrawn from Hofstetter (1981) p. 86

See page 3 for details

FIG 5: GUIDO RHYTHM PROGRAM



Redrawn from Hofstetter (1981) p.87
See page 3 for details

Time Machine Traces

Fig 6 Fast Regular Beat

Fig 7 Slow regular Beat

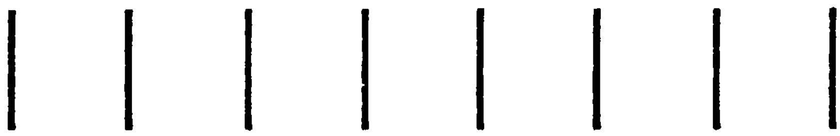


Fig 8 Mary had a little lamb (American version)

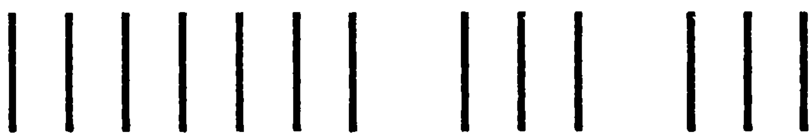


Fig 9 Mary had a little lamb - American version - (with pulse)

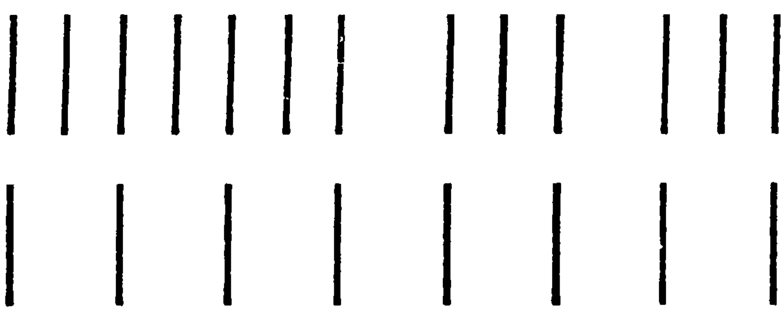
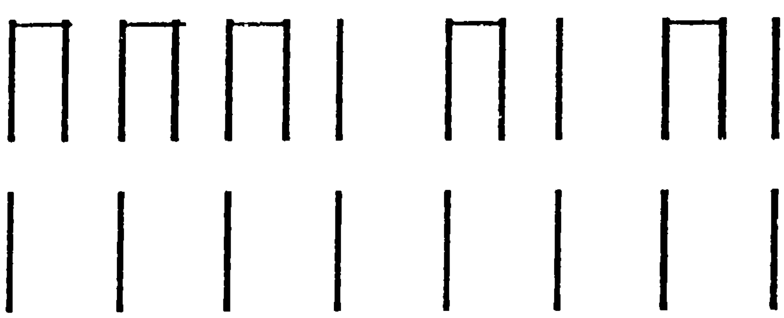


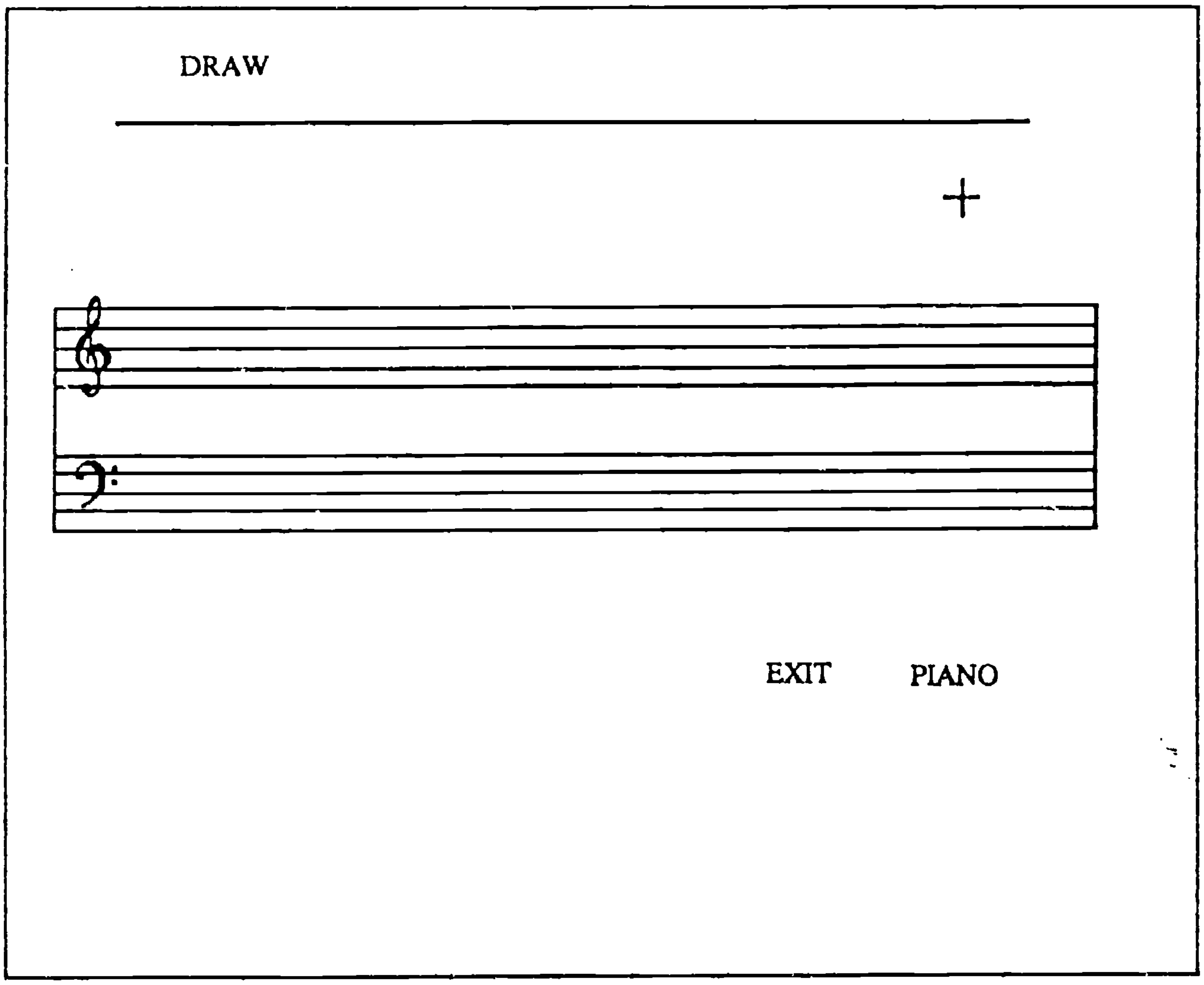
Fig 9a Mary had a little lamb - American version - (with pulse & linked trace)



Redrawn from Bamberger 1974.

See pages 6 and 7 for details

FIG 10 Lamb's Interactive graphics Game

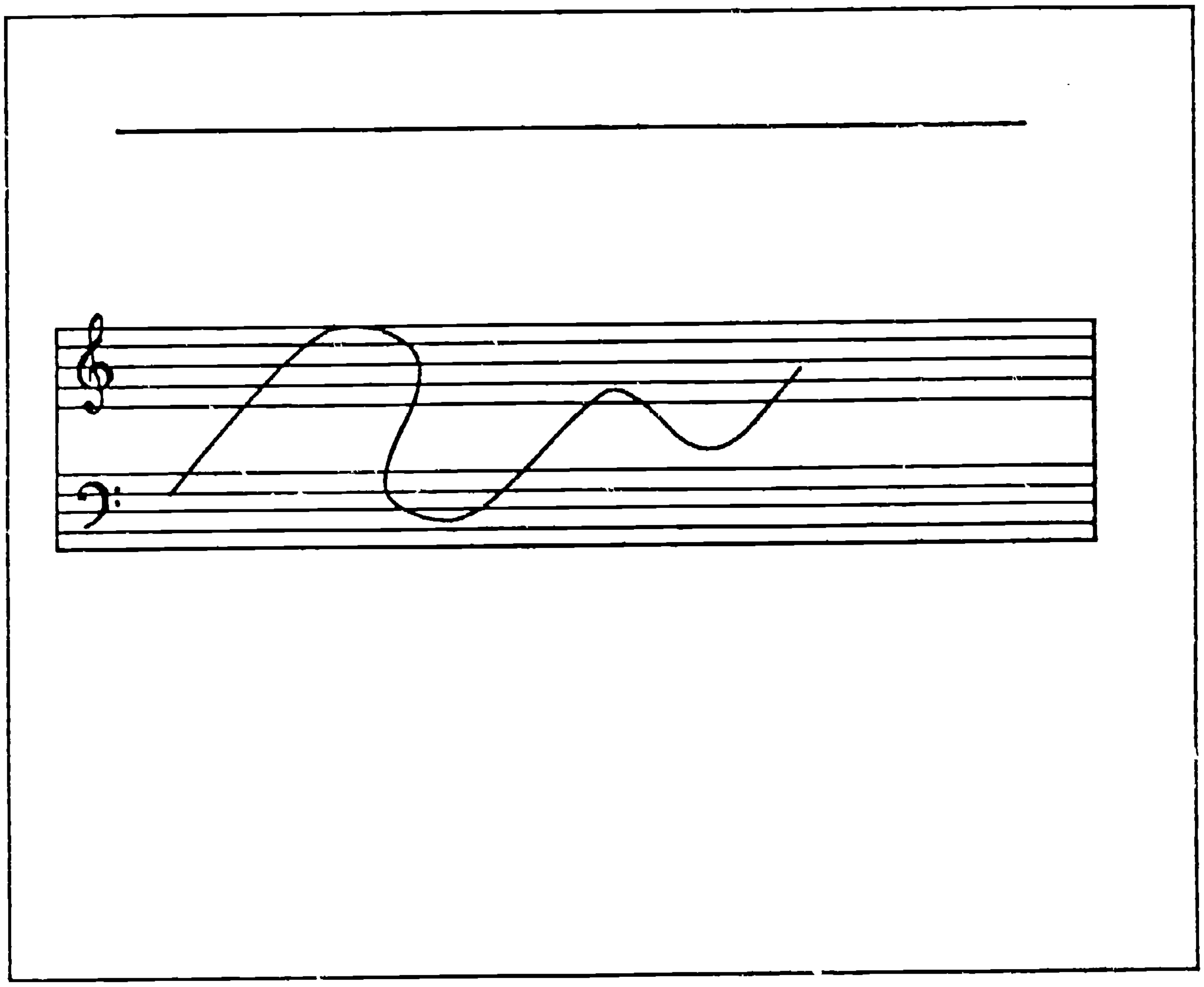


Initial set up

Redrawn from Lamb (82)

See page 10 for details

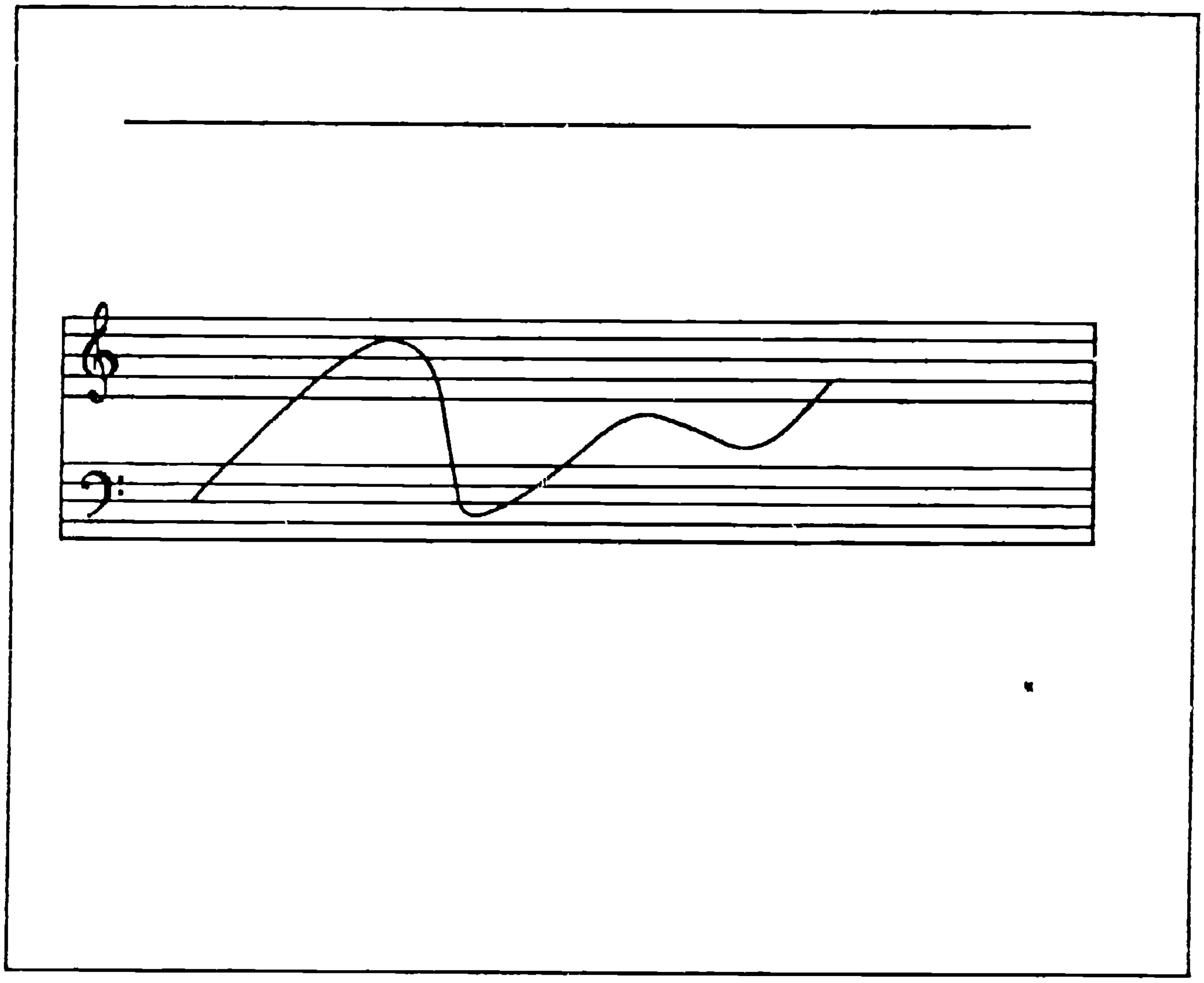
FIG 11 Lamb's Interactive graphics Game



Player draws a curve

Redrawn from Lamb 1982
See page 10 for details

FIG 12 Lamb's Interactive graphics Game

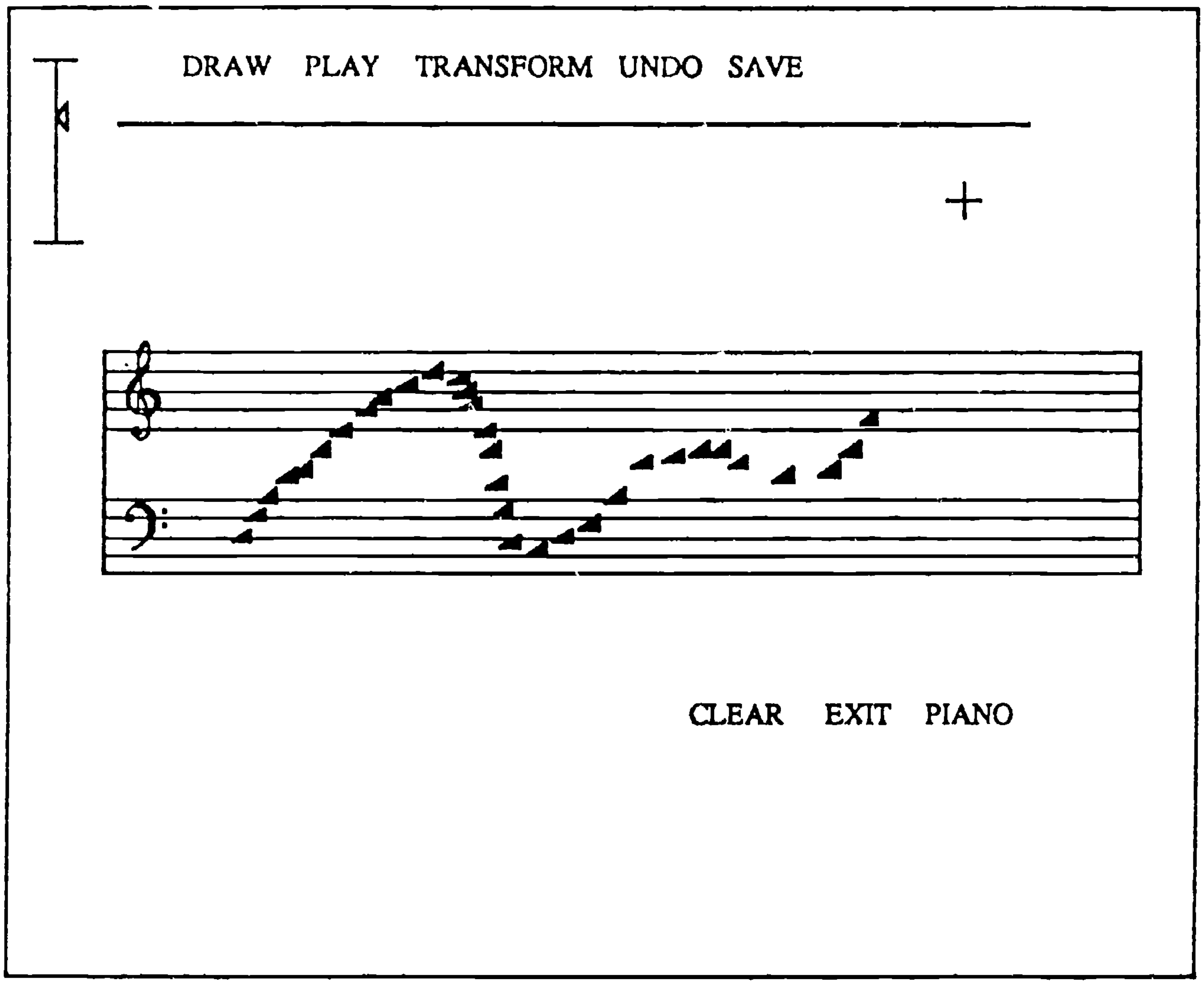


Player draws a curve

Redrawn from Lamb 1982

See page 10

FIG 13 Lamb's Interactive graphics Game

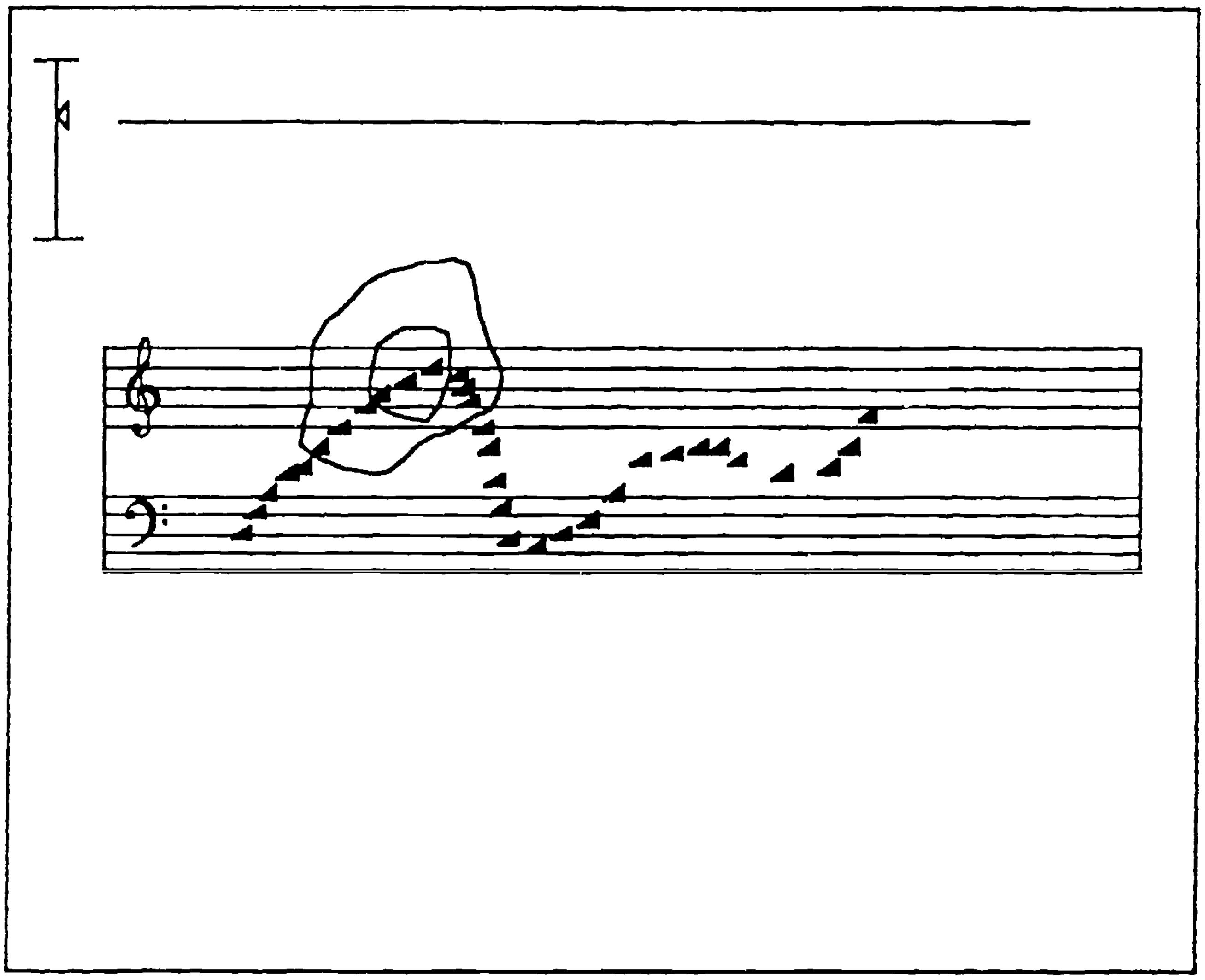


Computer changes curve into discrete notes

(Redrawn from Lamb 1982)

See page 10 for details

FIG 14 Lamb's Interactive graphics Game

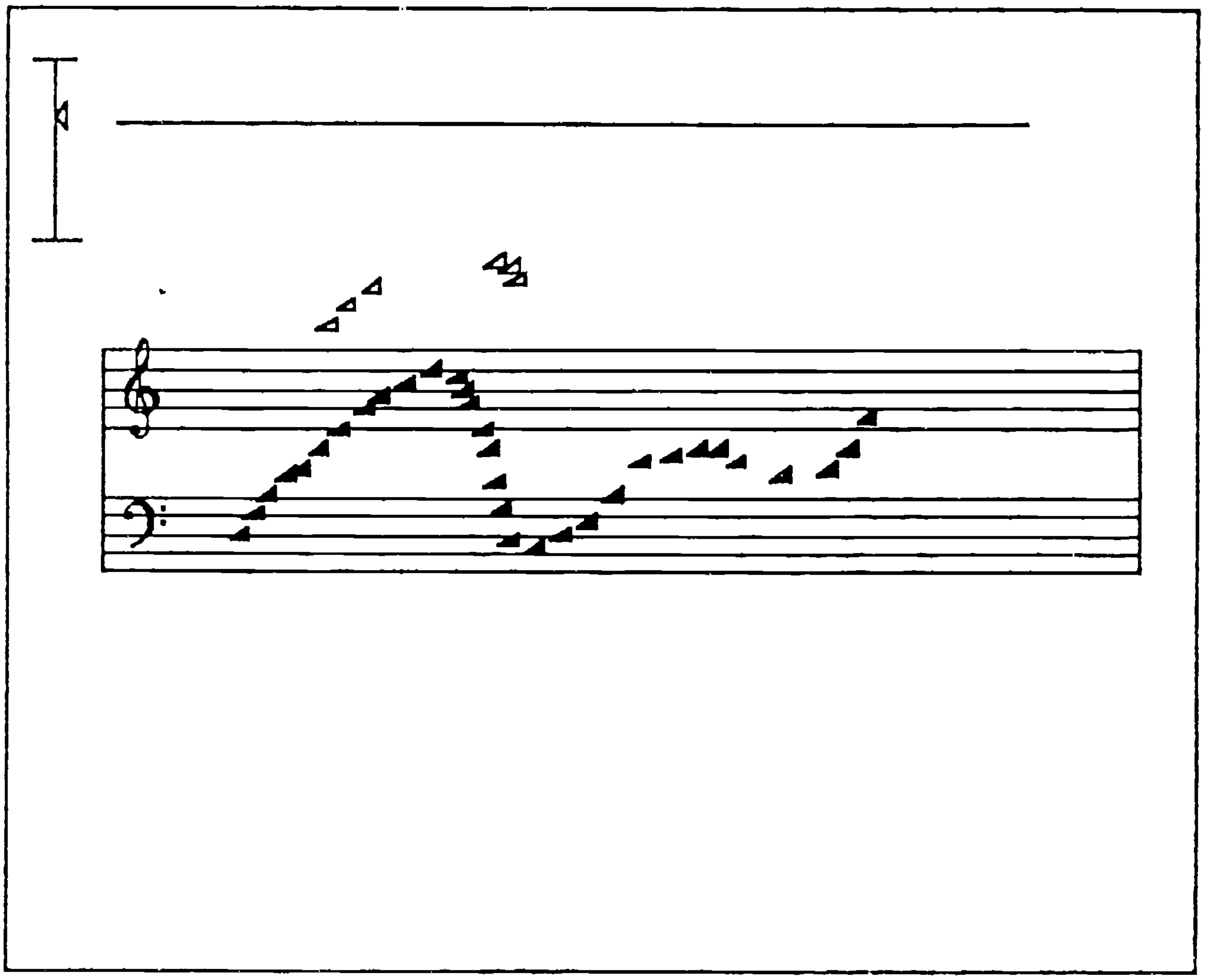


User has selected transform. Circled notes are to be transformed
Notes in inner circle are to be excluded

(Redrawn from Lamb 1982)

See page 10 for details

FIG 15 Lamb's Interactive graphics Game



Notes to be transformed are displayed as hollow triangles

(Redrawn from Lamb 1982)

See page 10 for details

Fig 16

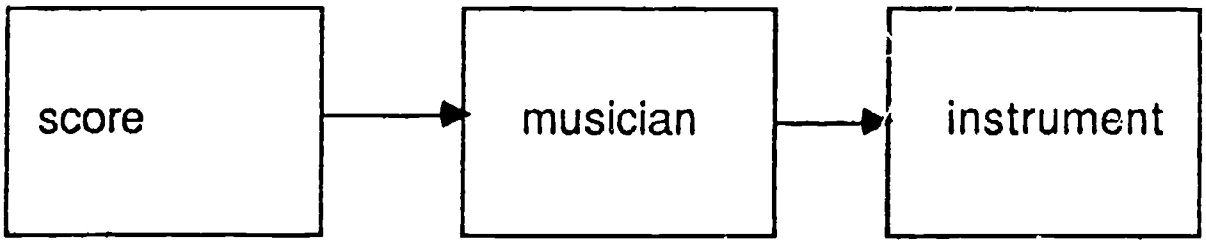
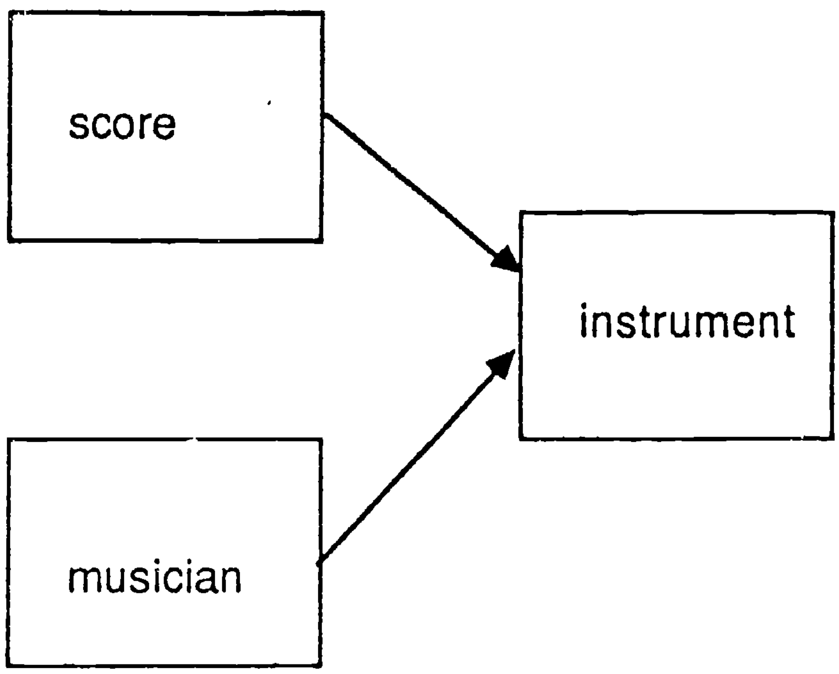


Fig 17

Fig 18



(See page 15 for details)

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