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TURNING MUSIC THEORY ON ITS EAR

Do we hear what we see; Do we see what we say?

Revisiting some of the hundreds of children's drawings of simple rhythms and melodies that I have collected over the years, I found myself marveling all over again at how it is we ever learn to turn the continuous flow of our own singing or our inner, bodily feel for continuous, rhythmic actions – clapping, bouncing a ball, swinging on the park swing – into static, discrete descriptions that hold still to be looked at "out there." I continue to be fascinated by children's spontaneous invention of notations because they show the complexity of this conceptual work and the evolution of learning involved *as it is happening*. Sometimes this complexity emerges by comparing one child's work with that of another's, and sometimes it can be seen in watching one child as from moment-to-moment she transforms for herself the very meaning of the phenomena she is working with (Bamberger, 1991a).

But in looking back at all these drawings, I was struck once again by how easy it is to miss these marvelous transformations from action into description if we limit our looking and take as givens just those kinds of entities that are selected by our conventional notational symbols. Indeed, the children's drawings reveal for scrutiny things that we have forgotten we ever did not know. Can you imagine what it was like before you learned how to read – words, numbers, equations, standard music notation? That piece of the past for most of us is simply *wiped out.* And I am going to argue that this wipe-out phenomenon plays a big role in our instructional dis-abilities.

Watching children invent ways of representing the music they have made, and also listening closely to the efforts of my MIT students as they try to say what they hear in more complex compositions, has helped to turn my beginning music theory classes on their ears. And to support this small revolution, I have developed an interactive, computer-based music environment where beginning music students are composers. Interrogating their intuitive abilities to compose coherent melodies and rhythms, asking questions that they put to themselves to account for what they are able to do, they are developing these powerful musical intuitions and going beyond

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them. Perhaps what I have learned can be helpful to those developing educational computer environments in other areas, as well.

STATING THE PROBLEM

There is a question being asked more and more frequently in the music education literature (and often echoed in the math and science education literature): Why do fundamentals courses which are intended to begin at the beginning, so often become problematic? Why do they so often seem irrelevant especially to those students who have already been identified as "gifted?" Why do they become more like therapy sessions treating student stress instead of an environment in which students are developing the healthy, powerful intuitions that they bring with them to these classes?

From everything I have learned so far, my best hunch is that these problems arise because we have been making some critically mistaken assumptions about our students' healthy musical intuitions – what they know how to do already. We are asking students to begin with what *we* believe are the *simplest* kinds of elements, but which for them may be the most difficult. In doing so, I think we are confusing *smallest* elements – in music, isolated, de-contextualized pitch and duration values – with what we assume are also the *simplest* elements. We focus on these small, discrete elements partly because they are the easiest to *define*, and thus also the easiest to assess with respect to whether students have learned them or not. But probably more important, the symbols that represent these elements are the tools of the trade for seasoned musicians – they are what we depend on for communicating with one another, for *saying* what we heard and for telling others what they should hear and play. But in doing so, we are not distinguishing between our own most familiar units of *description*, the notes shown in a score, and the intuitive, contextual units of *perception* – those which young children and most adults, too, are attending to in making sense of the music all around them.

To be even more provocative, I will argue that the kinds of elements and relations that untrained listeners and also self-taught players are attending to in making musical sense, are closer to those we associate with the artist who plays "really musically" – the ability to shape a phrase, to follow the musical line, and to expressively project feeling and meaning. This is what I think the violinist Louis Krasner[1] was getting at when I heard him say to

[1] Krasner was an eminent violinist who died in 1994. In recent years he taught at the New England Conservatory of Music and it was there at one of his master classes that I overheard this comment.

a student, "Forget about the notes and play the music." But of course there is a paradox, here: the student had to have the notes before she could forget about them. It is this paradox that is, I think, at the crux of the matter.

PROBLEM 2: THE WIPE OUT PHENOMENON

The problem is that once we have thoroughly internalized conventional symbolic expressions associated with a professional community of users – the things we name and our categories of analysis – they become the tools of our trade, and we are no longer aware that in internalizing them we have also made a *tacit ontological commitment*: Put most strongly, we come to believe in the objects and relations we name with our descriptive, symbolic conventions as just those which exist in our particular domain. Through practice, these are the objects, features, and relations that tacitly shape the theory and structure of the our domain – how we think, what we know and teach to others, and thus what we take to be "knowledge." Our units of *description* come perilously close to becoming our units of *perception* – we hear and see what we can *say*.

My research and that of others strongly suggests that what we can say with standard music notation – the elements and relations referred to by its conventional symbols, differs in specific and provocative ways from the "natural kinds" that inhabit the spontaneous descriptions made by musically untrained children and adults (and I mean here, specifically those who have not been taught to read standard music notation (SMN)). Most important, the evidence shows that spontaneously invented notations not only give priority to specifically different but also *equally valid* musical features and relations as compared with those that inhabit SMN (Bamberger, 1986; 1991a).

The nature of these differences is embedded in our everyday experience. For example, in moving around in real life, we must do so it sequentially, one thing after the other – the next step cannot come BEFORE the last step; the 4th of July is always AFTER the 3rd and BEFORE the fifth; and Wednesday always comes AFTER Tuesday. These calendar sequences are, of course, symbolic artifacts and they are certainly useful to believe in – we can compare one Tuesday with another, count up Tuesdays, use "Tuesday" as a tag to remember what we have to do, because Tuesday is always the same, the same place in the sequence – but only partly. Consider the following events: This year the 4th of July was "a Tuesday," but it FELT more like "a Sunday." So the NEXT day I got mixed up; I kept thinking it was "a Monday." After all, Monday does come after Sunday. In the passing of time in real life we take things as they come, one at a time and one thing

after the other. But what we take as a "thing," the symbolic artifact or the perception of it, how we use it, influences what we take to be coming next. 12 comes AFTER 5 if you are counting, but the bunch of 12-grapes might come BEFORE the bunch of 5-grapes if you are hungry. Alice and the Queens make the point. The White Queen says:

"... we had SUCH a thunder storm last Tuesday – I mean one of the last set of Tuesdays, you know."

Alice was puzzled. "In our country," she remarked, "there's only one day at a time."

The Red Queen said, "That's a poor thin way of doing things. Now here, we mostly have days and nights two or three at a time, and sometimes in the winter we take as many as five nights together – for warmth, you know" (Carroll, 1960).

Everyday life is what Alice is talking about and that is what is reflected in everyday drawings of children and adults who are not trained musicians. The Queens are like the others who live and believe in a symbolic world where the names for things (nights, days, notes) name property classes and these are useful because they can, in talking and in paper-space, be put in any order, in bunches, several at one time. But even in talking or notating, the names have to come one after the other, not in the bunches the names name. It all depends on what you can and want to do with "things" – but you need to be able to tell the difference.

Our conventional units of description function like lenses that shape, select, sort out, and segment the world. And like eye-glasses, as long as they are left alone, as long as they are not perturbed, we are happy to just look *through* them. It is only when something goes wrong – the lens gets cracked, scratched, fogged up – that we are forced to *look at* what we normally look through. For instance, when musicians look through their conventional eye-glasses at children's invented notations, these inventions seem simply wrong. With the symbolic conventions shaping meaning, the inventions appear as exceptions, abberations, contaminants. But what if we take the drawings seriously, positing that if we only knew where to look and how, they could make perfect sense? On this view, the inventions become an occasion to look at the lenses that we usually look through. And if we succeed in doing that, then these inventions can become clues to the powerful strategies that children and also adults bring with them in constructing musical coherence.

Barbara McClintock, the Nobel prize winning biologist, puts it this way:

"So if the material tells you, 'It may be this' allow that. Don't turn it aside and call it an exception, an aberration, a contaminant. That's what's happened all the way along the line with so many good clues" (Keller, 1983).

As Leo Treitler has so eloquently put it: "There is no immaculate perception" (Treitler, 1989). Every description, every set of symbolic representations, those invented by children as well as those associated with a community of professional users, are necessarily partial and they are so in two senses: they are partial in being *incomplete*, and they are also *partial to* certain aspects of the phenomena while ignoring others. With respect to a community of professionals, Thomas Kuhn has pointed out, for example, that the physicist thinks with the relatively few but powerful symbolic formalisms shared by this community of users, and these shape the theory and the structure of that domain (Kuhn, 1977). Similarly, Phillip Morrison has said of maps, the cartographers' working notation:

"Each map is in a way a *theory* that favors certain approximations. Procedures like selection, simplification, smoothing, displacements to make room, out-of-scale notation for bridges, streams, and roads so narrow that they would become invisible at true scale, enter inescapably" (Morrison, 1991).

All of which may appear to be an argument against teaching and learning notational conventions, but that is not at all the case. The interesting questions are: what are the approximations a community favors, what kinds of entities and relations is the community partial to, how do these differ from the kinds of entities and relations that other communities are partial to, how can we find out, and what difference do the differences make, to whom, for what, and why?

To study children's spontaneous productions, taking them seriously in search of answers to questions such as these, we need to become something like cultural anthropologists: like the anthropologist entering a new culture, we need to begin with the assumption that what is found there – rituals, myths, modes of representation – no matter how initially strange, incomprehensible, meaningless, they make sense to the inhabitants of that culture. Once making that assumption, the task becomes mutual and reciprocal: we must learn to understand our own belief systems, our own deeply internalized intuitions for making sense, even as we learn to understand the sense-making of the other. As Clifford Geertz has said of the practice of anthropology:

"... 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).

But how do we go about such studies, what sorts of questions, situations, will effectively reveal the meaning-making of our so-called "naive informants" while also perturbing, vexing our own assumptions? I have found that the most evocative situations, the most productive research questions, and the greatest learning happen in the real life of the classroom – the moments that arise in trying to understand puzzling events that occur in

the midst of working with students. In these moments caught on-the-fly, teaching and research, instead of being separate and different kinds of enterprises, become a single, mutually informing one.

AN EXAMPLE, AN EXPERIMENT, ANOTHER PROBLEM

Consider the following example: While working in active music classroom situations, I was surprised to see (based on my assumptions about what needed to be taught) that 5 and 6 year olds, without anyone teaching them or even asking them to do so, were showing me where phrases end and where a new phrase begins, where to stop and start again. Puzzling over this unexpected happening, it struck me as obvious (but probably for the first time), that if any of us in listening to a piece, cannot tell where to stop and start again, we say the music simply doesn't make sense. This often happens in listening, for instance, to music of another culture. Although having learned just as naturally to hear where their music stops and starts again, the same music makes perfect sense even to the youngest children in that other culture.

Try a little experiment that I have often watched in my MIT classes. Sing the first, big part of the tune, "Did you ever see a lassie" to yourself (up to and including the words, "this way and that"). If I ask you, "How many 'chunks' are there in what you sang?", like most people, even if you don't know the words, you will probably say, "two." That is, you hear this first big part of the melody grouped into two larger "chunks" or phrases:

1. Did you ever see a lassie go this way and that way?
   and
2. Did you ever see a lassie go this way and that?

Now if I ask you, "What is the difference between the end of the first phrase and the end of the second phrase," you will probably say that you heard the end of the first phrase ("that way") as relatively incomplete, left hanging, while you heard the end of the second phrase ("and that") as relatively settled, complete and resolved. Why is this so?

Your first hunch, like my students', is probably that the two phrases end on *different pitches*. But, remarkable as it may seem, both phrases end on the *same pitch* (see Figure 1).

Moreover, your reference to pitch was most likely only triggered by my question – you grabbed for the name of a thing that you associate

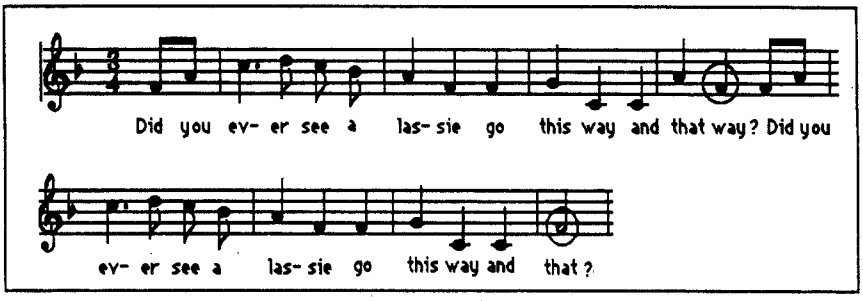

Figure 1. Both phrases end on the same pitch.

with answers to questions like that.[2] But in actually singing and listening, "pitch" as a separate entity, as a property class, was almost certainly not what you were attending to. The feeling of tension at the end of the first phrase, followed by resolution at the end of the second results from the reciprocity between at least pitch and rhythm. You were responding to this confluence of features and their relations which together generate *situational meaning and function.* And it is interesting that this reciprocity is reflected in our metaphors that conflate "up and down" in pitch with "up and down" in rhythm ("up-beat, down-beat"). When Tuesday is the 4th of July and its situational meaning and function is "Sunday," then Monday comes AFTER Tuesday.

The problem is that we have no way of talking about and accounting for these perceived, situational confluences without taking them apart into their separate properties. We can say that in perception the multiple properties of events are highly aggregated, merged, fused. But putting it that way states the problem rather than solving it. For terms such as "confluence," "aggregated," "fused," already imply a *collection of separate properties* when, in fact, as you have experienced in the Lassie example, these properties simply do not exist as separate entities in our feelingful, functional hearings. We do not piece together a hearing, putting it together out of the separate features we can name – a paste-up collage of, for instance, pitch, duration, accent, timbre, register.

And it is not only in musical experience that this is the case. Consider the experience of "going faster." You say, while sailing your boat or even walking, "Now I am going faster." There is no ambiguity about it, you experience the change as just that. But to express that change, and especially to *measure* it, you have to take apart what was an all-at-once kind of

[2] In fact, the endings of the two phrases sound different because of differences in their rhythmic structure. Specifically, the first phrase ends on a "weak beat" with a shorter duration, while the second phrase ends on a "strong beat" and with a longer duration.

thing into two separate kinds of things that did not exist in the moment's experience – time and distance. Indeed, first you have mentally to *construct* them, invent them, find them as constituents of your experience. And you also have to construct the *reference systems* in which each of the appropriate units and their symbolic expressions are given meaning. Moreover, having done so, you have to mentally construct the *relationship* through which to put them together – ratio. And the resulting ratio is no longer two things but a single "thing" – velocity. Distance and time, each of which you may have been able to experience separately, are now one – velocity, the interaction between them. And finally you must compare this resulting velocity-thing with another velocity-thing – the velocities before and after the change. And that result you are asked to believe in as a representation of your familiar experience, "going faster."

We can, however, interrogate these experienced "momentary confluences." Turning back upon them, taking them apart, we can liberate from the meld and name the component pieces of these experienced confluences. In doing so we are also, in a profound sense, bringing these components into existence. And once giving names to things, we also gain a certain power, the power to play with the things named, shifting our attention at will among them and combining them in novel ways. The trick is to be able to selectively choose among these multiple representations depending on when, why, and what we want to use them for.

As teachers and researchers we also use named kinds of features in an effort to interpret behaviors, to describe and to differentiate among hearings made. But that puts us again in the center of the paradox: how can we account for hearings of another by making reference to those entities and relations embodied by our symbol systems, when they have not yet been constructed, when they do not yet exist as entities in the coherence-making of those whom we are trying to understand? While we might think of the "others" as our naive "informants," they may also be our avid audiences and certainly they are quite effectively making sense of the world all around them. So we are inevitably left with a problem of our own creation: having once taken apart what is experienced as functions and feelings, we are tempted to believe that what we have thus learned to say is what is being heard and felt, leaving us to puzzle over how to piece together what, in experience, is not in pieces at all. While I find no easy way out of this confounding situation, recognizing it helps to temper conclusions, most of all conclusions about how we learn and what that might tell us about how we teach. And that brings me back to the classroom.

IMPROMPTU: A REFLECTIVE PLAYGROUND FOR DEVELOPING MUSICAL INTUITIONS DESIGN PRINCIPLES[3]

Impromptu is a more intuitive, icon driven version of MusicLogo developed in S. Papert's Logo Lab beginning some 20 years ago.[4] Two very basic principles have guided the design of both MusicLogo and Impromptu. First, computers should be used only to do things we cannot do better in some other way. Second (borrowed from Hal Abelson), an educational computer environment is valuable to the degree it causes its developers to re-think the structure of the relevant domain.

Thus instead of saying, "Here is this computer with all these neat possibilities, what can I do with it?" I said, "Here are some things that beginning music students need to be able to do and they can't do them with the means that are around." In short, having taught beginning music courses for years and written a music text that lots of others were using (Bamberger & Brofsky, 1988), I got tired of hearing myself talk about music, and asking students to listen to music just so they could talk back, because it did not work.

So I took the plunge: "Let's see if a computer/synthesizer environment can be developed that will *meet these unsatisfied needs.*" Moving in on the process, I worked together with folks in Papert's lab and later most intensively with my programmer and former student, Armando Hernandez. Mixing my musical thinking with Armando's "for instance" initial implementation of ideas, created startling surprises; my head was often spinning as I came to see/hear some very basic musical entity or relationship in a new way. For example, I recognized that my notions of fast and slow were slim, indeed – up and down in pitch and rate of change were also making fast and slow; time-units became hierarchical and had to be differentiated from phrase boundaries; and representations had to be invented to show all of this. But just as insights happened, they continuously generated more questions, leaving us with new problems: How could we invent ways to make the computer technology be responsive to these insights and new ideas?

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[3] Impromptu in its present version, along with a text and projects, will be published by Oxford University Press in 1996.

[4] While Impromptu is easier to use, more accessible than MusicLogo, it is constrained by not giving the user access to a real computer language. We hope in the near future to embed Impromptu in a Logo-like environment. Users will then be able to evolve from Impromptu's easy-to-use but limited technology to a truly extensible environment where possibilities for learning and for composing become "topless."

Musical Intuitions: Three Premises

So what are these unsatisfied needs of beginning music students? My sense of them derives from three premises about everyday musical intuitions gleaned from teaching and research:

1. The kinds of elements and relations novices attend to in making sense of music as it unfolds in real time, are highly aggregated, structurally meaningful entities such as motives, figures, and phrases.

   These are the "units of perception" – the elements that novices have ready access to, their focus of attention. We do not listen to "notes" anymore than we listen to letters printed on the page. For instance, if you have ever watched kids picking a tune off the tape onto their guitar, you will have noticed that they rarely go note-to-note. Rather, they listen to a selected portion of the piece, a reasonable structural chunk, heading for what they call a target tone or goal – not just any stopping place will do. Then approximating the general shape and feel of the selected portion on their guitar, listening again and again, they gradually move in on the details. I take this as further evidence that we intuitively begin by hearing structurally meaningful figures as musical entities, and only with further effort do we move in on the "notes."
2. Through listening to music of our own culture, we have become most responsive to structural functions such as stability and instability – whether a phrase sounds ended or is still going on; even given a context, whether a note sounds at rest or not.

   And here the novice and the expert come together again: both are highly responsive to context – the function of events within the situation where they occur. Our units of description – what we name and notate – tell us that the pitch, C, or a major third are the same wherever they occur. But the musical novice hears notated "same pitches" as different in response to the changing functions of those same pitches within the particular context where they occur. And so does the performer whom we describe as playing "really musically." That is why string players, for instance, pay careful attention to fingering, bowing, and to the subtlety of intonation – these are the means through which the artist performer projects contextual differences and changes in structural function among instances of the same notated pitch. And it is structural functions that generate feelings, images, and associations. But we seem, by convention or habit, to keep the language of structural functions (harmonic functions, rhythmic functions) and the language of feelings in separate realms of discourse and culture.
3. Those who play an instrument know a piece best as the feel of their bodies (lips, arms, fingers) on the terrain of their instrument. Just as

we must move sequentially in real time (one step or one day at a time), so performers must play a piece sequentially as it unfolds in time. And while the pianist must play one finger after the other, she knows the piece not as a sequence of separate notes or actions, but as a sequence of shapes, figural movements, "handings" – what I have called a "felt path" through a piece. Felt paths are, I think, the most intimate way of knowing and also hearing a piece for the artist performer as well as for the novice who "plays by ear."

As evidence, try to sing a song you know very well starting somewhere in the middle. For instance, try singing America ("My country 'tis ...") starting right up from "of liberty." And if you do play an instrument, recall what happens when, having learned to play a piece from memory, you forget somewhere in the middle. In both situations, you most likely have to go back and start over again from the beginning or at least from some memorable structural boundary. As further evidence it is amusing to watch music students in the traditional task called "taking dictation" – writing out in SMN, a melody played to them by the instructor. Those who play an instrument are quietly, probably unaware they are doing so, fingering the dictated passage on an imaginary instrument (the flute player up in the air, horizontally; the pianist on her desk in front of her; the guitar player on the pretend neck of his instrument): in order to hear the melody, they need to feel it on their instrument.

These, then, are my best hunches at the intuitive, generative primitives from which musical development builds and grows: the ability to focus on and hear the arrivals and departures of figures and phrases, responsiveness to contextual functions, and the feel of a piece in the fingers.[5] And if I am right about them, it is not surprising that students, often those who are best at improvising and playing by ear (as well as those who are best at improvising when making and fixing mechanical gadgets), are baffled and discouraged when we ask them to start out by listening for, looking at, and identifying the smallest, isolated objects – to classify and measure with no context or functional meaning. For in stressing isolated, de-contextualized objects to which our units of description refer – to measure and name objects in spite of where they happen and their changing structural function

[5] I find it quite telling that when I have, on a number of occasions, asked a car mechanic who has just solved some knotty problem, "How did you do that?" he says, "Smart hands." And when, in different contexts I have asked a jazz pianist the same question, "How did you do that?", after he has just performed a particularly ingenious improvisation, he too says, "Smart hands."

– we are asking students to put aside their most intimate ways of knowing – figures, felt paths, context and function.[6]

But how can we give beginning students structural figures to play and to play with that match their units of perception instead of our units of description? Here is the paradox, again: how can we give beginning music students ready-made meaningful structural entities that they can hear and work with, when *notes* are necessary to make them? It was in an effort to answer these questions and to satisfy what I believe to be the needs of beginning students that I was drawn to the possibilities of the computer, now coupled with a synthesizer. Even though I resisted taking the plunge, it became necessary as a means for doing what I could not do in any other way.

Entrances and Exits

In designing Impromptu and in working on the projects that form the students' working context, the following general question became of critical importance: where can students most effectively *enter* their study of some domain, in this case the musical world, and how can they can most effectively proceed – where and when should they exit to somewhere/something else? Figure 2 shows a working model of entrances and exits reflected in the design of the projects and in their progression.

As Figure 2 suggests and following my first two premises, Impromptu makes it possible for students to begin their music study at the mid-level of structure – figures, phrases, functions. From the outset, students work with these meaningful structural entities, using them *simultaneously as units of description and units of perception.* Structural entities, what we call "tuneblocks," are represented in Impromptu as patterned icons. With the computer connected through a MIDI interface to any synthesizer, the icons play when selected (clicked on). Given a set of tuneblocks, students use them right from the outset as the functional elements to experiment with

[6] It is revealing that in our Laboratory for Making Things in a local public school, we have found that children who are virtuosos at building and analytically "debugging" complex structures using legos and other materials, are often the same children who are having the most difficulty in their regular classroom subjects. This is not so surprising since the emphasis in classrooms is primarily on learning and manipulating symbols. In the Lab, children are learning to move back and forth between action and symbolic descriptions by making "working systems" with materials in real space/time and making "working systems" (music and graphics) in the virtual world of computer design. And in that moving back and forth, the emphasis is on *confronting the differences between them.* In this way children recognize what they know how to do so well in one world, while also recognizing the transformations that might be necessary for making sense of the other, symbolic world of school (Bamberger, 1991b).

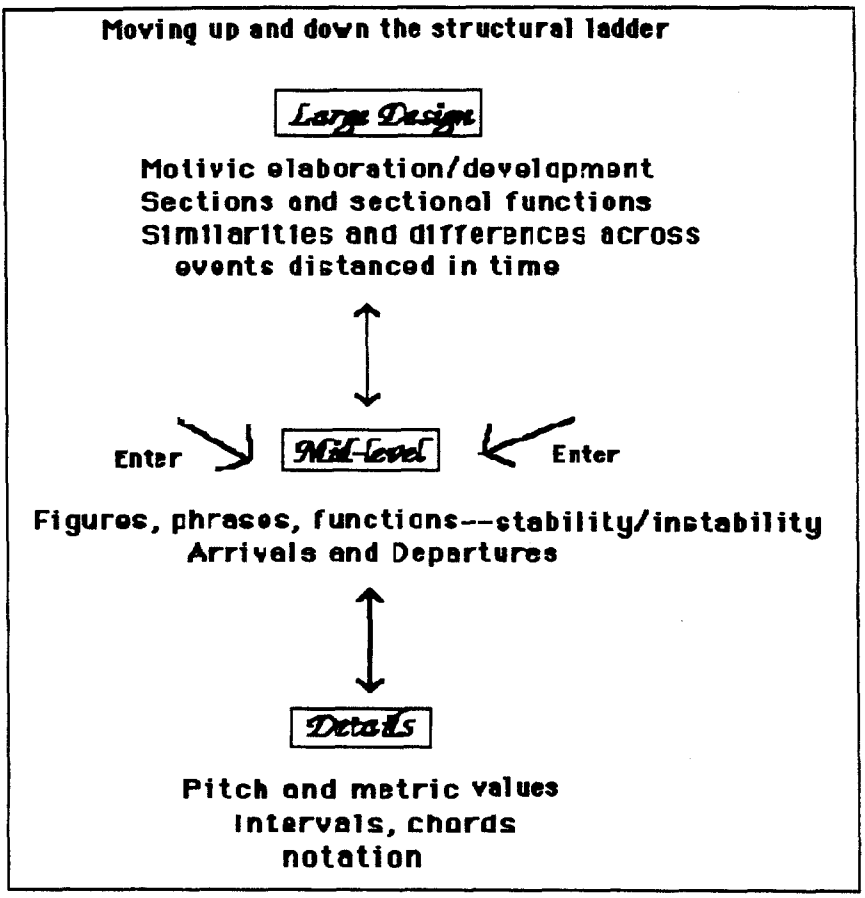


Figure 2. Moving up and down the structural ladder.

the design of simple compositions. As students listen to tuneblocks, "grab" them so as to arrange and rearrange then in the Playroom, their experiments in generating musical coherence are much like the work of a composer in sketching out a piece. Figure 3 shows Impromptu's TUNEBLOCKS window.

Successfully composing a tune that "makes sense and that you like," inevitably raises questions when students try to account for their intuitive compositional decisions. Deconstructing to explore what they cannot yet do so well, they can look at the general shape or "pitch contour" of their blocks (shown in the Graphics Window in Figure 3). And later, they can "open up" the tuneblocks, moving down the structural ladder to look at

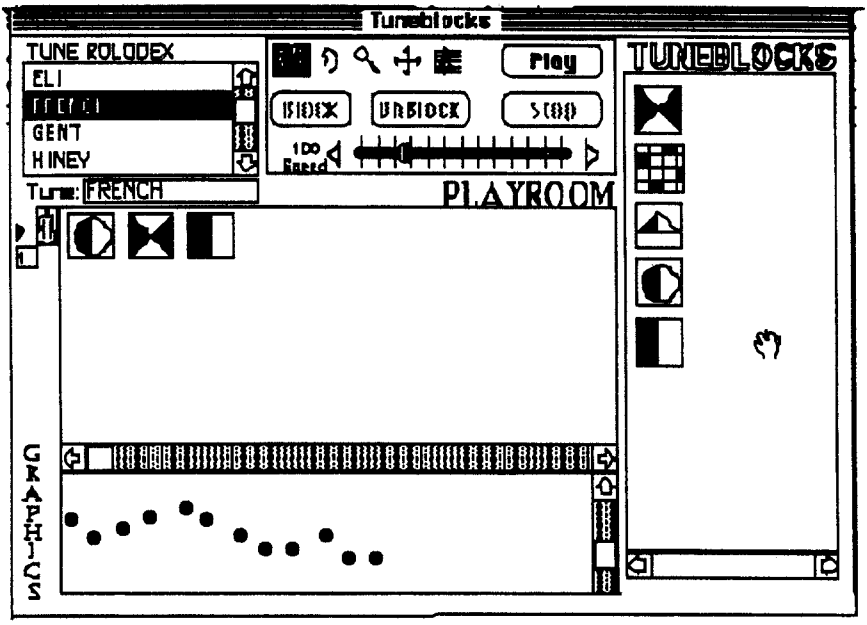


Figure 3. Tuneblocks window.

the more detailed *contents* of these mid-level structural entities – pitch and duration values (see Figure 4).[7]

Circling back up through their familiar, mid-level functional entities, hearing them now in new ways, they go on up the structural ladder to larger structural relations – to sections and sectional functions, to motivic development and to comparison of events that are distanced in time within a piece. Listening to compositions of more well-known composers, they seek to account for the affect and function of these larger structural relations by circling down again through the structural ladder to the details.

Through this process students learn freely to shift their focus of attention among the many possible kinds of musical entities and multiple dimensions at differing levels of structure depending on their questions, what they want to hear, and what they want to account for. For instance, they may initially, as you probably did, hear the ends of the first two phrases of "Did you ever see a Lassie" as different (in response to aggregated function). But later, taking the momentary confluence apart, looking into the contents of

[7] Students can select their own special name for a block (e.g., "fast," "sad") which replaces the patterned icon. They can also design their own patterned icon, or they can request an icon that shadows the pitch contour of the block. And a full selection of colors is also available.

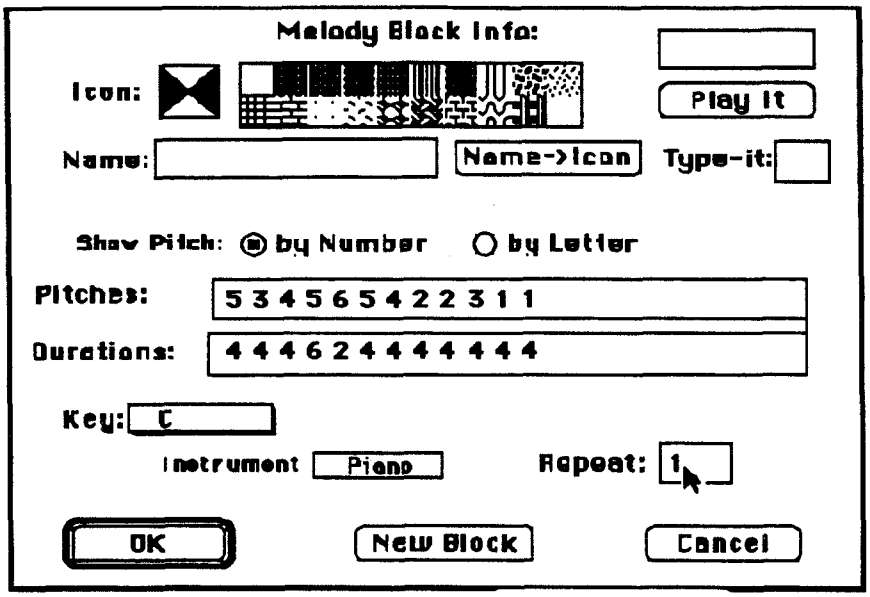


Figure 4. The contents of blocks.

the blocks, they surprisingly discover that the phrase endings are the same (in pitch). Same or different depends on what you choose to or are able to select for attention. To account for the difference between the two phrase endings, it turns out that you have to shift your attention to the rhythmic dimension of the tune. But to do that, you have to "liberate" that separate dimension from the meld, taking apart the aggregate that was your initial unit of perception.

Learning selectively to move their hearing up and down the structural ladder also helps students towards a critical ability in the appreciation of musical complexity: to coordinate detail and larger design. As the composer, Roger Sessions, used to say: the details are generating the large design and the large design is informing the details, together they make the unique coherence of a complex composition.

Going on to projects involving rhythmic structure, students compose with "drumblocks" to make percussion accompaniments for tunes. Students listen to a tune, "keep time" by clapping to the underlying beat hierarchy that the tune generates, and then "matching" their live performance, compose accompaniments to their tunes using multiple percussion instruments. Later, more interesting patterns are composed: first, accompaniments that "fit" with the underlying beat structure of a tune, and then accompaniments that conflict with its underlying rhythmic organization.

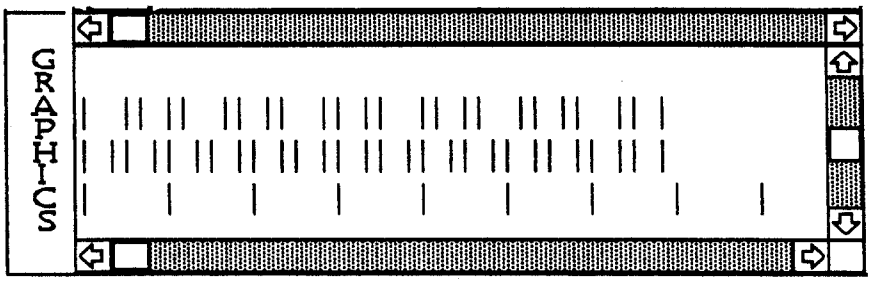


Figure 5. African drum piece.

Students go on to compose more complex percussion pieces, modeled for instance, on African, Balinese, or jazz drum rhythms that they have listened to in class. Temporal relations of rhythm pieces are captured in space-to-time analog graphic representations (see Figure 5). These help students to account for the relationships they have composed and also to make live, group performances of their pieces on real percussion instruments.

Two other projects extend their work: playing canons (such as Frere Jacques, Three Blind Mice, or riddle canons composed by Mozart), and harmonizing melodies. Students work on both of these projects interactively in real time, thus combining performance and listening.

To make projects more exciting, students use Impromptu's MIDI interface to choose a wide range of both melody and percussion instruments from a selected synthesizer by simply clicking on an instrument name in the Instrument Menu.[8] And since all music is saved as MIDI data, compositions can be sent to any music editing application to be printed in standard music notation.

Multiple Representations

Impromptu includes, as you have seen, several different *kinds* of notations. To help students learn to move up and down the structural ladder, each of these multiple representations has been designed to show different *kinds* of entities at different *levels* of structure. The block-icons capture the more aggregated figural level of a melody; "pitch contour" graphic representations trace the general pitch/time shape of a block as it plays; "rhythm bars" are a space-time analog representation showing only temporal relations. And moving farther in on the details, opening up a block (by clicking on

[8] Impromptu makes it easy for instructors to map instrument names to the instrument numbers of individual synthesizers through its MIDI menu. Impromptu includes pre-programmed mappings for any General MIDI synthesizer and specific mappings for most commonly used synthesizers.

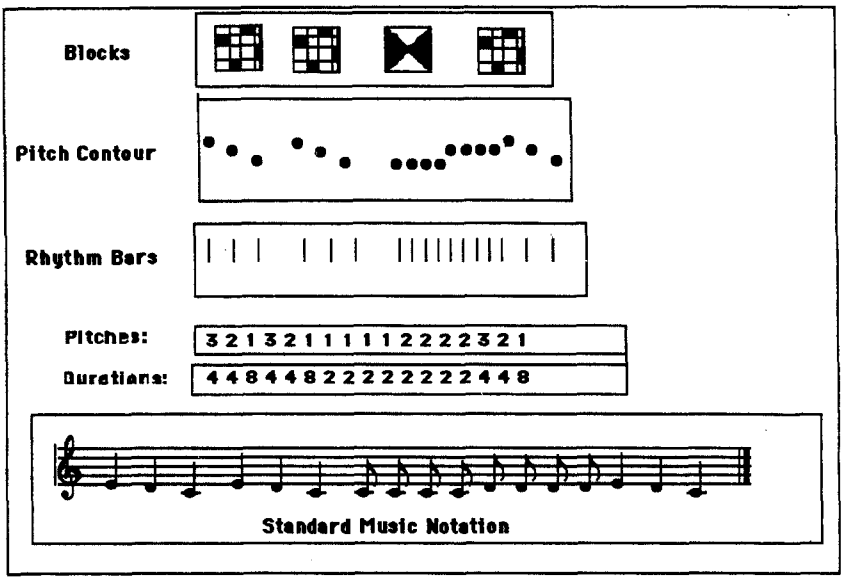


Figure 6. Multiple representations for "Hot Cross Buns".

it with the "magnifying glass"), scale degree and letter notation for pitch are displayed, as well as proportional numbers for time values. Students also have the opportunity to build "bigger blocks" made up of structurally significant groupings of the given tuneblocks. Icons for "bigger blocks" represent and play these more aggregated structural entities. Students can "edit" the contents of blocks by changing pitch or duration, and they can also make their own entirely new blocks.[9]

An Example: Learning with Multiple Representations

How do students use these multiple representations to make explicit and thus to learn what they already intuitively know? Consider the simple tune, "Hot Cross Buns," and its multiple representations as shown in Figure 6.

Students begin by re-constructing the tune with tuneblocks – a task that is immediately obvious for most. But the act of construction simultaneously turns into a process of "constructive analysis." Looking at the completed sequence of blocks on the screen and listening back to it, the larger structural relations of the tune emerge: two repeated figures (A), contrast (B), and return (A').

[9] Standard music notation is not provided within Impromptu in part to encourage students to learn to write music notation using paper and pencil, and also because, if they wish to compare, they can send computed data to any common music editing software for a print out.

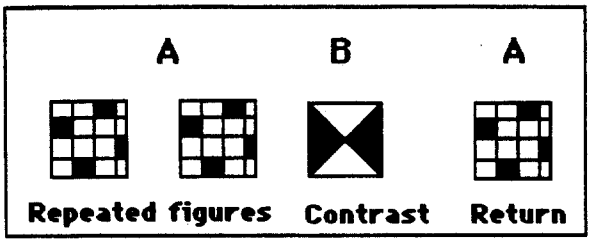


Figure 7. Structural relations.

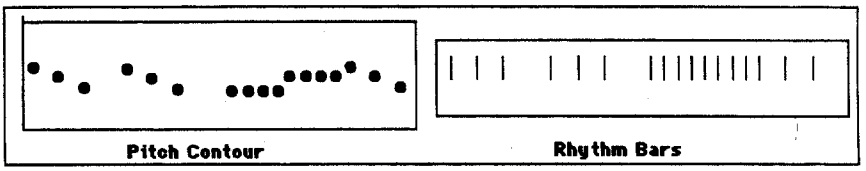


Figure 8. Revealing distinctions.

While working on the re-construction of the tune, students can choose to watch more fine-grained representation – either pitch contour or rhythm bars graphics in the Graphics Window. While both kinds of representations seem to fit with the blocks, comparing them reveals distinctions that are hidden in the more aggregated blocks representation.

For instance, the return to the opening figure after the contrasting middle is perfectly clear in the tuneblocks representation, and it is also perfectly clear in the pitch contour representation: the same three-note descending configuration stands out both at the beginning and at the end. of the tune. But looking at the rhythm bars, the return is obscured. Specifically the boundary between the contrasting middle figure and the return seems to have disappeared – the tune ends with just two events instead of three.

Indeed, if you clap just the rhythm of the tune, or play just the rhythm using an Impromptu drum, you hear the same effect – two events at the end and the boundary between the faster middle and the return seems in the wrong place. Why?

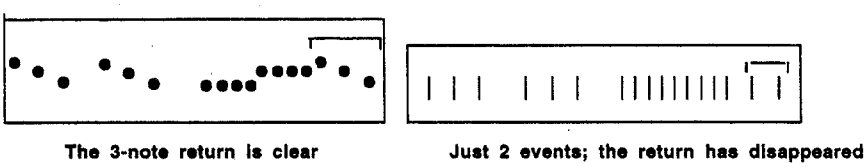


Figure 9.

The boundary is obscured because when only temporal relations are represented, the faster events of the middle figure *run right on into the return*; there is no change to generate a boundary at that moment. Looking again now at the pitch contour graphics where pitch relations stand out, it becomes clear that it is the pitch dimension which is critical in creating and accounting for the perceived boundary – temporal relations alone will not succeed.

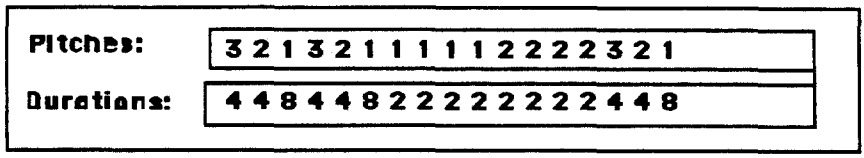
Several insights result from this comparison and each is an example of how reflectively multiple representations can help students look AT their intuitive know-how while also building on it. First, by comparing the two representations, the pitch and time dimensions become clearly differentiated. Along with that, the role each dimension plays in generating boundaries is also revealed: Once the two dimensions have been disentangled, it becomes clear that, in the momentary confluence of our live listening, the pitch dimension wins out in generating the coherence we hear.[10]

Second, our habits of grouping in visual/spatial perception are similar to our habits of grouping in temporal perception, but not necessarily in pitch perception. As the gestalt psychologists have taught us, where elements that are otherwise the same are relatively closer together in *space*, we see them as grouping together; and where elements are farther apart in space, we see the space between as forming a boundary between groupings. Similarly, when sounding events that are otherwise the same, are relatively closer together in *time*, we hear them as grouping together; when events are relatively farther apart in time, we hear the gap between as forming a boundary between groupings. The space-for-time graphics clearly reveal these similarities between the two modes of perception.

And third, the comparison leads again to some insight concerning the strong influence of context. For instance, even though the beginning and ending blocks are exactly the same with respect to their pitches and durations, "The same block," as one tuneblocks player reported, "is not the same at the end." When the beginning block is heard following right on after the faster, and more onward-moving middle figure, we hear the beginning configuration not as a start-up but as a resolution. The figure is "infected" by its new contextual association, acquiring in the process different meaning and function.

[10] Which is just the opposite of Lassie. These findings suggest empirical research questions which some of my students have been playing with: when is it the case that pitch wins out in generating boundaries, what makes the differences in the situtations where rhythm wins; and how would you design experiments to find out?

What about moving in still further to a notation that represents pitch and duration with numbers?



This representation is close to conventional notation. However, to make sense of these two sets of numbers (which have entirely different meanings) requires first mentally constructing the framework, *the reference systems*, in terms of which the numbers gain meaning. If we help students construct these reference systems, the numbers gain the power that has made them survive; if we fail to do so, the symbols may be used by students as just a code for button-pushing. It is a bit like "plugging in the numbers" in an equation (W=F*D) without worrying about what real world objects the numbers and the relations described by the equation refer to.[11]

These symbols and the reference systems in terms of which they acquire meaning, gain power by being internally consistent. However, for just this reason the symbols of SMN tend to obscure the changing contextul meaning that the same pitch or duration can accrue as a melody unfolds. And it is for this reason that students working in the Impromptu environment are introduced to these notational conventions only when the particular kinds of entities and relations to which they refer become necessary as means towards answering the students' own questions.

The focus then turns to a consideration of differences in the kinds of features represented by these various representations, and to finding congenial means for developing the *transformations necessary to moving meaningfully among them.* Invented drawings for rhythms have been crucial in guiding this process.[12] Beginning with tuneblocks, "units of description" that closely match the novices's intuitive "units of perception," students move into more detailed but still basically configurational graphics that closely match their invented drawings – pitch contour and rhythm bars. Only then do they move on to the conventional symbols that reflect, even depend on, the previous mental construction of an ordered system of relations – numbers for pitch and duration. In a profound sense the process of

[11] For example, the MIT students in my education classes have all passed freshman physics, are thoroughly familiar with the equation W=F*D, but fail to recognize its embodiment in the pulley mechanism they are asked to design and build.

[12] I refer, here, to drawings made by children over the age of eight or nine which are much the same as those made by college students with no formal music training.

moving through these varied representations brings into existence kinds of elements, features, and relations that were simply not constituents of the students' working musical universe before.

So we need to ask: how do multiple representations actually influence experience? Do newly existent constiuents change our immediate experience of a piece? Do multiple representations result in multiple hearings? And can we compare these musical questions to questions in other domains: does inventing (or re-inventing) the consituents distance, time, and their relationship, change our immediate experience of "going faster?"

To come full circle, I will argue that the goal of education (for both teachers and students) should be to make questions like these become an integral part of the life of classrooms. And critical to making that happen is learning to construct, to understand, to appreciate, and to confront the differences among multiple possible representations of phenomena – to choose which kinds of kinds and at what level of detail you want to focus your attention, and to know how to do that most effectively depending on when, where, and what for.

A REFLECTIVE PRACTICUM

In keeping with my design principles, then, I have exploited computer technology to do what I could not do in any other way. Instead of looking for what to do with the trendy technology, or creating a receptacle holding information that mimics what we already had, the technology becomes a resource that encourages students to experiment with, interrogate, and develop their own intuitive musical know-how. Students are asked to watch themselves at work, to reflect on the process, as an integral part of the process, itself. To do so, students keep a log as they go along – a log of their spontaneous responses to a hearing and of the decisions they make along the way. They are also asked to try to *account* for their decisions, and to ponder how their decisions are made manifest in the unfolding structure of their final compositions.

Students are urged to keep in mind that the computer literally reflects back, mirroring in every detail what it is "asked" to do. Bearing this in mind, a surprising hearing, an unexpected "talk-back," can become a moment of poignant insight, the trigger for a stop-and-think – "I wonder why that happened?"

It is these continuing investigations into their own musical intelligence which become the generative base for developing hearings and appreciations that go beyond what students know-*how* to do already to knowing *about* and knowing *why*. Going beyond their initial musical intuitions, they

are able to make explicit, for example, why they hear particular grouping boundaries, why one phrase "wants to follow another," why one phrase sounds like an ending while another more like a beginning, even to ask what generates a beat and what generates weak and strong beats. As one student wrote in her log at the end of her work on the first tune-building project:

"A big question in my mind: what makes a certain sequence of notes, blocks – sound like an ending? We see that most people agree on what things have ending sounds, so what makes it that way?"

In searching for answers to questions such as this one that they have put to themselves, students begin to hear and to appreciate musical complexity, to hear the details in the larger design. Rather than giving up their intuitions, they learn in the service of better understanding them.

NEXT STEPS: A NEW PROBLEM

Working with the students has confirmed my initial hunch that if given the opportunity to start with what they know how to do already, and to actively explore and experiment with musical materials and relations that progressively build on these intuitions, students come to understand, appreciate, and perhaps most importantly, to care about and be moved by compositions that previously passed them by. At the same time, using Impromptu myself and in watching the students, I am discovering aspects of musical structure and particularly aspects of musical perception that have made me re-think not only some of the common assumptions of music instruction, but those of music theory as well.

The problem I face, now, is not with the students but with music faculty. Some younger faculty in more progressive music departments have greeted Impromptu and its underlying premises as productively addressing the problems they have been confronting: – students can become engaged with their own learning instead of becoming disengaged, disenchanted, drifting away from even passing the course because it seems to them irrelevant to what they care about.

But others see this approach as changing tradition in rather too drastic ways. This is not surprising: The combination of a computer environment which many faculty still find strange and intimidating, notations that are different from the those through which they usually think and act, together with a teaching approach that stresses experiment rather than drill, has the effect of pulling the rug out from under them. But hopefully, given time and the opportunity to play with the new approach, more will come to

realize, as I have, that a period of confusion and disequilibrium can, with patience, generate new insight and even a renewed interest in teaching.

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