

Channeling Bamberger: An Unorthodox Appreciation of Jeanne Bamberger's Work on Musical Development and Musical Understanding

By

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Abstract

This article serves as a tribute to Bamberger as a notable researcher and teacher. The author articulates “working principles” that characterize Bamberger’s work and draws comparisons between two programs, Impromptu and Music Exploration Machine (MxM). From the perspective of music cognition, the most significant elements of this paper concern explicitly representing grouping structure and reductional structure of melodies within a computational formalism. From a developmental perspective, the most salient element is the identification and discussion of working principles associated with Bamberger’s compelling and challenging approach to research on musical development.

Recently, I read “Coming to Hear Music in a New Way” by Jeanne Bamberger in a collection of essays called *Musical Perceptions* (Aiello, 1994). I found at once that I could relate to much of what Jeanne Bamberger had to say about musical development and musical understanding and was interested in a software system that she crafted to promote musical understanding.

In this article, I will utilize two organizing themes. First, I will identify a number of “working principles” that I have gleaned as representative of influences on Jeanne Bamberger’s research methodology. It may be enlightening to view the subsequent narrative as a rationale for these working principles through writings in cognitive psychology and related fields. I will discuss the working principles by juxtaposing elements of Bamberger’s work with aspects of my own in an effort to illuminate their meaning. In particular, I will compare two software systems designed to help students develop their musical intuitions, and I will discuss matters pertaining to their nature and use. I have named the working principles in honor of some leading thinkers that, for the most part, Bamberger has mentioned in her writings. Collectively, these working principles serve to characterize parts of Bamberger’s approach to the study of musical development. Second, I will present elements of a software system called *Music Exploration Machine (MxM)* that I have been developing in recent years. Considered as a running theme, discussion of this computational system will provide the framework through which I will discuss Bamberger’s working principles.

Prolegomenon: Distributed Cognition and Curricular Implications

For a number of reasons, including the nature of Jeanne Bamberger's work, it is appropriate and beneficial to contextualize the following discussion within a set of ideas

that have come to be identified with “distributed cognition” (Salomon, 1993). According to Pea (1993), distributed cognition is the conception of cognition as something accomplished through collaborative interactions involving people and artifacts, as opposed to something possessed by individuals in isolation. This is a controversial idea in educational circles, passionately embraced by some and skeptically eschewed by others. Nevertheless, the essence of distributed cognition permeates Jeanne Bamberger's work on developing musical intuitions. The *Impromptu* system (Bamberger, 2000) coupled with a person is a distributed cognition system, as is the *MxM* system (Graci, 2009) coupled with a person. *Impromptu* and *MxM* are examples of cognitive artifacts, which Norman (1991) defines as “those artificial devices that maintain, display, or operate upon information in order to serve a representational function and that affect human cognitive performance” (p. 17). In other words, a cognitive artifact is a man-made object that helps one to think. The trade-offs associated with the educational alternatives of distributed cognition versus “person-solo” are important and far reaching (Perkins, 1993), making it worthwhile to consider the educational implications of the ideas presented in this article.

Pea (1993) suggests that distributed cognition “is not a theory of mind, or culture, or design, or symbol systems and their impact on human thought so much as it is a heuristic framework for raising and addressing theoretical and empirical questions about these and other topics” (p. 48). It is in this light that music educators should view cognitive tools for music education. Pea (1993) also observes that distributed cognition and its educational implications are most often discussed in relation to mathematics, science, and technology. As with so many phenomena relating to the mind and brain (e.g., perception, action, emotion), it seems that theoretical and practical work on

distributed cognition systems will benefit from the inclusion of music among its domains of discourse. Reciprocally, as musical cognitive artifacts inform developments in distributed cognition, ideas from distributed cognition will influence the learning and teaching of musical knowledge and skills. Appreciating systems such as *Impromptu* and *MxM* as cognitive artifacts for musical activities within a distributed cognition framework will provide music educators with new resources to help their students develop musical intuitions.

MxM provides infrastructural support for a simple symbolic music knowledge representation language, called “Clay,” that operates at the level of the note. Users can manipulate the note, which is the basic object to think with in Clay, in terms of pitch (i.e., scale degree), duration, register (i.e., location in pitch space), amplitude, and timbre. For example, users can raise the pitch of the note by one scale degree (RP) or lower the pitch of the note by one scale degree (LP). Users can expand the duration of the note by a factor of two (X2) or shrink the duration of the note by a factor of two (S2). Users can sequence these manipulators and name the sequences. These named sequences are programs in Clay. For example, if a user gives the sequence P RP P RP P LP LP P the name of “X,” and then the user plays X twice, the resulting pitch sequence would be C / D / E \ C C / D / E \ C in some register.^{1,2} If a user gives the sequence P RP P RP X2 P S2 LP LP the name “Y,” and then the user plays Y twice, the resulting pitch sequence would be C / D / E2 \ C / D / E2 in the same register.³ Going a step further, the user might

¹ The note’s default values include: scale = C major, degree = 1, location = register 4, duration = 1 beat, amplitude = medium, and timbre = electric piano.

² The slashes indicate relative direction of pitch movement, up or down.

³ A number to the right of a pitch class symbol indicates the number of beats for which the pitch is sounded. No number indicates a duration of one beat.

write the sequence X X RP RP Y Y LP LP and call it Z. The resulting melodic sequence will be the first four bars of “Are You Sleeping.” One possible lesson that users could glean from this activity would be the way that motives and phrases make up a melodic line. Users could also glean a deeper understanding of the importance of invariance⁴ for the reuse of programs and the ideas that programs computationally encapsulate.

Two salient aspects of the Clay language are that the language operates at the level of the note and that the note tends to be manipulated in procedural terms, at least when constructing motives. Other music analysis and composition tools are based on different formulations. Bamberger's own *Impromptu* system, for example, operates at the level of the motive and represents musical knowledge in a more declarative fashion. There is merit to each of these designs and to others as cognitive tools for developing musical intuitions.

Carefully designed, well-crafted cognitive artifacts for musical activity may be essentially what Todd Machover (Oteri & Machover, 1999; cited in Rowe, 2001) sought in discussing the possibility and consequence of placing focus on the mental and emotional activities of music, rather than the physical skills required to play a musical instrument:

Traditional instruments are hard to play. It takes a long time to [acquire] physical skills which aren't necessarily the essential qualities of making music. It takes years just to get good tone quality on a violin or to play in tune. If we could find a way to allow people to spend the same amount of concentration and effort on listening and thinking and evaluating the difference between things and thinking about how to communicate musical ideas to

⁴ A command is invariant with respect to some property if the value of that property after the command has been executed is the same as it was prior to command execution. An understanding of invariance is key to building stable programs that can easily be modified or reused.

somebody else, how to make music with somebody else, it would be a great advantage. Not only would the general level of musical creativity go up, but you'd have a much more aware, educated, sensitive, listening, and participatory public. (p. 6)

There is an enormous opportunity to explore the role that distributed cognition involving students and representationally rich cognitive artifacts could play in enhancing various aspects of music education. This sort of exploration will continue the line of research championed by Jeanne Bamberger in her work involving software to facilitate the development of musical intuitions.

Basic Elements of *MxM*

One particularly fascinating aspect of the fields of music cognition (i.e., psychology and music) and cognitive musicology (i.e., artificial intelligence and music) is that in these fields of study, there tends to be more focus on the processes associated with music informed by musical artifacts than on the music itself (Sloboda, 1985; Dowling, 1989; Hamman, 1999; Laske, 1988, 1999). Long before Christopher Small (1998) coined the term “musicking” to emphasize the significance of the processes that permeate music, Aristoxenus (1950), championed the same idea:

And we must bear in mind that musical cognition implies the simultaneous cognition of a permanent and of a changeable element, and that this applies without limitation or qualification to every branch of music. We shall be sure to miss the truth unless we place the supreme and ultimate, not in the thing determined, but in the activity that determines.

(p. 31)

Bamberger (2007) opens one of her articles on musical development with these words of Aristoxenus and clearly takes them to heart in her work. In slightly different terms, they constitute an important working principle.

Aristoxenus's Principle:

A focus on the processes associated with musical products is pivotal to enriching musical development and enhancing musical understanding.

(Bamberger, 2007)

Focusing on process generally leads to the identification or invention of what Seymour Papert (1993) refers to as “objects to think with” or “transitional objects” when he emphasizes their role in learning situations. Bamberger (2007), who collaborated in work at the MIT Media Lab alongside Papert in the early 1970s, says the following about objects and symbols in the context of cognitive development:

It is important to remember, in this regard, that because of their power and efficacy in providing stable “things to think with” and shared means of communication, professionals and educators in all disciplines give privileged status to symbolic notions and theoretic categories associated with their domain. (p. 2)

Bamberger qualifies the nature and scope of symbol systems, and she expresses cautionary notes to those who would be carried away by their enthusiasm for symbol systems. She nonetheless shows a great appreciation for their role in facilitating development. Despite Papert's steadfast efforts, the idea of crafting objects to serve as tools of thought for use in constructing systems of knowledge, particularly within a computational realm, is greatly undervalued.

Papert's Principle #2:

Appropriate “objects to think with” engage the imagination and empower

learning.⁵ (Papert, 1993)

Bamberger (2000) exploits the power of objects to think with and their symbolic manipulation in a software system called *Impromptu*. The featured object to think with in *Impromptu* is the “tuneblock,” which corresponds roughly to a musical motive. In contrast, the featured object to think with in *MxM* is the functionally loaded note. As I discuss the two systems side by side, it will become apparent that, while they differ from one another in a number of significant respects, they share the essential goal of providing opportunities for learners to develop their musical intuitions.

At its core, *Impromptu* is a program for manipulating and reflecting upon musical objects and the relations among the objects. In Bamberger’s (2000) own words, *Impromptu* provides students with a framework “in which to explore, experiment, and question the materials and relations that help to give musical structure its coherence” (p. 2). Precisely the same statements hold true for *MxM*.

In short, *MxM* is the coupling of a simple symbolic programming language (i.e., Clay) with infrastructural support for producing sonic, graphic, and textual representations of music. The program models melodies by playing the note, resting the note, and manipulating the state of the note in ways the user prescribes. This paper will only present a small number of low-level constructs that the program uses to generate melodic sequences, along with one definitional construct for naming sequences of commands.

⁵ I have labeled this Papert’s Principle #2 as I recall Marvin Minsky (1986) introducing “Papert’s Principle” in his book *Society of Mind*, and I thought that I should honor it as Papert’s Principle #1. The important principle that Minsky (1986) ascribes to Papert is: “Some of the most crucial steps in mental growth are based not simply on acquiring new skills, but on acquiring new administrative ways to use what one already knows” (p. 102).

The Clay commands to play and rest the note are simply P and R. The lowest level note manipulation commands include the pitch changing commands RP and LP to raise and lower the pitch by one degree of the scale; the expansion commands XD, X2, X3, X5, and X7 to expand the duration of the note by factors of 1.5, 2, 3, 5, and 7; and the shrink commands SD, S2, S3, S5, and S7, which are inverse to the expansion commands. For example, given the default state of the note, the sequence of commands P LP LP P RP P RP P produces the sequence of notes C \ A / B / C, and the sequence of commands P P X2 P S2 P P X2 P S2 produces the note sequence C C C2 C C C2.

Three definitional constructs in Clay collectively constitute a distinctive approach to computationally modeling music. The first of these simply names sequences of commands. The other two are mechanisms for explicitly modeling grouping structure and reductional structure. The first definitional construct, the *macro* definition, is used to name sequences of commands and consequently provides an invaluable cognitive convenience. To illustrate, the first two lines of the following Clay code transform PL and RL into symbols that play and rest the note for twice the current duration of the note. The last two lines transform PS and RS into symbols that play and rest the note for half the current duration of the note.

```
PL >> X2 P S2
```

```
RL >> X2 R S2
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```
PS >> S2 P X2
```

```
RS >> S2 R X2
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When modeling music in Clay, one generally defines a fairly large vocabulary of general purpose macros, including the four presented here. While vocabularies vary from

individual to individual, the intersection of these vocabularies, modulo name differences, tends to be quite substantial. An individual's vocabulary of macros can be viewed as a form of "inner speech" in the Vygotskian sense (Vygotsky, 1986).

Motivic Manipulations, or Tinkering with Tuneblocks

For a number of years, I have taught a course, Cog316 "Cognitive Musicology," which relies heavily on *MxM* to foster musical imagination and to reify musical intuition. This course appears to parallel, in many respects, the course that Bamberger describes in her book on developing musical intuitions with *Impromptu* (Bamberger, 2007). My course tends to be populated by undergraduates majoring in cognitive science, computer science, music, and linguistics. My experiences confirm the more significant observations made by Bamberger concerning non-music majors who engage in activities of reconstructing tunes and composing tunes with the help of cognitive artifacts in a distributed cognition environment.

The graphics-oriented *Impromptu* system and the inscription-oriented *MxM* system each have their own respective strengths within a distributed cognition system oriented towards developing musical intuitions. These strengths derive largely from their orientation, graphical or inscriptional. This section will establish a correspondence between these two systems through an outline of their role in courses such as Bamberger's and my own. It is worthwhile to compare and contrast systems like *Impromptu* and *MxM* because there is a need to further develop cognitive artifacts oriented towards expanding and refining the musical intuitions of non-musicians. This is a very different proposition than that of developing computational tools to facilitate the work of practicing musicians. It seems that the coalition of music cognition researchers

who do focus on crafting computational systems to promote cognitive musical development and understanding have merely scratched the surface of what is possible. My hope is that in the future, ideas from *Impromptu*, *MxM*, and other systems will be artfully incorporated into increasingly better cognitive artifacts for enriching the musical lives of all people. Bamberger (2003) articulates the basis for these beliefs in a sentence that motivates much of her work.

Bamberger's Principle:

With the opportunity to work at their own pace with immediate sound feedback from their own sketches, together with access to multiple representations at differing levels of detail the students are also able to develop, to some extent, explicit criteria for their decision making as they design-in-action. (Bamberger, 2003, p. 8)

In adopting this principle, Bamberger resists a view of maturation as a passive process, instead ascribing to the notion that under laboratory conditions, one can provoke development. In adhering to this view, she professes to be a follower of the great Russian developmental psychologist, Lev Vygotsky, who is associated with the following more general principle.

Vygotsky's Principle:

Cognitive development is encouraged by coupling a suitable infrastructure for cognitive activity (cognitive scaffolding) with appropriate cognitive tasks (interesting activities which fall within the individual's cognitive

*reach*⁶). (Vygotsky, 1978)

It turns out that both Bamberger and I begin our courses with reconstructive exercises and compositional activities in order to acquaint students with our systems and establish a musical foundation for subsequent work.

Reconstruction Exercises

According to Bamberger (2003), “cognitive developmental progress is characterized as transformations that occur over time in how individuals organize their perceptions and the strategies they bring to bear in constructing their understandings of the world around them” (p. 2). This claim is loosely grounded in, or at least metaphorically related to, Piaget’s notion of accommodation, a notion that “elaborates an action schema, making it more flexible and universal” (Droz & Rahmy, 1976, p. 44). This idea deserves to be added to the growing collection of working principles because it provides a powerful rationale for engaging students in melodic reconstruction exercises.

Piaget’s Principle:

Knowledge is constructed incrementally as mental structures and processes are productively modified in response to problems that are encountered in the environment. (Droz & Rahmy, 1976)

The first sort of exercise that Bamberger has her students engage in involves arranging a given set of tuneblocks in such a way that they play a given tune. The tuneblock is the featured “unit of perception” in the *Impromptu* system. I like to think of a tuneblock as a sign that represents a sequence of notes and appears as a patterned

⁶ By “cognitive reach” I mean essentially “zone of proximal development” (Vygotsky, 1978). I chose to avoid the latter term here simply because in Vygotsky’s original conception, society served as the scaffolding role. In this paper, I embrace the modern distributed cognition twist of opening up the scaffolding role to include cognitive artifacts, as well as other people.

square. For example, Figure 1 presents five tuneblocks, each corresponding to a segment of Dmitri Kabalevsky’s “Little Tune.”

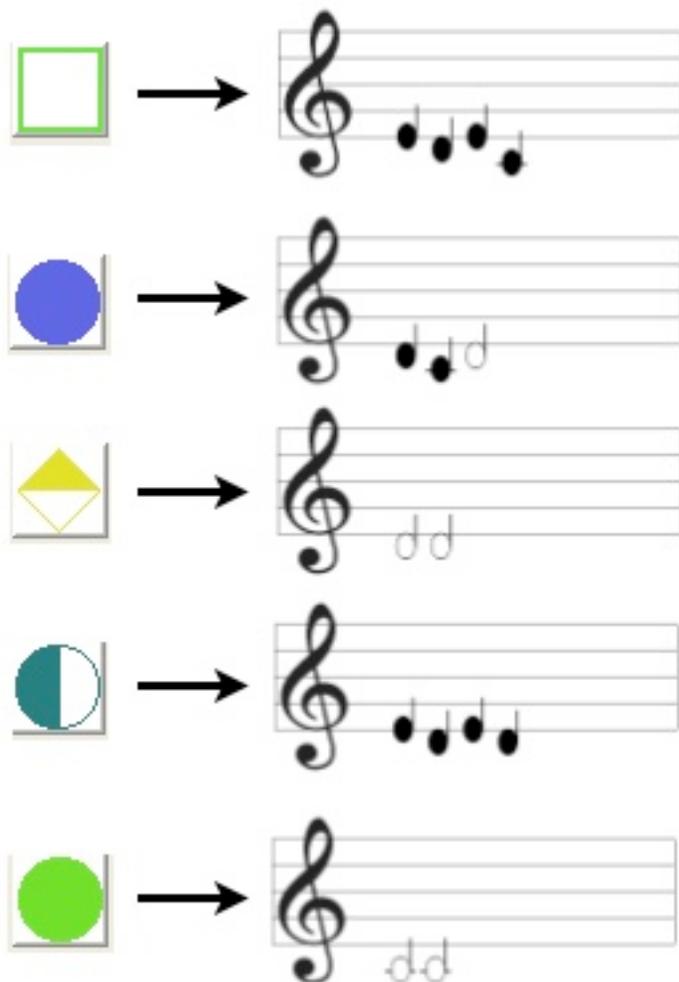


Figure 1. Tuneblocks for “Little Tune”

When working with the *Impromptu* system, if a user clicks on a tuneblock icon, the user will hear the associated sequence of notes. In viewing these figures, it is important to bear in mind that the signified content is sonic, not a score. Using my own term, suppose that a “goalblock” corresponding to the tune is provided, as shown in Figure 2. The reconstruction exercise would then be to sonically search for the sequence of tuneblocks

It is then an easy matter for students to sequence the motives to model the tune as a program:

```
LT >> M1 M2 M1 M3 M1 M2 M4 M5
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In the snapshot of the *MxM* system in action shown in Figure 4, the *MxM* Control window on the top-left provides functionality in terms of buttons, menus, and a text input field.

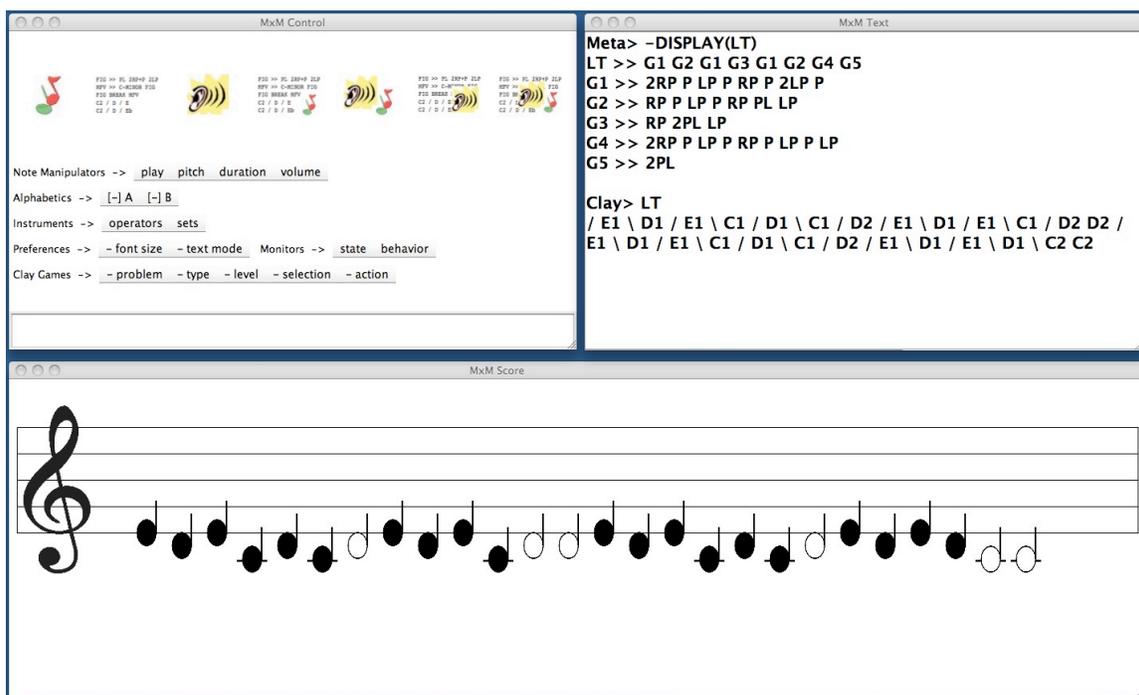


Figure 4. Unstructured “Little Tune” in Clay

Due to the nature of the system, most interaction takes place through the text input field. The menus, while functional, tend to serve mainly as a form of documentation. The *MxM* Text window displays programs and a primitive form of program output. The *MxM* score window shows musical scores, optionally augmented to show grouping structure or reductional structure.

Composition Exercises

After her students get acquainted with the *Impromptu* system via reconstruction exercises, Bamberger poses informal melodic composition assignments to them (Bamberger, 2000). Specifically, she provides students with a palette of tuneblocks, and from these she asks them to create a melody by stringing a number of occurrences of each tuneblock together as a chain of tuneblocks. It is important to note that Bamberger encourages students to modify tuneblocks according to their needs or desires. This modification is accomplished by means of dialog box interaction, which involves altering pitches and durations. As a result of these experiences, Bamberger (2003) concludes: “The data show that the students, taken as typical musically untrained adults, are able to produce coherent tonal melodies, even when given tonally and metrically ambiguous melodic materials with which to work” (p. 8). The compositions produced by her students, most of whom had little formal musical training, provide empirical evidence to support Meyer’s Principle.

Meyer’s Principle:

We all have access, whether or not we are conscious of it, to culturally derived sonic patterns that serve as organizing constraints on which music cognition is based. (Meyer, 1956)

Bamberger also recognizes another role that constraint plays in facilitating creative composition. Letting Stravinsky speak to the issue, Bamberger writes:

In using the term, constraints, I am influenced, in part, by Stravinsky (1947) who couples the term not with a sense of restriction or containment but rather with a role in creating freedom. He says, in *The Poetics of Music*: “The more constraints one imposes, the more one frees one’s self of the chains that shackle the spirit” (p. 64). (Bamberger, 2007, p. 2)

The idea that creativity is fostered by constraint is so integral to programs of development that incorporate objects to think with that it is worth recording as a working principle.

Stravinsky's Principle:

By placing constraints on certain resources and processes, one unleashes creativity with respect to other resources and processes. (Stravinsky, 1947)

Consistent with Bamberger's pedagogical routine, I follow up modeling activities in the *MxM* environment, which correlate to reconstruction exercises in the *Impromptu* environment, with compositional activities. Like Bamberger, I provide my students unfamiliar materials with which to work. She incorporates some atonal concepts (Bamberger, 2000). To some extent, I follow an approach advocated by William Russo, who makes a point of stressing that "control and restrictions lead to creativity and expansion" (Russo, 1980, p. 3). Some compositional exercises involve pitch restrictions, others involve rhythmic restrictions, and others involve timbral restrictions. Students typically respond very positively to these restrictions, as demonstrated by the quality of their melodic achievements.

Structural Generality

This section illustrates how elements of musical structure are explicitly captured in the inscription-oriented *MxM*, but not in the graphics-oriented *Impromptu*. According to Wiggins and Smaill (2000), structural generality "measures the amount of information about musical structure which can be encoded explicitly" (p. 37). Two dimensions of structural generality are grouping structure (Lerdahl & Jackendoff, 1983) and reductional structure (Deutsch & Feroe, 1981).

Grouping Structure

The *grouping* definition construct in Clay serves not only to name a sequence of commands, but also to mark the sequence explicitly as a perceptual group. It is not a mere cognitive convenience, but a theoretical convention. A Clay grouping command definition takes the form *symbol = sequence*. For example, $G1 = 2RP P LP P RP P 2LP P$ defines a grouping command such that $G1$ produces $\{ / E \backslash D / E \backslash C \}$. Braces indicate that a sequence of notes forms a group. As another example, $G2 = RP P LP P RP PL LP$ defines a grouping command such that $G2$ produces $\{ / D \backslash C / D2 \}$. Given these two grouping command definitions, $PH1 = G1 G2$ defines a grouping command such that $PH1$ produces $\{ \{ / E \backslash D / E \backslash C \} \{ / D \backslash C / D2 \} \}$. The *MxM* infrastructure provides a way of viewing the explicit grouping structure encoded in Clay programs, as indicated by Figure 5.

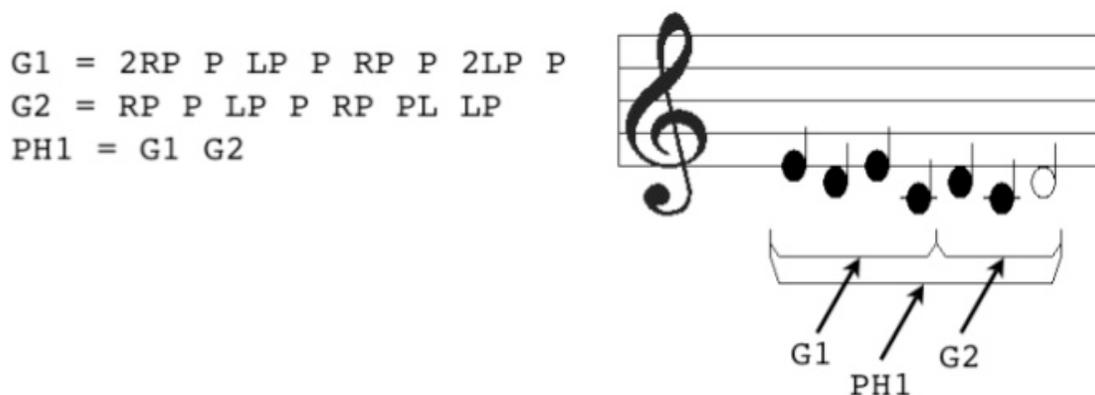


Figure 5. Grouping structures and spanning trees

A snapshot of the standard *MxM* configuration that displays a model of “Little Tune” with a spanning tree structure is presented in Figure 6. The program is presented in the *MxM* Text window. The score, together with the spanning tree corresponding to the grouping structure, is shown in the *MxM* Score window. The point to emphasize here is

that different grouping structures for a particular melody can be modeled and visualized with ease. Therefore, *MxM* is a very useful tool for probing subtle differences in grouping structures.

The screenshot displays the MxM software interface. On the left, the 'MxM Control' window contains various settings for note manipulators, alphabets, instruments, preferences, and clay games. The main window, 'MxM Score', shows a musical score for a melody on a treble clef staff. Below the staff is a waveform visualization. On the right, the 'MxM Text' window displays a hierarchical notation for the melody, starting with 'Meta> -DISPLAY(LT)' and defining parts, phrases, and groups. The notation is as follows:

```

Meta> -DISPLAY(LT)
LT = PART1 PART2
PART1 = PH1 PH2
PH1 = G1 G2
G1 = 2RP P LP P RP P 2LP P
G2 = RP P LP P RP PL LP
PH2 = G1 G3
G3 = RP 2PL LP
PART2 = PH1 PH3
PH3 = G4 G5
G4 = 2RP P LP P RP P LP P LP
G5 = 2PL

Clay> LT
{{{ / E1 \ D1 / E1 \ C1 } / D1 \ C1 / D2 } } { / E1 \ D1 / E1 \ C1 } / D2 D2 } } { / E1 \ D1 / E1 \ C1 } / D1 \ C1 / D2 } } { / E1 \ D1 / E1 \ D1 } { \ C2 C2 } } }

Meta> -SPAN

```

Figure 6. Structured “Little Tune” in Clay

Users can group tuneblocks within “superblocks” in *Impromptu* as well as being able to group superblocks into higher-level superblocks. Thus, users can capture grouping structure in *Impromptu*. Figure 7 presents a snapshot of the *Impromptu* system after the hierarchical modeling of “Little Tune” has been accomplished. However, there is no way to visualize the grouping structure in *Impromptu*. Bamberger does encourage students to model grouping structure and then render a visual of the structure by hand, as suggested in Figure 8. It is noteworthy that explicitly rendering the grouping structure of a melody is much more laborious when working with the *Impromptu* system than when working with *MxM*, since the rendering must be done by hand outside of the system. Similarly,

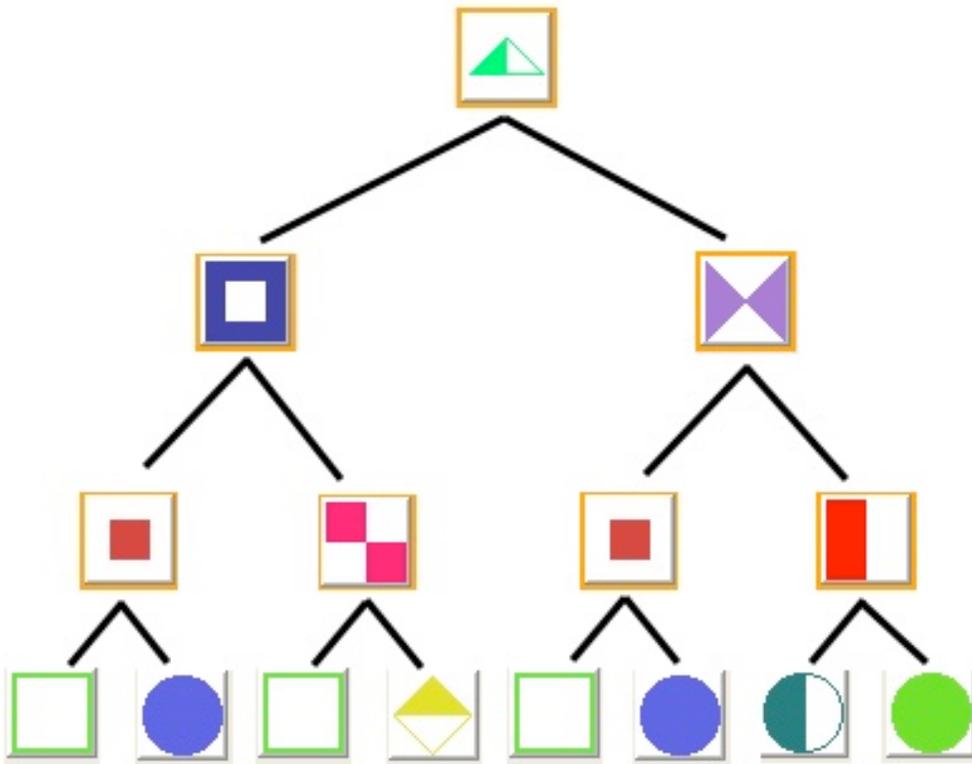


Figure 8. Tree Structure of Tuneblocks for “Little Tune”

Reductional Structure

Another form of melodic structure is reductional structure. Described by Deutsch and Feroe (1981) as the internal representation of tonal sequences, this type of model can be viewed as reductional because it is characterized by the stepwise reduction of a sequence of notes to a single note. For example, consider the sequence of notes presented in Figure 9. The eight note sequence $B / C / D\# / E / F\# / G / B / C$ can be reduced to the four note sequence $C / E / G / C$, consisting of notes of the C-major triad, by focusing on the even numbered notes of the original sequence. The resulting four note sequence can be reduced to the single note, C, by focusing on the root of the chord. This conception of the sequence is depicted by Deutsch and Feroe (1981) as the tree structure shown in by Figure 10.

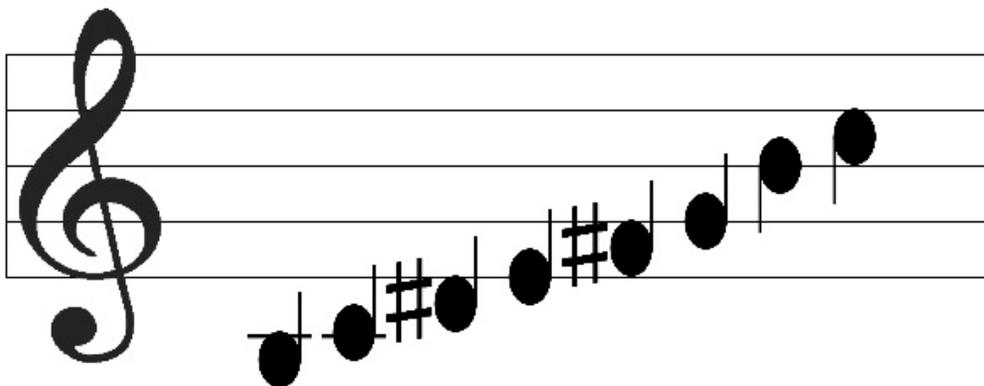


Figure 9. An eight note sequence from Deutsch and Feroe (1981)

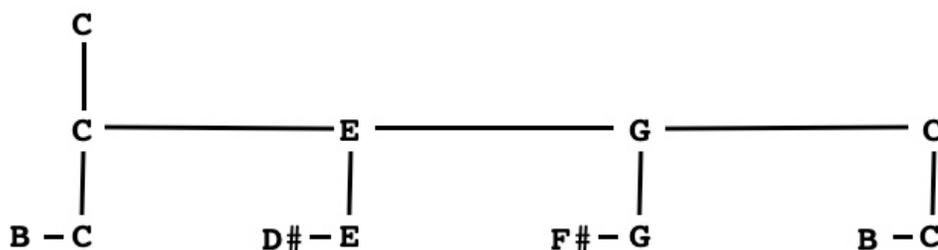


Figure 10. Tree Representation of an eight note sequence from Deutsch and Feroe (1981)

The reductional representation of this melodic sequence is presented in the Deutsch and Feroe (1981) formalism in the top portion of Figure 11. The reductional representation in Clay is shown in the bottom portion of Figure 11. A point to be emphasized here is that reductional structure captured in Clay runs on a real machine. Moreover, there is a mechanism in *MxM* to render the Clay representation visually, as shown in Figure 12. The result is a medium through which users can explore reductional structure via reflective practice.

The Deutsch/Feroe representation of the eight note sequence (Deutsch and Feroe, 1981).

$$A = \{(*, 3n); C_{tr}\}$$

$$B = \{(p, *); Cr\}$$

$$S = \{A[pr]B;c\}$$

The Clay representation of the eight note sequence.

LINE -> P

RAMP -> C-MAJTRIAD P! 3RP+P

STEP -> CHROMATIC LP P RP P!

LINE:P->RAMP:P->STEP

Figure 11. Deutsch/Feroe representation (top) and Clay representation (bottom) of an eight note sequence

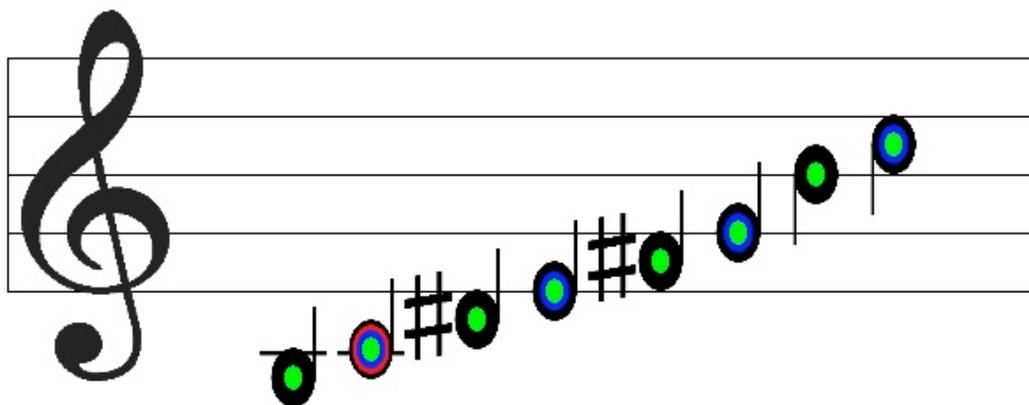


Figure 12. *MxM* color coding of reduction in an eight note sequence

Unlike the Deutsch and Feroe (1981) formalism, the Clay representation accommodates durational variation. Figure 13 displays the *MxM* visualization of a variant of the eight note sequence presented in Figure 9. This variant, which was introduced by Deutsch and Feroe (1981) as motivation for subsequent discussion, may be encoded in Clay by replacing the STEP definition in the bottom portion of Figure 11 with STEP -> CHROMATIC LP PS RP PL! RS.

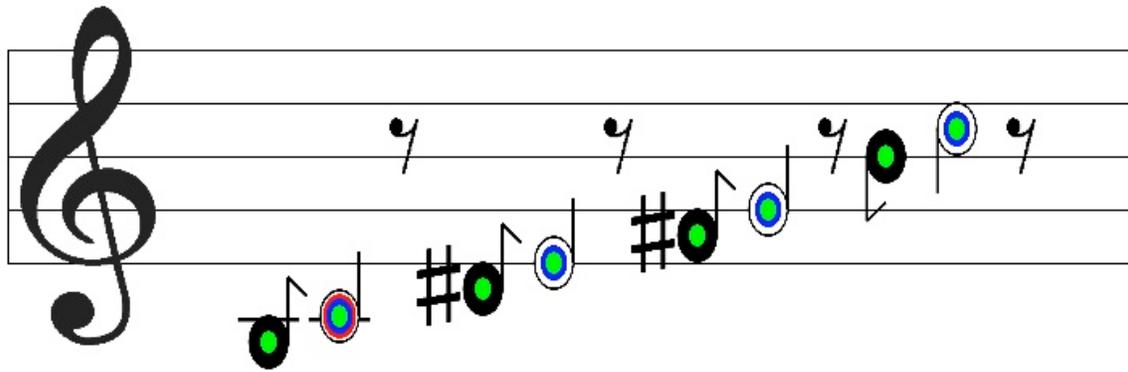


Figure 13. *MxM* color coding of reduction in an eight note sequence with durational variation

Multiple Hearings

According to Bamberger (1994), the mind organizes the information in an input stream of sound, and the result is a hearing. Thus, she argues that a hearing is the result of a process of perceptual problem solving. However, Bamberger (1994) is careful to be precise about what she means in this regard:

But I do not want to suggest that by “organizing” I mean some kind of “decoding” process, as if the incoming material has already been segmented, and these entities labeled or otherwise symbolically “encoded.” Rather, it is exactly because sound/time phenomena do not come already structured, but rather hold the potential for being structured that different hearings are possible. (p. 134)

Throughout much of her work, Bamberger emphasizes her view that the phenomenon of multiple hearings is a potentially rich source of musical understanding.

One particularly salient manifestation of multiple hearings can be seen in the different grouping structures that can be derived from a sequence of notes. For example, Figure 14 presents two grouping structures for the first 8 beats of “Little Tune.” If users privilege similarity of pitch over symmetry of beat duration, they will probably like the first. If users privilege symmetry of beat duration over similarity of pitch, they will

probably like the second. The point is that they are distinctly different, viable hearings.

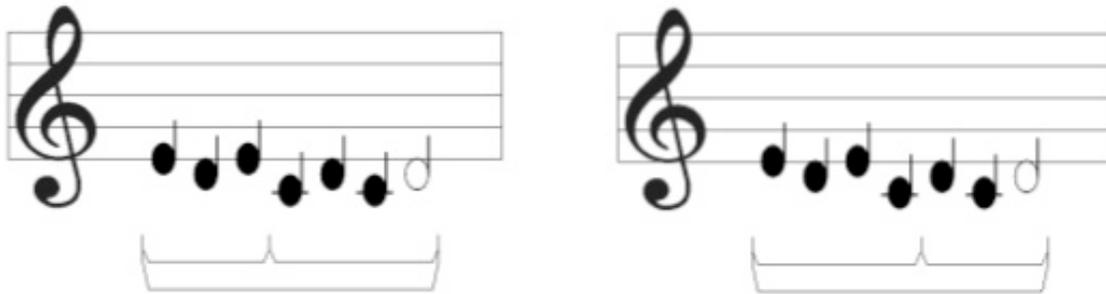


Figure 14. Two different hearings: one privileges similarity of pitch (left) and one privileges symmetry of beat duration (right)

Bamberger mentions Israel Rosenfield in conjunction with alternative perceptions of a given stream of input, which is a recurrent theme in her work (Bamberger, 1994).

Rosenfield's Principle:

We perceive the world without labels, and we can label it only when we have determined how its features should be organized. (Rosenfield, 1988, p. 187)

The medium of Clay dramatizes the idea that users can label percepts only after they have determined how features should be organized. Only if users determine to privilege similarity of pitch over symmetry of beat can they write something like $G1 = 2RP P LP P RP P 2LP$ and $G2 = P RP P LP P RP PL LP$ and $PH1 = G1 G2$ in order to establish the grouping illustrated on the left in Figure 14. Only if users determine to privilege symmetry of beat over similarity of pitch can they write something like $G1 = 2RP P LP P RP P 2LP P$ and $G2 = RP P LP P RP PL LP$ and $PH1 = G1 G2$ in order to establish the grouping illustrated on the right in Figure 14. There is no room for vagueness when modeling grouping structure in Clay.

Consider the ways in which users could group the simple melody presented in Figure 15. Users would probably not group it in the manner indicated by the spanning tree of Figure 16, for reasons given in the figure that pertain to the well-known grouping preference rules (Lerdahl & Jackendoff, 1983). Users would probably not group it in the manner shown in Figure 17, for the key preference rule of “parallelism” is simply not acknowledged in that grouping structure. Arguably, the grouping structure displayed in Figure 18 is a candidate for a sound grouping structure for the melody, one that an experienced listener would find sensible.

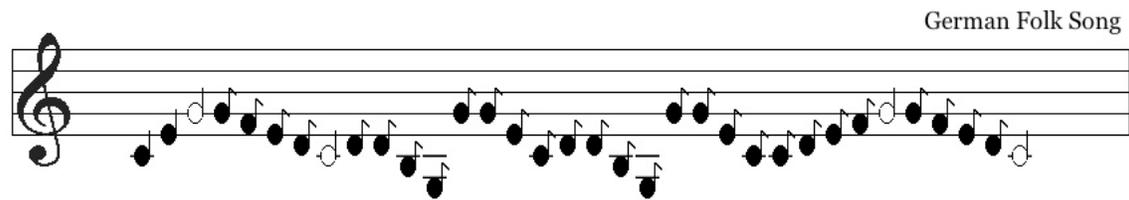
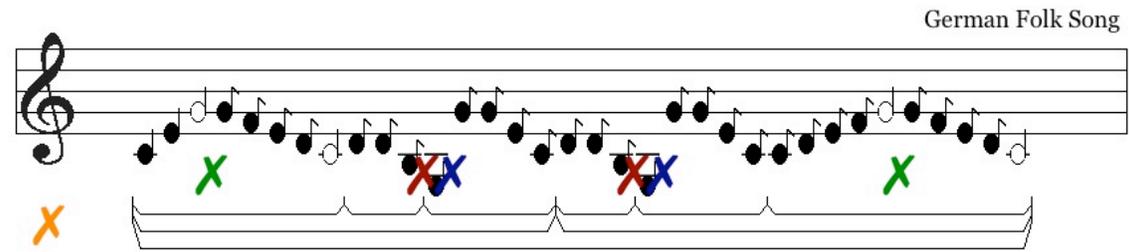
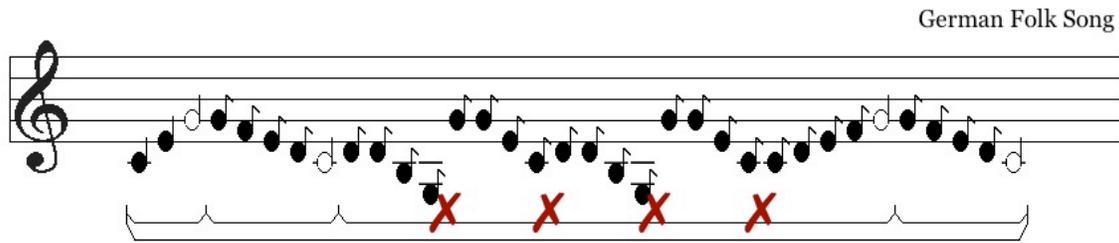


Figure 15. German Folk Song



- X** - proximity break is indicated
- X** - similarity break is indicated
- X** - no break is indicated
- X** - issues pertaining to the intensity of breaks

Figure 16. Bad grouping structure #1 for German Folk Song



X - breaks due to **parallelism** and other phenomena are **not** recognized

Figure 17. Bad grouping structure #2 for German Folk Song

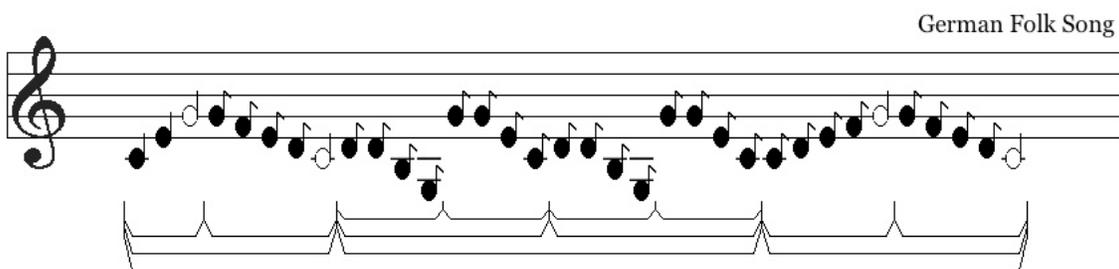


Figure 18. Sound grouping structure for German Folk Song

The significance of this grouping discussion is that it reinforces the pedagogical powers of inscription languages that are supplemented with visualization tools. Modeling mechanisms that are sensitive to salient features in a rich domain like melody and that are at once flexible (i.e., easily adjusted) and concrete (i.e., clearly understood) provide a basis for making “progress” with respect to understanding phenomena associated with the domain.

Geertz's Principle:

Progress is marked less by a perfection of consensus than as a refinement of debate. (Geertz, 1973, p. 29)

The spanning trees corresponding to different grouping structures constitute a tool for refining debate on the perceptual problem of grouping in tonal music. The grouping

preference rules of Lerdahl and Jackendoff (1983), grounded in well-known Gestalt principles, conflict with one another in fascinating ways. The result of this conflict is debate pertaining to “proper” hearings and creative interpretations of tonal melodies. The spanning trees in Clay and *MxM*, defined with inscription and pictured graphically, serve as a cognitive tool for refining debate on issues pertaining to grouping structure. The significant side effect of this debate is a deepened appreciation for aspects of the grouping problem in tonal music. Bamberger (2007, p. 21) addresses the issue of multiple hearings from a Geertzian perspective in the following passage:

So, as educators and as researchers, rather than arguing about what counts as progress in the course of musical development and what determines a hearing that counts as better than another, it seems more productive to follow the view of Clifford Geertz, the cultural anthropologist, when he proposes that “... progress is marked less by a perfection of consensus than as a refinement of debate. What gets better is the precision with which we vex one another” (Geertz, 1973, p. 29).

A hallmark of Bamberger’s research is an embrace of this idea. The caricature that she presents in her work on rhythmic conceptualization via her MET/MOT dialogs (Bamberger, 1991, 1994) is a powerful example of Geertz’s principle in action.

A very different way to conceive of multiple hearings is by contrasting grouping structure with reductional structure. Grouping structure can be understood in terms of general purpose gestalts. To understand reductional structure requires additional knowledge associated more directly with tonal considerations. The ability to alternately or simultaneously focus on grouping structure and reductional structure enriches musical understanding.

Making Meaning

Bamberger has championed the use of multiple representations of musical knowledge in the service of developing musical intelligence. She acknowledges the influence of Marvin Minsky on her thinking in this regard when she writes, “A thing with just one meaning has scarcely any meaning at all. That’s why its almost always wrong to seek the ‘real meaning’ of anything” (Bamberger, 1991). Another example lies in the statement:

Rich meaning-networks, however, give you many different ways to go: if you can’t solve a problem one way, you can try another. True, too many indiscriminate connections will turn your mind to mush. But well-connected meaning structures let you turn ideas around in your mind, to consider alternatives and envision things from many perspectives until you find one that works. And that’s what we mean by thinking! (Minsky, 1986, p. 64)

The value of multiple meaning networks is so palpable in Bamberger’s work that it is worth recording as a working principle.

Minsky’s Principle:

Multiple representations are essential to robust thinking. (Minsky, 1986)

Musical representations can be “superficial” or “deep”—both of which are important. Superficially, a melody can be rendered sonically, graphically (e.g., a score or piano roll notation), or textually (e.g., MIDI notation). To capture elements of its deep structure, a melody can, for example, be modeled in terms of its grouping structure or its reductional structure. The meaning of a melody, according to the absolutist position, lies in the musical processes themselves (Meyer, 1956). Grouping structure and reductional structure are two dimensions from an absolutist perspective, along which musical meaning is derived.

Sloboda (2005) has observed that making sense of music has often been equated with the process of discovering and representing its structure. I have tried to suggest that executable inscription languages tied to automatic visualization procedures provide a good medium through which to discover, explore, and represent musical structure. The ultimate rationale for this suggestion lies in the value of writing in order to clarify and expand ideas. In discussing the development of thought in human history, Wolf (2007) writes the following on Vygotsky's understanding of the importance of writing in the processes of learning and development.

As the twentieth-century Russian psychologist Lev Vygotsky said, the act of putting spoken words and unspoken thoughts into written words releases and, in the process, changes the thoughts themselves. As humans learned to use written language more and more precisely to convey their thoughts, their capacity for abstract thought and novel ideas accelerated. (pp. 65-66)

Computationally transforming inscriptions into conceptually grounded graphical output animates the process of writing to learn. In view of the fact that Pea (1993) is so closely associated with the use of the term "inscription" to refer to external representation intended to further collaborative understanding, I am inclined to associate Pea's name with the following working principle.

Pea's Principle:

*Cognitive tools for mapping inscriptions onto pictorial representations
hold great potential for fostering individual development through
collaborative progress. (Pea, 1993)*

Pea's principle suggests that incorporating substantial inscription components into computational systems designed to foster musical development and understanding is a

potentially positive activity, which is something that I have experimented with in *MxM*.

Future Research Considerations

This paper has framed a view of music education that is grounded in a collection of powerful ideas centered on learning and knowing and has featured cognitive tools for developing musical intuitions. The implicit suggestion is that this approach to music education is a valuable accompaniment to more well-established approaches to music education. In considering how the advocated approach can be advanced and what lies ahead for those interested in exploring this educational expanse, three salient directions for future research that come to mind. These directions for future research involve the design of cognitive artifacts for musical endeavors, theoretical considerations for music mediation technology, and the design and evaluation of classroom activities that incorporate cognitive tools of a musical nature.

Concluding Remarks

In this paper, I have used the names of Aristoxenus, Bamberger, Geertz, Meyer, Minsky, Papert, Pea, Piaget, Rosenfield, Stravinsky, and Vygotsky in the service of enumerating a number of working principles that I feel collectively characterize the sound conceptual medium in which Jeanne Bamberger approaches much of her research. I have surveyed some of her work and discussed some of my own work in an effort to delineate strands of research pertaining to the design and use of cognitive tools for the development of musical intuition. Finally, I have suggested a number of directions for future research in this area of music education.

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