

The Art of Design: Expressive Intelligence in Music

by

Gregory Gargarian

MS, Massachusetts Institute of Technology, 1987

Submitted to the Media Arts and Sciences Section,
School of Architecture and Planning,
in partial fulfillment of the requirements for the degree of

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Submitted to the Media Arts and Sciences Section, School of Architecture and Planning, on January 8, 1993 in partial fulfillment of the requirements of the degree of Doctor of Philosophy at the Massachusetts Institute of Technology

Abstract

The research reported in this thesis is dominated by the combined perspectives of the developmental psychologist and tool designer. The developmentally sensitive tool designer is interested in designing tools that support learning how to design.

The author uses music composition as the research domain. As with other kinds of designing, music composition is a good domain in which to study the relationship between design and interpretation, reasoning in dynamic problem contexts, and the role of concept design in artifact design.

Through an examination of the compositional process, the author shows how the designer customizes his design environment around the artifact under design. Designing is also shown to be experience-based. Designers use different customization methods, and designers use the same customization methods in different ways. Finally, the author shows that the designer engages in a process of situated planning as a means of reducing design problems to conventional ones.

Through the development of two computer-based design environments, one in music and the other in textile design, the author outlines an aesthetic for developing computer-based design environments that preserve the qualities of interaction found in design environments predating computers.

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Introduction Overview and Background

..the proper study of mankind is the science of design, not only as a professional component of a technical education but as a core discipline for every liberally educated person.
Simon's *The Sciences of the Artificial*

Overview

Personal experience has convinced me that music composition is an instance of a larger class of practices where something is produced or decided within a dynamic problem context. I call this class of practices *designing*. For many years I composed music for Susan Rose, then a Boston-based choreographer and dancer. Her choreographic methods seemed similar to my compositional methods. I have occasionally composed music for animators and found similarities in our ways of working. As a manager of research and development laboratories, I had the opportunity to work closely with virtuoso programmers whose ideas about programming resonated with mine about composing. Management, itself, felt like a kind of composing.¹

My research has only strengthened the conviction that designing is at the core of many of the activities we value. It is my belief that the future competitiveness of companies, effectiveness of schools, and relevance of liberal arts programs to society will depend on the time we are willing to dedicate to understanding designing and developing tools to support the acquisition and use of design skill.

To serve these ends this thesis provides a theoretical framework in which composing is seen as a kind of designing and designing is seen as a kind of learning. In addition, it outlines an aesthetic for designing and evaluating design support tools.

* * *

For me, it was an obvious choice to examine designing in the domain of music—I understand composing better than other kinds of designing. However, there are other reasons for using music to investigate the dynamics of design.

Music is a good domain in which to examine the relations between interpretive thought and designing, a background theme for parts 1 and 2 of this thesis. The product of composing is an artifact that is intended for use by a particular interpretive community. An artifact has expressive

¹ Many artists have found it synergetic to work in several media concurrently: Babbitt in mathematics and composition, Xenakis in architecture and composition, Cummings in poetry and painting, Schoenberg in painting and composition, Barth in fiction and composition, etc. Are these artists simply high achievers or does experience transfer across media? Is it design experience?

potential, is interpretable, when composer and listener share a common knowledge; otherwise, what a composer thinks is music, a listener may hear as noise.

Interpretive knowledge not only comes into play for the listener, it functions in an evaluative role for the composer. A composer examines his emerging artifact based upon its (presumptive) expressive potential. This idea generalizes to other kinds of designing. To ask whether a piece of music is interpretable is equivalent to asking whether a designed artifact has utility for its intended user. The bridge between interpretability and user utility is one way I connect composing to a more general notion of designing.

Music is a good domain for expanding research in artificial intelligence because it is both media rich and enveloped in a tradition of rigorous, sometimes formal, theory. At the same time, problems in the domain of music are ill-defined, calling for the examination of kinds of reasoning that have been difficult to formalize. For example, music is an ideal domain in which to study skills and how they are organized, themes that run across parts 2 and 3 of this thesis. I define *skills* as tools (material, conceptual or computational) plus knowledge about the cases in which they can be productively employed. It is not only know-how but *know-when*, the circumstances in which to use know-how.²

Some skills are concerned with the utility of an artifact for the user; others are concerned with managing the complexity of the design process and are opaque to the "user"; they are for the designer only. While particular skills are application-dependent, the general notion of *skills* is not.

Design problems are by nature ill-defined, under-determined. This requires a *rationalization process* through which local actions are given increasingly global justification. Through rationalization, an analysis of a previous action is not used to explain what was done; rather, it is used to plan what to do next. Rationalization plays a constructive role in designing where objectives are being continuously re-assessed. Viewing rationalization as a help rather than a hindrance seems to dissolve a debate between planning and situated action theorists by moving toward a more situated notion of planning in which plans and actions are co-constructed.

The rationalization process is an example of creative thinking, another theme in the background of parts 2 and 3. More generally, I argue that the creativity in designing is found in the way skills are organized. Designing involves more than the construction of an artifact; it involves the management and construction of skills for designing the artifact. What I call the *design environment* includes both; it is the conceptual interface between the internal world of the designer and the external world in which the emerging artifact resides. Working on the *artifact* involves the use of skills; working on the *design environment* involves the design and organization of them.

² The term *know-when* comes from Aaron Falbel through conversation.

In part 3 I use data gathered from self-reflection and from the observation of five composers in order to examine how skills are constructed, used and organized. Artifact design and environment design are two examples of *perspectives on designing*, mental schemes for managing skills so that they can be easily retrieved during the design process. I describe and illustrate perspectives on designing and other kinds of skill management schemes.

Finally, music composition is a good domain to study the required quality of tools to support learning by designing. *Learning by designing* refers to the fact that designing, by either expert or novice, is always also about learning how to design. Learning how to design is a natural consequence of designing because new tools are required to deal with unanticipated problems; therefore, acquiring skill comes from using a tool. Learning how to design is also a natural consequence of environment design since the conceptual interface is customized around the emerging artifact; therefore, acquiring experience in skill management comes from developing design environments.

In part 4 I examine the development of two design environments (one for music composition, the other for textile design) written in the Logo computer language. Issues that arose during the redesign of these environments lead to an aesthetic for evaluating the quality of these conceptual interfaces, what I call *constructionist interactivity*.

* * *

In order to design tools to support designing, we need to understand the design process. Since designing results in artifacts used by others, we need to incorporate factors of use, of interpretability, into the design process. The following the background section (below), the chapters on interpretive theory pave the way for these discussions.

Background

This extremely difficult, strange, wild, ultra-modern Russian Concerto is the composition of Peter Tchaikovsky, a young professor at the Conservatory of Moscow...We had the wild Coassack fire and impetus without stint, extremely brilliant and exciting, but could we ever learn to love such music?
Dwight's *Journal of Music*, Boston, November 13, 1875

The above assault on Tchaikovsky is taken from Nicholas Slonimsky's book *Lexicon of Musical Invective*. It is one of many scattered throughout the footnotes of this thesis to remind readers that the unfamiliar has often been met with resistance and become familiar through the act of re-interpretation. As with designing, the interpretative process is a learning process.

One will notice the angry tone in many of the comments compiled by Slonimsky. Expression is important business, especially when one's notion of musical experience is put in question. Today's interpreters do not respond to the musics of Beethoven or Debussy with the disdain felt by some of their contemporaries because we have learned how to interpret them. Even for those of us who are

not admirers of Tchaikovsky, our reasons are likely to be that his music is simple, predictable, tame and old-fashioned, not difficult, strange, wild, or ultra-modern.

A common complaint found in the statements of critics compiled by Slonimsky was that it was difficult to hear a melody or any organization to the sounds. How can music be music without melody and organization? Such a question demands a deeper examination of the role of learning in interpretation.

Take the simple example of a child being asked to clap her hands faster. She will usually clap faster and louder. If she is asked to clap her hands slower, she will usually clap slower and quieter. Most novice musicians have trouble differentiating between faster and louder, slower and quieter, rushing the music during crescendos and dragging it during diminuendos.

The cognitive psychologist Jean Piaget would have explained these actions by saying that faster-louder and slower-quieter are undifferentiated in the minds of novices. Clapping is a physical coordination task that is difficult for children or novices to execute. Piagetian theory says that the "improper" execution of the physical coordination task can give rise to a correspondingly incorrect mental scheme. For Piaget, we learn by interacting with the world. If these interactions are undifferentiated, the mental representations of them will also be undifferentiated.

To say that the novice executes the faster-louder or slower-quieter tasks "incorrectly" is an assessment of the novice's performance based on a more differentiated understanding of the task--on developmental hindsight. From the novice's perspective, the task has been performed properly. An important idea in Piagetian psychology is that one first needs to examine the coherence of a learner's thinking before considering interventions to change it.

Piagetians believe that people retain experience in the form of mental schemes that help us to recognize *objects* in the external world (like melodies) and *operations* that can be performed on these objects (like faster or slower). For some readers it may be difficult to think of a melody as an object. After all, a melody has none of the physicality of objects like (say) tables. This difficulty quickly vanishes when one imagines the memory of an object and not the object itself. The memory of a melody is no less or more physical than the memory of a table. In both cases, recognitions require mixing and matching features of the observed object with already acquired mental schemes.

Consider concrete objects like tables. We recognize tables because we have mental schemes for recognizing structural features of *tableness*--kinds of tables like wood, plastic or aluminum tables, and features of tables like legs, flat surface, etc. General notions of *tableness* are mentally constructed by finding the features that remain invariant across particular table experiences. Melodies, like tables, must have common features which give them their *melodyness*. The process of differentiating structural aspects of them is a kind of learning.

We can also distinguish between tables based on their function (e.g. for supporting kitchenware or officeware). One reason we can recognize *tableness* in objects that we have not previously experienced as tables—e.g. a door supported by two filing cabinets—is that we can mix and match structural and functional properties that are familiar and construct a new mental scheme for the new kind of table.

In 20th century music, melody is often replaced by motive, and harmony is replaced by other features like dynamics or orchestration. One reason Slonimsky's angry critics did not hear the music in the music is that they were looking for familiar mental schemes, like *melodyness* or *harmonyness*, and did not find them. Listeners eventually did learn to construct new mental schemes using familiar properties of melodies (e.g. contour or ornamentation) and harmonies (e.g. pitch-interval or orchestration) as building blocks.

On one hand, objects are seldom so completely unfamiliar that we cannot find analogs in objects that are familiar. On the other hand, even the simplest recognition requires extensive mental construction. Simply put, observing is a kind of doing, a mental doing. Piaget's notion of *constructivism* reflects this assumption of thought. Slonimsky's angry music critics had interpretive difficulties because they could not perform the necessary mental constructions; they had no mental schemes for determining the functional role of musical features they recognized, or they were *epistemologically* deaf to the features that were musically salient, or both.

Historically, epistemologists were concerned with the right organization of knowledge; i.e. the truth. Over time, epistemologists discovered that the notion of "truth" changes as truth-seekers learn more about the external world and themselves. One can look at the history of science for examples; earth-centered astronomy gave way to sun-centered astronomy during the Copernican revolution; Aristotelian physics gave way to Newtonian physics; spontaneous generation gave way to Pasteur's microbiology; Lamarckian evolution gave way to Darwinian evolution; and so on. What many historians of science describe as "paradigm shifts" in scientific thought are analogous to what Piaget discusses as stages of development in the child. While paradigms or stages are neither rigid nor pure, the point is that what and how we know and learn constrains what else we are willing to admit as knowing and learning.

Slonimsky points out that some critics changed their minds after a period of time (Slonimsky, p. 11). Contrast Philip Hale's comments about Strauss's symphonic poem *Don Juan* in his 1891 article with Hale's 1902 article about the same piece.

Hale-1891

Strauss uses music as the vehicle of expressing everything but music; for he has little invention, and his musical thoughts are of little worth....

Hale-1902

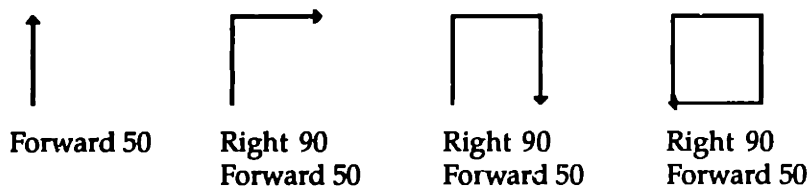
A daring, brilliant composition; one that paints the hero as might a master's brush on canvas. How expressive the themes! How daring the treatment of them! What fascinating, irresistible insolence, glowing passion!

Hale must have learned something to change his mind. From an epistemic perspective, we can say that the Hale-1891 and the Hale-1902 are different critics. Piaget uses the term *accommodation* to refer to learning that requires radical re-organizations of thought and not just the addition of new features to old mental schemes. Even a casual sampling of musics found around the world will provide most listeners ample examples of musics for which their native mental schemes are inadequate. For these unfamiliar musics, listeners are very much like Hale-1891.

* * *

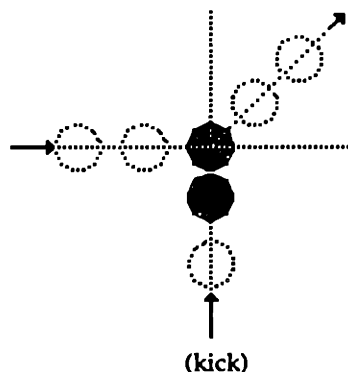
As Papertians, we believe it is possible to construct learning tools, microworlds. *Microworlds* are virtual worlds in which a learner has access to kinds of thinking to which it is difficult to get access within the real world. A classic example of a microworld is Andrea diSessa's dynaturtle, a cousin of the Logo turtle. A Logo turtle is a graphic object that can be navigated around the computer screen using commands like FORWARD or BACK some number of steps, or LEFT or RIGHT some number of degrees, both specified by the user.

Logo's screen turtle (▲) executing a square procedure:



A dynaturtle is a reprogrammed Logo turtle that operates by the laws of Newtonian motion. Instead of moving by steps it moves by KICKS (given to it from different directions and with different strengths). A dynaturtle also conserves momentum. Kicking the dynaturtle has an effect similar to striking a billiard ball into another one that is already in motion; i.e. the new KICK is "averaged in".

Giving a first billiard ball (in motion along the horizontal plane) a "kick" using a second billiard ball (in motion along the vertical plane).



While our earth-bound world does not provide pure examples of Newtonian motion, dynaturtle's computational world does. When a child navigates a dynaturtle on the computer screen, he begins to have experiences with Newtonian objects and can use these experiences to construct more formal understandings [see Appendix A: diSessa's Dynaturtle].

Microworlds support what Papert calls *constructionist learning*. Piaget maintained that we construct our knowledge by interacting with the world, making theories about it, testing and revising them. What microworlds (like diSessa's dynaturtle) do is provide us new kinds of worlds (like Newtonian motion) with which to interact.

Design microworlds are kinds of microworlds, microworlds for producing artifacts used by others. They can be thought of as conceptual interfaces between the internal world of the designer and the external world in which the emerging artifact resides. Examples of design microworlds are wind tunnels and spreadsheets. Both are "virtual" worlds in which only the features of the real world that are salient for the particular design activity are represented. With wind tunnels, models of airplanes can be tested before full-scale planes are built and used; with spreadsheets, budgets can be tested in virtual time before real money is expended. diSessa used Logo as a design microworld for developing dynaturtle.

* * *

Social constructionism is about how a community becomes an interpretive community, how its members come to share certain epistemic commitments, make and interpret certain kinds of artifacts. Social constructionism can be illustrated using a study of a micro culture, a particular classroom of children using the Logo computer language to make music. In this study, music "classes" were under the direction of Paula Bonta. She taught the children how to make Logo procedures and use TONE, a simple Logo music command for specifying note frequencies (from 1 to 10000) and durations (from 1 to N). It is important to mention that Bonta told the children how to define notes, not what notes to define.

In Logo, typing the following command causes a note to sound with a frequency of 440 and a duration of 60 (i.e. 1 second).

```
TONE 440 60 =>
```

Below are two Logo procedures and what they look like when they are being executed. To give a particular note frequency a name (e.g. A = 440), a child could write the program shown on the left. To modify the same procedure so that durations are variable, the child could write the program shown on the right.

Introduction: Overview and Background

(Notes with fixed durations)

Procedure	Execution
TO A TONE 440 10 END	A => (plays A for a duration of 10)

(Notes with variable durations)

Procedure	Execution
TO A : <i>duration</i> TONE 440 : <i>duration</i> END	A 5 => (plays A for a duration of 5)

Armed with this basic knowledge, the children went to work making tunes. Children began to copy computer programs that produced the "most interesting" tunes and re-use the note procedures they contained to produce their own tunes. Several months later, Bonta observed that the children had composed several tunes using the same small collection of notes from the thousands available to them (Bonta).

It is difficult to say why certain tunes were deemed prettier than others. It is also true that the children were not totally ignorant of their native music (from Argentina). Nevertheless, the 8 or 10 notes and smaller number of rhythms they used as well as the aesthetic standards they tried to maintain did not come directly from the wider culture but were constructed within the micro-culture of their classroom.

Because Bonta's children were designers as much as interpreters, her study illustrates how practices become shared and, therefore, meaningful. Bonta's child-designers began to produce melodies using a common "musical scale" because the notes of that scale had produced some "pretty" melodies. The musical scale became meaningful because it had proven itself in real music compositions and became a source of common knowledge and practice. The scale provided each child-designer a means to foster interpretability within her community.

Having a musical scale also simplified practice by providing designers a means to control design complexity. The children did not have to re-invent all aspects of their micro-culture every time they wanted to make a melody. Instead of having to select notes from the thousands of sound frequencies available to them, the children could restrict their design choices to a small collection of notes; indeed, this is what it means to "use" a musical scale.

Problems of interpretability and design complexity are not necessarily connected as they were with Bonta's child-designers. Each child might have designed her own musical scale to address the problem of design complexity while ignoring the problem of interpretability. Actually, the children did invent personal scales and only later abandoned them for those they found more expressive. Meaning is a problem for the interpretive community; complexity is a problem for the individual designer. Only when the two are connected is there the potential for shared musical experiences. By subscribing to a shared notion of "scale" and "pretty" Bonta's classroom began to share a particular epistemology and practices that made the production and interpretation of certain kinds of melodies easy for its members to do.

In Bonta's classroom, the creation of a classroom culture was facilitated by a tool, Logo. In general, any tool that makes new kinds of practices and thinking possible--be it material, conceptual, or computational--can facilitate culture creation. In hindsight, we can see that science often advanced with the presence of new tools that made the invisible visible or the abstract concrete. The telescope, the microscope, X-rays, and cell staining techniques in neurobiology are some past examples. Logo served as a culture creating tool in Bonta's classroom.

* * *

Designing is not the same as conventional problem solving: it is above all a *process of discovery*. Conventional problem solving is routine once the designer has established a perspective in which the skills he already has or believes he can construct can be employed. For Newell and Simon, two scientists of artificial intelligence, conventional problems are well-defined and their solutions recognizable (like tic-tac-toe or chess). In such problems the solutions to all problems within the domain can be anticipated. The issue is to find effective strategies for navigating through the space of possible solutions, the *search space*. In designing, problems are ill-defined and solutions are often provisional or debatable. Design solutions may be unknown or provisional because they depend on factors that can be related to each other in a number of different, frequently unanticipated, ways.

Simon's notion of problem solving borrows much from his work in economics and decision theory. According to decision theory "the need for a decision presupposes the existence of a problem. To make a good decision, you must first have a complete understanding of the problem" (Arnold, 1978, pp. 40-43). Newell's and Simon's general problem solver (GPS) operates within the decision theory tradition. GPS provides a number of smart methods for navigating through a space of answers to known problems, using the principles of *feedback* and *difference reduction* (Newell and Simon, 1972, pp. 414-417).

GPS can be illustrated using the children's game of "hot and cold", an activity in which both feedback and difference reduction are used. In this game, two children are in a room. One child, child A, has an object in mind that is visible to both children. The other child, child B, has to guess which object it is. If child B guesses correctly the roles of the children are reversed and a new game is played. However, if child B guesses incorrectly, child A answers "cold, hot, cooler, warmer, etc.". Child A's temperature reading gives child B *feedback* about his progress. Child A's temperature reading represents the *difference* between Child B's answer and the right answer; for example, "warmer" is closer to the answer and "very hot" is nearly right.

GPS is basically a depth-first problem solver since "each method attempts everything appropriate to achieving a subgoal before returning control to the method of the subgoal that evoked it" (Newell and Simon, 1972, p. 415). Newell and Simon provide an example of a depth-first problem solving strategy.

Nursery School Solution

I want to take my son to nursery school. What's the difference between what I have and what I want? One of distance. What changes distance? My automobile. My automobile won't work. What is needed to make it work? A new battery. What has new batteries? An auto repair shop. I want the repair shop to put in a new battery; but the shop doesn't know I need one. What is the difficulty? One of communication. What allows communication? A telephone...and so on" (Newell and Simon, 1972, p. 416).

The solution to the nursery school problem requires the construction of a sequence of subproblems. After the most deep problem is solved, GPS "pops up" to a more shallow subproblem, and so on, until the problem is solved.

Important to the game of hot-and-cold and GPS is that the inferencing process does not change mid-stream. Designing, on the other hand, allows such changes. Consider the difference between the nursery school problem and the following trivial problem in which I made a tuna fish sandwich. My reader will see that my approach was GPS-like only to a point, and then it diverged. Here is the sequence of steps where my behavior and a GPS problem solver were identical.

Tuna Fish Sandwich Solution

I want a tuna fish sandwich made with onions, parsley, pepper and mayonnaise. I have the subproblems of opening the can of tuna and adding the tuna into a bowl, chopping the onions and adding them to the bowl, sprinkling the parsley into the bowl, etc. Each of these problems were successfully solved. However, when I got to the "add pepper" subproblem, I found that the pepper shaker was out of pepper. I had a new subproblem; namely, to add pepper from a can of pepper into the pepper shaker. Unfortunately, I added too much pepper to the shaker and needed to return some of the excess pepper to the can. This became another subproblem.

So far so good. All of my actions would mirror the actions of a GPS-like problem solver. Now, here is where my actions diverged.

When pouring the excess pepper back into the pepper can I left a considerable amount of spilled pepper near the lip surrounding the hole in the can. I had a new problem; namely, how to get rid of this spilled pepper? My solution was to pour the spilled pepper into the bowl containing the tuna.

According to a GPS-like problem solver, I should have produced a new subsubproblem "throw away the spilled pepper" and then pop up a level to the "sprinkle pepper from the shaker into the bowl" subproblem. My solution was ingenious by GPS's standards but quite ordinary by human standards; I popped up to a higher-level subproblem and used it as the context for the problem I was previously solving at a lower-level.

Notice that it was my process and not the visible result of that process that distinguished my approach from GPS. In my process, I used a learning method that one might call *serendipity*:

Serendipity. See if the current subproblem is a solution at some higher problem-solving level.

Introduction: Overview and Background

One might say that serendipity—at least, my narrow definition of it—is one method for controlling discovery, a process which has no place in GPS. Methods for controlling discovery offer flexibility rather than rigidity. With these methods we can change our minds, view the world from a number perspectives, and be more, not less, receptive to its variation and richness. Performance isn't everything; improving future performance, learning, matters.

Because we know that some designers are better than others, there must be design knowledge, what we casually speak of as "creativity". As Piagetians, we know that learning is not separate from doing, but intertwined. As Papertians, we know that it is possible to design environments for making contact with knowledge to which it is difficult to gain access. "Creative" people are those able to design environments for designing, design microworlds. But then, the barrier to creative action is the absence of knowledge about microworld design, evaluation and use.

Part 1
Interpretive Theory

Chapter 1

The Rehearing Problem

Introduction

In this chapter I use the rehearing problem to motivate a discussion about interpretation as a learning process. Briefly stated, if a musical experience depends on the element of surprise, hearing pieces repeatedly should result in diminished musical experiences. Since it usually does not, one might ask why. The complexity of the interpretive process will reveal itself as I begin to answer this question.

In subsequent chapters I will examine the interpretive process by contrasting two broad categories of interpretive theory, anticipatory listening and anthropomorphic listening, as well as the problem of interpretive context. Still later, I will show how designers can use their understanding of what interpreters do to evaluate the interpretability of the artifacts they make.

1 Musical Expectations

For most western theorists, music proceeds in patterns of tension and repose. The tension is created by the composer giving the listener a musical situation that provokes an expectation about what will occur next, and the repose is created by the composer satisfying the listener's expectation. Even if the composer withholds what the listener expects, this only postpones the repose, it does not do away with it.

Tension and repose usually describes patterns across a variety of spans of time. The smallest phrase made up of antecedent and consequent parts can be viewed as a simple tension-repose unit. These units are, themselves, patterned to produce successive spans of tension and repose. This is how tension and repose is characterized by *phrase structure* analysts (Bent, pp. 20-25).

Charles Rosen focusses on the role of harmony in tension-repose. He talks about the sonata form as the "polarization of the tonic and dominant triads" and "a 'tonicization' of the dominant set into relief". The phrase "tonicization of the dominant" describes how the dominant becomes the harmonic point of reference of the music and, therefore, takes on the functional role of the tonic. As listeners we expect one tonic. A second tonic – i.e the dominant functioning as-if it was the tonic -- creates harmonic tension. The tension is resolved during the recapitulation, where the real tonic is restored. This resolution serves to unify form parts into a tension-repose pattern at the highest level of pattern abstraction (Rosen).

1.1 A Naive Expectation Theory of Listening

The idea of tension-repose can be expressed using the following naive expectation theory of listening. The theory has three steps.

- (1) Given that two patterns are already recognized by the listener,
- (2) a listener recognizes the composer's intent to relate the first pattern to the second.
- (3) With the recognition of intent (#2) the listener is able to combine the patterns he has already recognized (#1) into a bigger ones.

This naive theory is powerful because it can be used recursively to produce *hierarchies* of patterns. For example, we can argue that the patterns used to construct bigger patterns are, themselves, products of previous mental constructions. Newly reconstructed patterns serve as components of patterns operating over longer spans of time, and so on.

This naive theory is also powerful because it leaves open what constitutes a pattern and, thus, allows *heterarchies* of patterns. Heterarchic representations are useful when an element can exist in a number of concurrent interpretive frameworks as it can in music. Patterns (e.g. of notes, rhythms, contours, dynamics, articulations, etc.) can be connected in a number of ways. Some may begin and end together, and others may overlap. Moreover, the same tension part of a tension-repose pattern can be connected to different repose parts. For example, a repose can serve as the end of a phrase as well as the end of a musical section.

1.2 Meyer's Listening Model

Leonard Meyer's *implication-realization* model of listening is a clear psychological model of the tension-repose type. He defines the implicative part of the model in the following way.

An implicative relationship is one in which an event – be it a motive, a phrase, and so on – is patterned in such a way that reasonable inferences can be made both about its connections with preceding events and about how the event itself might be continued and perhaps reach closure and stability (Meyer. 1973. p. 110).

Because "a pattern implies alternative modes of continuation" (Meyer. 1973, p. 115), a listener's inferences are not likely to be reliable. For this reason considerable interpretive work is done in retrospect, once the implied pattern has been realized. Therefore, a listener guesses where the music is headed based on where it has already been, and reflects on his guess based on the musical result. The "implication" stands for what is possible and the "realization" stands for what actually occurs.

Understanding what is possible requires knowledge about the kinds of reasoning one can expect to find in the music one is hearing. Meyer says that "...our understanding of a past event often includes not only our knowledge of what actually occurred but also our awareness of what might

have happened" (Meyer, 1973. p. 112). My naive theory of listening leaves room for Meyer's claim that there are many levels of implication and for each implication there is a variety of possible inferences and revisions based on what actually happens.

This awesome amount of complexity requires the kinds of reasoning we use to produce and evaluate *intentional statements*. Unlike causal statements which predict effects from causes, intentional statements predict causes from effects. Intentional statements are often unreliable since many causes can give rise to the same effect.

While musical interpretations are unreliable, they are not random, because there are conventions that dictate how music is expected to proceed. A *convention* can be viewed as a plausible hypothesis about pattern continuation that is evoked under certain pattern conditions. Meyer's implication-realization loop is the means by which previous hypotheses are evaluated, old ones pruned away and new ones generated. Hypotheses that are confirmed become more plausible, those that are refuted become weak or are eliminated. Previous experiences at making interpretations also makes it possible for listeners to acquire new kinds of conventions for subsequent interpretations.

Part of Meyer's claim is that musical surprises are a result of composer's using results which the listener is unlikely to guess. This is different from saying that the results are unreasonable. In retrospect, the listener is able to incorporate unexpected results into some reinterpretation of the musical data, either because shared conventions are in operation or variants are learnable by the listener during the listening process.

"...a piece of music must seem in retrospect to have fitted together -- to have been 'right'. A good composition makes us feel the uncertainty of the improbable, even while convincing us of its propriety. It confronts us with the capricious and cons us into believing it was necessary (Meyer, 1973. pp. 20-21).

Music is expressive because guesses will lead to surprises that are found to be reasonable in retrospect. Surprises that do not make sense are without expressive reward. They are meaningless.

1.3 The Rehearing Problem

Whether composers and listeners share conventions or composers are able to "teach" variants of conventions to listeners, it seems clear that the interpretive process is also, in part, a learning process. A back-door way of exploring learning is by asking how we might explain the listener's musical experience on repeated hearings of the same music? In principle, the surprises should gradually disappear the more a listener remembers from previous hearings. Music should lose all expressiveness if we accept a narrow formulation of Meyer's model! I will explore a variety of answers to this question in the form of five little theories of listening. The names I give these little theories are forgetting, second guessing, illusioning, conscious desiring, and unconscious desiring.

There are two restrictions I enforce on the discussion. First, my hypothetical listener lacks experiences between hearings. This restriction helps to sharpen the debate about rehearing by removing obvious sources of interpretive renewal. Second, I ignore music with lyrics in order to concentrate on aspects of expression that are not extra-musical [also see Appendix B: Some Theoretical Assumptions and Background].

1.3.1 Forgetting

One reason something remains surprising is that we have simply forgotten the pattern which led to the surprise in the first place. We may seldom remember, or even notice, enough of the numerous surprises to make a difference from hearing to hearing. This builds on the claim that experience is naturally distributed with many tension-repose units operating over different spans of time. Musical experience is comprised of many smaller musical experiences. The more there are, the less of a difference it makes if a few of them are forgotten or unnoticed.

Some music (eg. the music from many old films) is less interesting the second or third time around. This is evidence that a music *can* be less exciting if its surprises go away. On the otherhand, some pieces have moments which are so compelling that we cannot listen to them enough. While forgetting seems to be part of the story, it is not the whole story.

1.3.2 Second Guessing

Perhaps, we need to look at examples of surprises. In artificial intelligence (AI), unexpected results in the interpretation of natural language have been called *garden path effects* (Waltz and Pollack. pp. 51-74). For example, sentences like:

The astronomer married the star.

or

The plumber filled his pipe.

lead a reader down an interpretive trail which is intentionally misleading. The presence of the words "astronomer" and "plumber" provoke interpretations of "star" and "pipe" (respectively) which are likely to be wrong initially, yet entirely reasonable in retrospect. A simple example of a garden path effect in music is the deceptive cadence where the expected pattern of I -> IV -> V -> I is replaced by the unexpected (or less expected) pattern I -> IV -> V -> VI.

The above examples suggest that anticipations are a result of observers guessing among one of the implied consequences of the observed data. According to Roger Schank, another AI theorist, all understanding requires the mental production of implied data through a process of *inference-making*. "Inference-making is the process of making best guesses about what a speaker must have

meant apart from what he said explicitly" (Schank, p. 222). A garden path effect can be thought of as design method which promotes inappropriate inferences on the part of interpreters.¹

There are two interesting things about garden path effects as they have been described. One is that it is primarily a trick of reason and only secondarily a trick of perception. The words "astronomer" and "plumber" lead to associations which have been socially constructed. The deception of a deceptive cadence works in the same way. People unaware of these word meanings or deceptive cadence knowledge will not be surprised.

Another interesting thing is the *reflexivity* which causes a garden path effect to work. By the composer using the pattern [I -> IV -> V], he expects the listener to infer "I". Based on this knowledge, the composer produces "VI". However, the listener, in retrospect, can recover from this trick and, thus, recognize the composer's full intention. All of this is quite civilized because such tricks of reason are accepted conventions of musical discourse. I call these garden path effects *second guessing* to remind us that they are reflexive, re-interpretive, requiring the presence of some prior guess that relies on conventions of musical discourse.

If we return to Meyer's model we see that it does contain feedback loops which allow second guessing. However, this is still not sufficient to explain how rehearing remains exciting since such interactions should become less surprising on rehearing also. On the other hand, second guessing adds more surprises to those we are capable of forgetting.

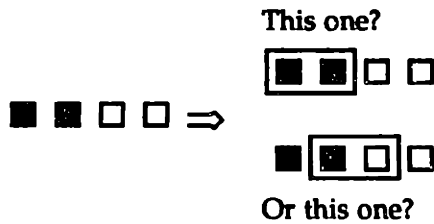
1.3.3 Illusioning

There is another explanation of garden path effects that has been eloquently argued by Ray Jackendoff. For him, there are built-in conflicts among mental agents designed to produce representations at various levels of abstraction. Garden path effects arise from a lack of time for mental process to resolve representation conflicts. I use the word *illusioning* (taking "illusion" as a verb) to suggest that the composer intentionally jams or overwhelms the processing system in order to create certain auditory illusions. A listener cannot avoid the effects of illusioning.

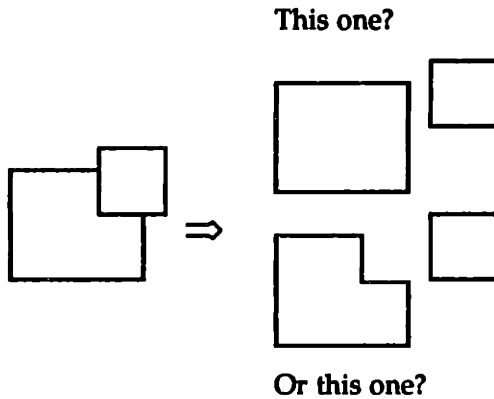
Cognitive scientists commonly talk about low-end processing as *local*, *bottom-up* or *data-driven*. In music, low-end agents usually operate over relatively short spans of time. Jackendoff uses *gestalt* grouping principles from vision research as examples of low-end agents (see below).

¹ In the spring of 1991 Boston taxis had a advertizing campaign to promote travel to the airport by cab. Some cabs had the sign THIS TAXI TURNS INTO AN AIRPORT; others had the sign TAXI TO THE AIRPORT. Garden path effects explain the humor in both of these cases.

Which grouping is preferred?



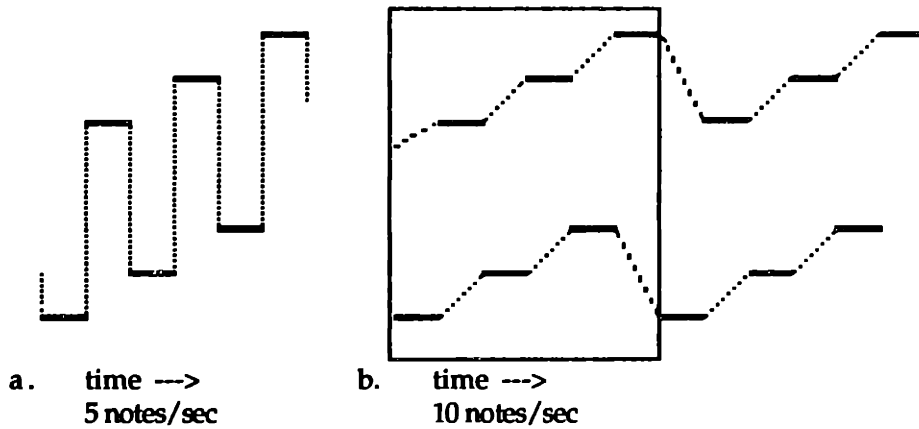
Which result is preferred?



Conversely, high-end processing is often described as *global, top-down* or *scheme-driven*. In music, high-end agents usually operate over relatively long spans of time. Jackendoff uses harmonic *abstractions* as an example of such agents.

Conflicts occur when these various processing agents are operating concurrently with different "goals". Resolving such conflicts takes time, time that illusioning effects do not allow. Since temporal constraints operate on the flow of information, they will always produce the processing lag necessary for these illusions to work. The more we pay attention to the music the more we are susceptible to these effects. Rehearing will not diminish them (Jackendoff, pp. 239-245).

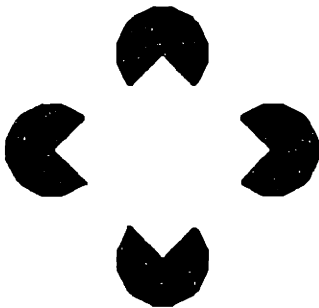
McAdams' and Bregman's work on *musical streams* provides a concrete example of how processing time can influence the way musical elements are interpreted. Graphic examples "a" and "b" (below) represent two interpretations of a pattern of notes. The notes in both examples differ only in the rate at which they occur. In example "a" the collection of notes is heard as one stream when played at a rate of 5 notes per second, and in example "b" as two streams when played at a rate of 10 notes per second (McAdams and Bregman, pp. 26-43).



Unlike second guessing, these effects rely on properties of auditory processing that are presumed to be invariant. Illusioning is certainly a partial answer to the rehearing problem, but only a partial one since observers from different cultures do experience the same music in different ways.

Illusioning is a limited explanation because gestalts are not only "perceptual" seeing but "conceptual" seeing. For example, the four pacman shapes (below) give rise to the "perception" of a square. The square is an illusion, a product of the field of perception defined by the positions of the pacmen. This illusion is consistent with traditional gestaltism.

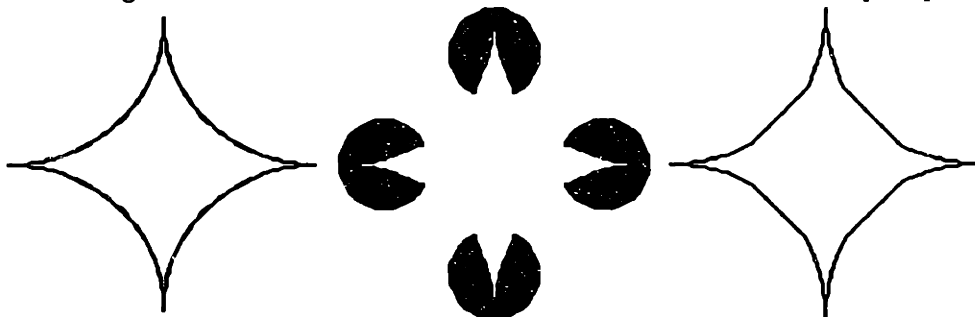
An illusory square



However, the following illusion is not a result of pure gestaltist seeing. Here the field defined by the pacman shapes supports the "perception" of the illusory figure shown on the left, not the one with the squared-off curves shown on the right.

The figure I see

An alternative perception



The drawn figure on the left continues the curve outlined by the mouths of the pacman shapes, using the concept of "curviness" to complete what is not directly seen. The drawn figure on the right is made by producing straight lines from the "lips" of the pacman shapes. Both figures operate by the gestalt "law" of continuation. However, because the way we apply the "law" requires the participation of higher thought processes, illusioning is only a part of the story as the following gedanken experiment illustrates.

Imagine the Pantheon. You may have a clear visual image of it, including its columned portico; but can you count the columns? You can choose to 'see' it as having three columns, or five or six, but how many columns were there in your original image? The question is, of course, unanswerable, because the image did not contain a set number of columns as such at all: rather, it embodied a generic property—we might call it 'many-columnedness'—which constituted one of the aspects in which the Pantheon presented itself to you" (Cook, p. 90).

These generic recognitions are described by Sartre and Minsky as *immanence illusions*. 'Seeing' is so often 'mental seeing' that we find it difficult to distinguish between them (Minsky, p. 155).

1.3.4 Conscious Desiring

Conscious desiring is exemplified by the backseat driver argument from Dipert. He argues that not only does a listener attempt to determine what the composer intends, he evaluates the composer's results based on what he would have done if he were in the driver's seat.¹ As Dipert puts it:

Often what we expect and what we want will coincide. But sometimes they will not. [Meyer's] theory with the addition of a notion of *musical desire* [my italics] completely solves the formidable problem of rehearing (Dipert, p. 16).

While Dipert's claim is a little ambitious, it does add a crucial kind of answer to the rehearing problem. In the narrowest sense, the composer and listener can share a knowledge of the musical alternatives but desire different alternatives. On one hand, since it is the composer's desires that dictate the path of reasoning actually followed, he can overpower the listener with his reasoning. On the other hand, the composer is not entirely in control of the listener's experience. A listener's desires are deep. Clashes of desires between composer and listener could keep rehearsals fresh. The film critic and theorist David Bordwell makes a claim similar to Dipert's.

"To some extent, the filmmaker (being himself or herself also a perceiver) can construct the film in such a way that certain cues are likely to be salient and certain inferential pathways are marked out. But the filmmaker cannot control all the [mental processing] which the perceiver may bring to bear on the film. The spectator can thus use the film for other purposes than the maker anticipated (Bordwell, p. 270).

¹ Note that this is an example of anthropomorphism, discussed in chapter 2.

Conscious desiring admits observer autonomy during the interpretive process, not only in what conventions are used to make interpretations but in the evaluation of the relevance of a particular convention.

1.3.5 Unconscious Desiring

Unconscious desiring is a different kind of theory of desire. Like Dipert's theory, it argues that even though the observer lives under the influence of his culture, he has some autonomy. Unlike Dipert's theory, *unconscious desiring* argues that the observer is not in charge of his own desires.

This argument draws from Minsky's computational theory of psychology called the Society of Mind Theory or SOM (Minsky, 1986). In his theory, the mind is a society comprised of many simpler minds-- i.e. mental agents--each with its own means for achieving specialized goals. These mental agents are like simpler instances of what we normally think of as "minds" because they are always active and perform with a certain degree of autonomy. What's different is that each agent has control over a small number of tasks and "knows" little or nothing about the operation of other agents in the society. For example, a society in its simplest form is comprised of agents which handle basic desires (like hunger, fatigue, and comfort). There is no reason why an agent concerned with hunger should "know" anything about an agent concerned with fatigue.

Complex tasks are handled by ensembles of agents--i.e. *agencies*-- which, in turn, may serve as components of agencies operating at higher organizational levels. A simple gesture like drinking a glass of water requires an ensemble of agents. Among others, drinking requires procedural agents for handling EYE-TRACKING, REACHING, TOUCHING and GRASPING.

There is no need for GRASPING agents to know much about the tasks handled by REACHING agents. It is the position of an agent in a process and the kind of agent it is which determines how it functions. For example, TOUCHING (the glass) should evoke some higher-up administrative agent which, in turn, evokes GRASPING (the glass). If GRASPING has been activated, some other administrative agent should inhibit REACHING (so that the glass is not toppled). Moreover, it would be inappropriate for GRASPING to always inhibit REACHING. GRASPING a baseball versus a drinking glass would require different relationships between EYE-TRACKING and REACHING.

This distributed view of mental process insulates agents from each other and allows thinking to be adaptive. The same GRASPING agent can be used for objects that are still or in motion, and agents found elsewhere in the mental society that perform the right kind of EYE-TRACKING or REACHING can be re-organized into new agencies.

However, problems can occur when agents are busy. For example, a glass may be knocked down because the agent that suppresses REACHING was not activated in a timely fashion. This would lead to an effect similar to Jackendoff's illusioning.

Other problems can occur when higher-level agents automatically evoke inappropriate lower-level agents. For example, an inappropriate EXPECTATION-agency may be evoked again and again until "precursor-sensitive censors" are constructed to inhibit it (Minsky, 1985). From Minsky's perspective, we cannot, nor do we wish to, avoid re-using mental agencies that have been constructed out of past experience. We have an "investment" in them that is proportional to how often they have been successful. These investments lead to interpretive effects like Dipert's desiring, theory 4, as well as more unconscious forms of desiring.

Moreover, unconscious desiring tells us that preferred ways of reasoning are as resistant to change as illusioning effects (theory 3). But then, it is difficult to distinguish between effects having a perceptual basis and those having a cognitive basis. This is not surprising because of the reflexive nature of the interpretive process itself.

1.4 Interpretive *Thinking Caps*

Indeed the first four theories of listening can be organized within the representation framework of Minsky's Society of Mind theory. Within this framework, there are minds that serve as different kinds of *thinking caps* and other minds that determine which cap to where and when. For example, each hypothesis, both guesses and second guesses, can be thought of as mental agencies—little theories that are "thought" by little minds. Each "believes" in a particular interpretation of the world and is activated when it "senses" the presence of that world.

* * *

This model of mind seems to reflect the way we learn how to think and act. We do not want theories so specific that they have no future applicability. We also do not want theories that are so general that they prevent subtle discriminations. We want them at just the level of abstraction where they can do the most good. The music theorist Joseph Kerman says as much in his appeal for theoretical pluralism. "The musician's instinctive tendency is always to choose among rival analytical systems or principles, rather than look for broader alternatives to analysis itself" (Kerman, p. 47).¹

In chapter 2 I will examine the interpretive process at a pragmatic level by contrasting the interpretive perspectives of anticipatory listening, of which Meyer's theory is an example, and anthropomorphic listening. In the chapters on design I will argue that composers sometimes put on these interpretive thinking caps in order to evaluate the interpretability (or user utility) of the artifacts they design.

¹ The temptation to look for a homogeneous theory of mind seems to be deep. Indeed, the idea of applying a theory broadly seems to be a very useful heuristic for determining the limits of a theory's productivity, for gathering new data and for generating new theory [see Appendix C: The Temptation for Homogeneity].

Chapter 2 Perspectives on Interpretation

Introduction

The interpretive process is a many-faceted process of perceiving and conceiving. Perspectives on interpretation that are of greatest interest to the composer are those which have operational content during the evaluation of the design process. I focus on two, anticipatory theory and anthropomorphic theory. Anticipatory listening relies on musical conventions to create expectations in the minds of listeners. For example, a composer can use a *crescendo* as a signal to the listener that something important will happen next. The more a crescendo is prolonged, the more intense a listener's expectation.

Anthropomorphic listening relies on identification. Musical patterns function as if they are dramatic actors; for example, sound effects in cartoons often function in this way. In fact, the crescendo can be used to illustrate this too. A crescendo can be a proxy for the windup before the punch. The longer the windup, the more vicious the punch.

In simple cases (e.g. crescendos) anticipatory and anthropomorphic approaches seem indistinguishable. In more complex cases, where interpretive acts are reflexive, these listening perspectives can be complimentary; listener's can switch between them. For example, a listener may infer a convention from a pattern and, through this process, identify with it; reciprocally, a listener may identify with a pattern as a means of relating it to others that are familiar and use them to infer conventions.

2.1 Anticipatory Listening and Expectation Theory



According to expectation theory, we select convention-memories to match what we anticipate will happen. In music an *expectation* is the work done by a music convention once it has been selected for interpretive use. When everything has gone well and expectations are fulfilled, there are no surprises. *Surprise* is the result of a convention-selection error. Mandler calls a surprise an *interrupt* that occurs when there is a significant mismatch between expectations and observed events. *Recovery* is the process of correcting the error: e.g. by selecting a different convention or modifying one that is a close match to the events one is observing.

Between the moment of surprise and moment of recovery an interpreter may be totally lost. More likely, the listener finds the music ambiguous. From a cognitive perspective, *interpretive ambiguity* occurs when a listener is entertaining many equally plausible interpretations. The fewer the plausible interpretations, the less ambiguous the situation, and the closer the interpreter is to recovering from surprise.

2.1.1 Plausibility

Mandler's notion of plausibility gives meaning to Meyer's use of probabilities (below) by connecting observation to a listener's interpretive history.

The more equal the probability of different alternative consequents, the more likely that the musical progression will seem ambiguous (Meyer, 1956, p. 52).

Mandler offers three criteria for determining plausibility; (1) the degree of *discrepancy* between the expectation-convention and the observed data, (2) the degree of *complexity*, and (3) the degree of *investment* in the convention.

Investment has to do with the number of times an expectation was successful in the past. The more successful it has been, the more likely we are to apply it. *Complexity* has to do with the number of events "captured" by an expectation. The more events an expectation captures, the more resistant we are to discarding it. *Discrepancy* has to do with the degree of mismatch between the expectation and what actually occurs (Mandler, pp. 171-188).

2.1.2 Surprise-Recovery

All of the expectation theorists I have read—Mandler, Iser, Bordwell, and Meyer—agree that surprise-recovery is a reflexive process. Iser describes it as "a continual interplay between modified expectations and transformed memories" (Iser, p. 111). Reflexivity is a part of Meyer's *implication-realization* model. An implication is the predicted result and the realization is what actually happens which is used to make new predictions.

2.1.3 Conventional Knowledge

Expectation theorists suggest that expectations are pieces of conventional knowledge. Meyer talks about them as "normative musical behavior". Bordwell suggests that they rely on shared assumptions, principles and stories.

"People tacitly assume that a story is composed of discriminable events performed by certain agents and linked by particular principles" (Bordwell, pp. 33-34).

"in a Western, we expect to see gunfights, bar room brawls, and thundering hooves even if they are neither realistically introduced nor causally necessary" (Bordwell, p. 36).

Expectations give structure to data at various *levels of abstraction*. In music, "levels of abstraction" are embodied in various spans of interpreted time. The level of abstraction keeps relatively constant the quantity of detail required to characterize an expectation. To take Bordwell's case, the particulars of any western are suppressed because the notion "western" is an

abstraction for all westerns. So are the particulars of "gunfights" and "bar room brawls". Expectations are all about the same "size" because their "size" is not a reflection of the complexity of the event but of the simplicity required to remember it. Expectations are "mind-size" not "world-size". The details of an expectation appear only when they are required to do some additional cognitive work.

Iser's "repertoires" and Becker's "I got rhythm" and "Honeysuckle Rose" are examples of conventions.

The repertoire of the text is made up of material selected from social systems and literary traditions (Iser, p. 86).

Young jazz musicians learn early in their training that the standard popular songs on which many jazz numbers are based have an eight-bar middle section (the "bridge") that takes one of two harmonic forms, each named after a well-known song in which it appears: an "I got rhythm" bridge, consisting of the following chords for two bars a piece – III7, VI7, II7, V7 – or a "Honeysuckle Rose" bridge – I7, IV II7, V7. Knowing that, anyone playing an unfamiliar tune can quickly learn eight of its bars by being told which sort of bridge it has, if it is one of those standard types (Becker, p. 60).

2.1.4 Emotive Role of Expectations

The emotive role of expectations is found in the element of surprise. However, Bordwell argues that expectations may not be about emotion even though they might "trigger" emotion (Bordwell, p. 40). Bordwell wants to distinguish between emotions that tickle the mind (like surprises) and those which produce more fundamental effects. Of those which tickle the mind he offers two categories, those that are the product of a satisfied expectation, and those that are the product of a thwarted expectation.

When we bet on a hypothesis, especially under the pressure of time, confirmation can carry an emotional kick; the organism enjoys creating unity. When the narrative delays satisfying an expectation, the withholding of knowledge can arouse keener interest (Bordwell, p. 39).

While Bordwell views expectation-based theories as limited to explaining mind-ticklers, Iser's notion of *entanglement* goes deeper. In discussing the nature of our investments in the interpretations we make, Iser says:

This whole process [of balancing discrepancies] takes place within the reader's imagination, so that he cannot escape from it. This involvement, or entanglement, is what places us in the 'presentness' of the text (Iser, p. 129).

Because (or when) we get entangled in the interpretations we make, the interpretive process can have deep emotional consequences.

The gradual process of this formulation draws the reader into the text but also away from his own habitual disposition, so that he finds himself impelled more and more to make a choice between standpoints (Iser, p. 218).

We can see from Iser's comments that deep interpretations are tied to the constraints enforced by the interpretive context as well as the experiences of the interpreter. Therefore, observations that collide with our expectations but make sense in retrospect can run deeper than Bordwell's mind-ticklers.

2.2 Anthropomorphic Theory



"Put three lines on a circle, and you will inevitably see it as a face. Why?"

"We tend to animate sounds as well as sight" (Kivy, p. 57).

2.2.1 Performer-Actors

Expectation theory is weak in accounting for the performance context. According to Keller, performers have control over phrasing, articulation, dynamics and tempi. Of these four, phrasing is the most constrained since it reflects the musical structure of a piece while articulation, dynamics and tempi follow more local laws (Keller).¹ These musical parameters give performers the means to make a wide range of interpretations.

Edward Cone's lovely book *The Composer's Voice* discusses the different kinds of relationship a performer has to the music and its performance. For Cone, the performer is, on one hand, an actor impersonating the composer and on the other his own person providing a reading of the music. The performer's analytic and personal knowledge, his "hyperconsciousness", causes a fusion between person and actor so complete that it often appears that the performer is composing the music himself. In addition, the performer is a member of his own audience, the most privileged member since he has control over the material that the listener does not have.

It seems true that as listeners, we compare performances by different orchestras, conductors and performers. We even compare different performances by the same performer over that performer's life, especially as we become more familiar with the piece or the performer. These comparisons are made not only to evaluate the technical or interpretive correctness of a performance. Whether the performer plays enough right notes or conforms to a particular interpretive tradition is only the beginning. Comparisons are made to reflect on the interpretive potential of a piece and the interpretive intentions of the performer.

¹ We might also add *ensemble color* to Keller's list; it is only hinted at by Keller's discussion of dynamics.

2.2.2 Pattern-Actors and the *Learning Paradox*

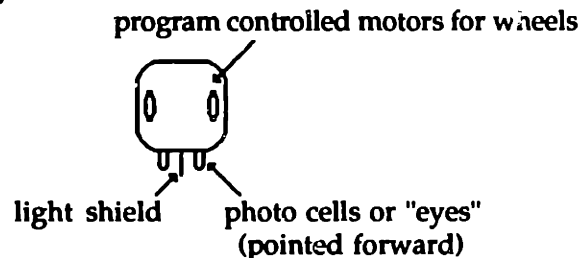
An interpreter not only identifies with the performer, he identifies with musical patterns by projecting intentional behavior onto them. For example, main and secondary themes are not unlike main and supporting actors; pattern conflicts are like dramatic conflicts between protagonists and antagonists.

Nira Granott argues that *anthropomorphism*—which she discusses as "animistic discourse"—is an efficient learning strategy for making the unfamiliar familiar. Granott traces animistic thinking beginning with Piaget's study of egocentric behavior among children. Young children have difficulty distinguishing between projections of themselves into the physical world and the physical world itself. For example, children have difficulty distinguishing between things that are alive and not-alive because they view *movement* (something of which they are capable) as a differentiating criterion; a ball is alive because it rolls while a plant is not because it does not. As children identify different criteria for making alive/not-alive distinctions, their answers become more reflective of adult understanding.

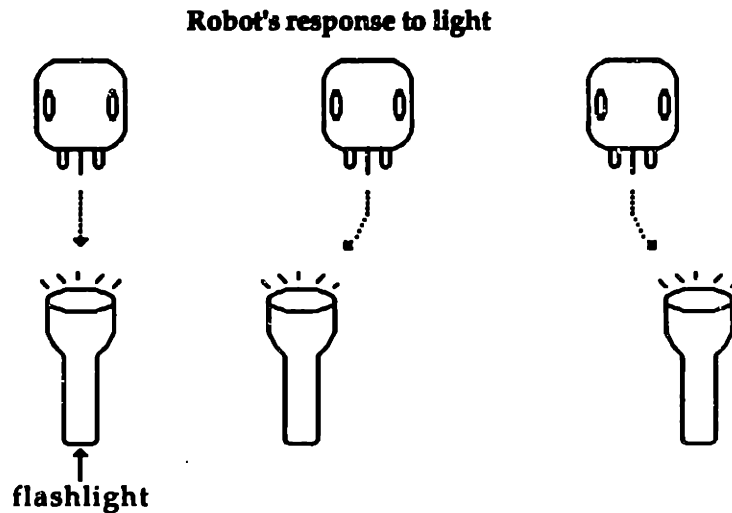
In Turkle's study of children's thinking about electronic "toys" (e.g. speak-and-spell, calculators, etc.), younger children do not attribute aliveness to these objects; after all, the toys do not "move". However, older children do attribute aliveness to them because they use psychological rather than physical criteria to make alive/not-alive distinctions. In this virtual world, there are actors taking and receiving actions much like there are in the real world. Because the older children can make analogies between virtual and real worlds, they are compelled to "animate" these transactions.

In Granott's own studies of animistic behavior she developed a collection of six *weird creatures*, Lego-Logo robots that combine sensors for detecting light, sound and touch with motors for moving the robots around and logic blocks to link detections to movements. Consider one of them, a robot with its photo-cell "eyes" pointing forward and separated by a light shield so that incoming light (from a flashlight) is registered differently on each "eye" depending on its incoming angle.

Self-regulating Robot (view from above):



The robot responds to light in three ways. If the flashlight is directly in front of the robot it moves forward, if the flashlight is to the left the robot moves left, and if the flashlight is to the right the robot moves right.



Granott wanted to know how people think about robots like this one. She asked teachers to observe it and describe its behavior as an ethologist might do with real animals. Granott noticed that the teachers tended to use anthropomorphic rather than mechanistic descriptions (Granott, 1990; Granott, 1991).¹

The Anthropomorphic Description of the Teacher

The robot loves light.

A Mechanistic Description

If the left eye receives more light than the right, the robot moves left.

If the right eye receives more light than the left, the robot moves right.

If both eyes receive equal light, the robot moves forward.

For Piagetians, new learning is possible because one uses what is familiar to get at what is unfamiliar. However, if something is totally unfamiliar one cannot use a familiar mental scheme to identify unfamiliar data; and without data, one cannot construct a new mental scheme. This *learning paradox* expresses the fact that learning something completely new is impossible; or if learning is happening, what one is learning is not completely new. Granott's research shows how different kinds of discourse might be used to transcend the learning paradox.

Mechanistic descriptions are not necessarily privileged among experts. Anthropomorphic descriptions can capture the functionality of complex processes one already understands in

¹ To the above descriptions, Resnick and Martin add *informational* descriptions. For our light-sensing robot, an informational description might read: The robot's sensors quantify light inputs. These values are used as inputs to a program that sends a control signal to the motors directing the movement of the robot (Resnick and Martin, 1990).

mechanistic terms. For example, computer programmers often describe program modules as "wanting" inputs from each other. Programmers use these anthropomorphic descriptions, not because they are unaware of the computational mechanisms that support these modules, but because they want to examine them at a level of abstraction where the modules interact. Knowing which kind of description will be most productive when is a kind of knowledge.

Music interpreters are faced with the same kinds of problems. They need a strategy for making the unfamiliar familiar and they need a strategy for abstracting the musical detail into functional parts. The first problem is about getting access to unfamiliar musical data while the second problem is about managing the data once it has been accumulated. Anthropomorphic theory provides a strategy for addressing both problems.

The music theorist Fred Maus argues that there are two kinds of musical descriptions, *technical* descriptions used by trained musicians to articulate a music's structure, and *emotive* descriptions used by music-lovers to express their experience of the musical drama. These two kinds of descriptions divide neatly into anticipatory and anthropomorphic listening.

Maus argues that both kinds of descriptions are crucial for producing musical understandings. More provocatively, he argues that an analyst uses the emotive to resolve ambiguities in technical descriptions (Maus, p. 58-63).

Not surprisingly, one of the problems with emotive descriptions is that they lack analytic clarity. Maus attempts to bring clarity to such descriptions by using terminology from narrative thinking; for example, a musical motive can be viewed as *dramatic characters*, as protagonists and antagonists, and certain musical events can be viewed as *actions*, and other events as *agents of actions* (Maus, pp. 67-70). For Maus, an observer attributes human intention to musical pattern and uses his intentional experience to examine relationships among these patterns. The projection of narrative thought onto musical thought illustrates anthropomorphic thinking.

Like Maus, Cone uses narrative thinking to explore and express emotive experience. He thinks of the musical background as performing the functional role of *stage direction* (Cone, p. 11). This resonates with the intuitions that a music background "sets the mood". Alternatively, the musical background can play a *rhetorical* role. This is especially true in opera, where the background can tell the observer whether the protagonist's statements are meant to be interpreted literally or sarcastically, or whether the protagonist is speaking for himself or for the composer (Cone, pp. 36-39). Cone defines *drama* as being between *ritual*--something identifiable, "repeated frankly"--and *game*--something unpredictable, "simulated reality" (Cone, p. 115). With this view of drama, one can imagine how a composer can use a musical background to modify the degree of dramatic ambiguity by balancing the amount of ritual and game.

Kivy calls the drama within the music *emotive predicates* or "music that expresses particular emotions" (Kivy, p. 6). Kivy wants there to be emotive predicates in order to explain "why there is

wide agreement about what emotive characterizations at least broadly fit many parts of many musical works" (Kivy, p. 16). However, he is also uncomfortable with the idea of emotive predicates because it can be easily shown that the same musical phrase can evoke different emotions depending on its context. As he says, "music is a protean expressive clay" (Kivy, p. 100).

Even though emotive predicates are pliable, we can be precise about where the pliability comes from. Interpreters construct the observed musical gestures into expressive behaviors much like Granott's teachers construct the robot movements into behaviors ("the robot loves light"). Because these behaviors are mental projections that draw from an interpreter's experience, they cannot be predicted in advance. However, because experience is, in part, socially constructed, projections are not entirely unpredictable.

* * *

Musical behavior is not embodied in the music but in the interaction of the music with the interpreter. For example, many of Granott's teachers found the anthropomorphism "the turtle loves light" acceptable. Now, I am sure that each teacher had a different notion of "love". However, while particular notions of "love" remain private, there is a public notion of "love". We can say that emotive predicates work at the *generic level* only.

Is not true that all interpretive "predicates" work at this level, that interpretive communities are, by definition, constructors of descriptions that are generic for its members? It seems to me that the indeterminacy of musical intent applies to either "emotive" or anticipatory "predicates". The problem, as it will be expressed in the next chapter, is that there are many interpretive contexts in which either kind of interpretive "predicate" is constructed. Each context provides the listener a little musical "evidence". The final interpretive "verdict" is based on the accumulation of "evidence". Moreover, all of the evidence does not have equal weight; indeed, the last piece of "evidence" can even reverse the "verdict"!

In the chapters on design I will show that what is problematic for the interpreter is an opportunity for the composer. Contextual ambiguity gives the composer considerable flexibility; he can change his mind by incorporating one interpretive context within one operating over a longer span of time.

2.3. Analogical Listening (Reminding)

Roger Schank's notion of reminding cuts across anticipatory and anthropomorphic listening. According to Schank, an AI theorist, the reason why inventive people can continue to draw from previous experiences is because experiences are *multiply indexed*. The current situation can contain details that remind us of many, often very different previous situations. For example, situations with dogs as their subject may remind us of a past event with a dog; going for a walk may remind us of the time we were walking our dog; or avoiding getting wet can remind us of the time we were

walking our dog while it was raining. Schank calls situations *cases*, and the class of mechanisms for matching past and current cases *reminders* (Schank, pp. 12-24).

An interpretive context is not fully determined by the musical detail—this is why something like Schank's reminders are necessary. They are used to activate networks of previously stored memories, constructed using either anticipatory or anthropomorphic listening.

There are also *generic experiences* that are quite complex, compiled from many sessions of musical listening. This is why listeners can immediately recognize something as Spanish-like, Beethoven-like, or Darmstadt-like. These experiences are also constructed using the kinds of listening we have already encountered.

Finally, musical events can remind us a variety of extra-musical events, some commonly shared, others quite personal. An example of the first case is the associative thinking Prokofiev¹ asks the listener to make between motivic elements and dramatic characters in *Peter and the Wolf*. An example of the second is what Sloboda calls "they're playing our tune" (Sloboda, p. 2). A tune might remind two lovers of the circumstances in which they heard it and, thus, inherit meaning from these circumstances. Obviously, none of these particular reminders could have been anticipated by the composer. Thus, the interpretive process is, in part, under the control of the interpreter.

2.4 Interpretive Synergy

Given some musical experience, the number of acceptable interpretations is too large or personal to anticipate. At the same time, just any interpretation will not do because there are common musical experiences and conventions that restrict interpretive indeterminacy. Kivy need not be disturbed about the lack of precision in emotive descriptions. It is only disturbing when one assumes that technical and emotive descriptions exist in an either-or relation rather than in a complimentary relation.

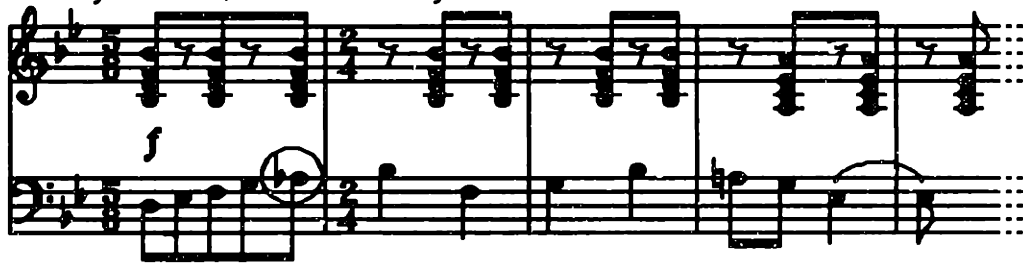
¹ An invective:

The music of The Love for Three Oranges, I fear, is too much for this generation. After intensive study and close observation at rehearsal and performance, I detected the beginnings of two tunes...For the rest of it, Mr. Prokofiev might well have loaded up a shotgun with several thousand notes of varying lengths and discharged them against the side of a blank wall.

Edward Moore, *Chicago Tribune*, December 31, 1921; in Slonimsky

Consider the first few bars of Stravinsky's¹ Royal March in *Histoire du Soldat*.

The Royal March, from Stravinsky's *Histoire du Soldat*



In the first measure we are reminded of a *generic* musical construct for marches and marching bands. The percussion writing that supports this material (not shown) reinforces this reminding which provokes an associated motor memory (i.e. of marching). The motor memory places us in an anthropomorphic relationship to the music and, at the same time, enforces certain expectations about how the music will continue. What is unexpected (and funny) is what happens in the second measure. Because the downbeats have become upbeats, we find ourselves out of step in our "mind's body". This is an anticipatory response, an unanticipated meter change, which depended on the anthropomorphic response, an out of step body experience. Both required the prior recognition of a generic musical construct, marches or marching bands.

The tiny surprise at the end of measure 1, the circled Ab in the ascending trombone line, may be considered strict anticipation except that we might think of this line as being *like* a scale before we recognize what kind of scale it is. Only when there is a hunch about what the scale is will the Ab seem unnatural (or less natural) than the A-natural it replaces. Such reflexive chains of interpretation are common.

The following example is taken from a book on Japanese music by the ethnomusicologist William Malm. He calls the effect *word painting*. The example shows a wavering movement in the melody which "paints" in time the pine branch (*matsu*) waving in the wind (Malm, pp. 68-69).

¹ An invective:

The audience expressed directly and flatly its dislike of Stravinsky's Concertino...The fiddles had spoken bitterly: futility. They had spoken angrily: boredom...The Stravinsky music is a drab, rasping tired shuffle and breakdown. It is like a locomotive which has fallen off the track, making its wheels revolve in air. Rhythms prolong themselves out of sheer inertia; pound on, wearily. A lyric coda of a few measures, a sort of momentary illumination of a darkened landscape, breaks off into silence.
Paul Rosenfeld, *The Dial*. New York, February 1921; in Slonimsky



Malm's *word painting* (Malm, p. 69). The wavering melody resembles the pine branch (*matsu*) waving in the wind.

The wavering melody is analagous to the behavior of the waving pine branch. Both oscillate similarly in time, both have similar movements—i.e. small displacements in space are like small displacements in pitch. We also see anticipatory listening in the example from Malm. Both the up and down movements of the wavering melody and pine branch exhibit slightly unpredictable behavior (i.e. the irregularities are judged against a predicted regularity).

Here is another example from Stravinsky's¹ *Histoire du Soldat* which is full of humor like many of his other pieces. It is the beginning of *Tango*, one of Three Dances (a tango, a waltz, and a ragtime). The melody is played by the violin and accompanied by a percussion line.

Tango from the Three Dances in Stravinsky's *Histoire du Soldat*



¹ An invective:

Stravinsky's *Symphony for Wind Instruments* written in memory of Debussy...was greeted with cheers, hisses, and laughter. I had no idea Stravinsky disliked Debussy so much as this. If my own memories of a friend were as painful as Stravinsky's of Debussy seem to be, I would try to forget him.
Ernest Newman, *Musical Times*, London, July 1921; in Slonimsky

The rhythms in the melody and percussion are the same in bar 1, establishing the tempo right away. We recognize that the melody is the same in bars 1 and 3, and the rhythm is the same in bars 1, 4 and 7. Somehow, these lower level recognitions evoke generic tango memories and enforce certain expectations. I expect the rhythm that starts on the second beat of bar 1 to repeat again on the second beat of bar 3. It doesn't. The melody should start at the beginning of bar 4. Instead, it starts after an eighth note rest. In both of these cases, something that I expect does not happen. In contrast, something happens that I do not expect. The rhythm that starts in bar 6 should be the same as the one that starts in bar 1. It isn't.

By the end of bar 1, I have guessed (wrongly) that the music is in C minor. Bar 4 casts doubt on this guess and bars 5 and 6 provoke the guess that the music is in A minor. Musical bars found later (and not shown) cast doubt on the A minor guess as well. What I will discover is that the music wanders through a number of keys. This happens through a succession of interpretations, each based on new evidence.

There are also anthropomorphic effects. The melodic and percussion lines serve as proxies for the musicians playing them, as if there were two "actors" in search of a tango. These actors do not appear to be paying much attention to each other except for the brief moment (in bars 6-7) where they sound synchronized. Paradoxically, all the ingredients of a tango are there but they do not fit to make a proper tango. Stravinsky paints a patchwork of tango-like sound images similar to what one finds in a cubist painting. (The face is there, but all the features have been re-arranged.) This patchwork tells its own ironic story, one not explained by the anticipatory effects alone.

The interpretive effects found in these examples are most rewarding when the listener can use them to support each other. If a listener has never heard a march or a tango, or seen a wavering branch his listening experience would be diminished. If he does not have conventional western musical notions, he won't enjoy the humor in Stravinsky's use of the Ab or the 5/8 meter in the first measure of the *Royal March*. I am sure that my experience of Malm's example would be enhanced if I was more sensitive to aspects of musical expression native to Japan.

* * *



I have argued that neither anticipatory nor anthropomorphic listening is adequate for explaining the construction of musical experience, though a synergy is created by the use of each interpretive perspective as scaffolding for the other. I have also suggested that these perspectives can serve as "thinking caps" during the design evaluation process. This will become clear when I apply them in part 3, and after I have added four additional perspectives in part 2.

Chapter 3 Virtual Worlds and the Context Problem

Of the two persons who possessed my entire love, and of whom one still lives, you are the third.
Beethoven, Letter to Amenda (1801)

Introduction

While the last chapter has focussed on *how* aspects of the interpretive process work, this chapter focusses on *what* is interpreted—the units of interpretation. This will lay a final stone in the foundation on which the design discussions will be built.

Anticipatory or anthropomorphic listening are used to make sense out of units of interpretation, spans of musical time, or what I call *contexts*. I assume that contexts are not givens, but mentally constructed. For example, a context can be defined as the time beginning with the recognition of an expectation and ending with the recognition of the expectation's fulfillment. Until the expectation is fulfilled, the context is not known; its fulfillment causes its recognition.

Most artifacts are sufficiently complex that they require the interpreter to make hundreds (or thousands) of interpretations, comprised of many contexts, large and small, contiguous and overlapping. The process of constructing and sorting out these various contexts is what I call the *context problem*. "Solving" contextual problems requires exploration because the interpretive process is constantly offering new evidence which, in turn, provokes the construction of new contexts to handle it. In this chapter I illustrate this process using the humor experience.

Interpretations are used by the interpreter to progressively construct (or live-out) a musical experience, what I call a *virtual world*. The musical artifact is not the virtual world, though it constrains its construction. Instead, the virtual world is a product of the interaction between the artifact and the interpreter. This formulation of a musical experience makes it easy to distinguish between the intentions of the composer and the intentions of the interpreter. For example, a composer can try to minimize context problems that he feels have little or no expressive value. By doing so he promotes interpretability even though he cannot insure that a particular interpretation will occur.

3. The Humor Experience

In his letter to Amenda (above), Beethoven used anticipatory writing to produce *garden path effects* (as in "The astronomy married the star" in chapter 1). Garden path effects can be used as a source of harmonic punning (e.g. right chord, wrong key = right word-sound, wrong word-meaning). In the finale of his 8th Symphony Beethoven produces a musical pun, beginning with an

"unceremonious modulation" in bar 372 and the use of enharmonics (Db <-> C#). Beethoven hammers away at the C# in measures 374-378. Is the C# the tonic? No, it is the dominant of F# minor (Schauffler, pp. 329-339).

Beethoven's 8th Symphony, Finale

Bar 372 Bar 374

Bar 376 Bar 380

The word-games that are characteristic of puns are humorous because they draw our attention to the ambiguities of sound and meaning that exist in English. Tongue twisters (e.g. She sells seashells on the seashore; she sits and shells, she shells and sits) are humorous because diction errors result in nonsensical phrases or prohibited utterances (Apte, p. 184).

The techniques used in the following word-puns are easy to see. The first pun produces its effects by mixing words that sound alike but have different meanings (e.g. wafer, away for),¹ the second produces its effects by playing with the different meanings of the word "racket", and the last by playing with the different meanings of the phrase "goes through".

Q: Why did the cookie cry?

A: Because its mother had been a wafer so long (Apte, p. 105).

Q: Why is tennis such a noisy game?

A: Because each player raises a racket.

Q: What goes through a door, but never goes in or comes out?

A: A keyhole (Apte, p. 181)

¹ A large sign on some Brigham's Ice Cream trucks reads: Sundae Driver.

Unlike music or stories, jokes require a small number of interpretations and relatively simple strategies for understanding them. However, I argue that while jokes rarely provide the richness that would make them repeatedly interesting, the mental mechanisms for producing humor from jokes are elements of mechanisms for producing experiences like those we make in dramatic or musical settings.

But, why is the humor or art experience useful in the first place? I argue that the humor experience is a risk-free world--a *virtual world*--in which observers can assess thought, feeling and action with immunity from judgment from the *real* world. Observers also calibrate their interpretations against those made by others in their interpretive community. This is why experience is both a private and public affair.

3.1 The Virtual World of Humor

Apte shows that *humor provides a means for establishing or evaluating social alliances*. Joking relationships are seldom found among members of the nuclear family, especially in preliterate societies. Feelings of authority, respect, love, and obligation are too strong for a playful attitude. This is not the case with members of the extended family. Cross-cousins, sister-in-laws and brother-in-laws can enjoy this playfulness. Similarly, sexual jokes are less likely to be found among close kin and more often to be found among more distant kin. However, because the notions of "close kin" and "incest" change from culture to culture, different people can be the subject of sexual jokes in different cultures (Apte, pp. 37-39).

Among the Tallensi and Lowili tribes of Africa, a woman calls her brother's wife "wife". The sister might joke by saying: "If I'd been a male wouldn't she (i.e. my brother's wife) then have been my wife?" (Apte, p. 43). Another form of joking is "playful insults", as in the following exchange between grandparent and grandchild in the Gusil tribe (Africa).

Grandparent: "Come, you dog, get me some water".

Grandchild: "Yaa, you are a dog yourself, go get me a drinking cup, I am thirsty!"

Grandparent and grandchild have a marginal role in society since the grandchild is beginning to enter the mainstream while the grandparent has begun to leave it. Their marginality becomes the source of a human alliance, an alliance founded on friendship rather than authority (Apte, p. 46). False accusations, like insults, are humorous when performed in a context of alliance building; otherwise, such accusations can have the opposite effect.

Among the Dutch a man can make flirtatious comments to his wife's female friend as long as his wife is present. These public displays assure his wife that no sexual affair is going on between them in private (Apte, p. 53). As in the playful insults between grandparents and grandchildren,

these flirtatious gestures are ways of examining in a virtual world behaviors that are normally unthinkable in the real world.

Humor can be an instrument of socialization. The *trickster* is a common character throughout world culture. Tricksters are naive, defy convention, are mischievous, excessive, lack common sense and social propriety. They also behave in unpredictable, inappropriate, unreasonable and exaggerated ways (Apte, pp. 217-233). The trickster teaches through counterexample since practically everything he does we should not do.

Humor provides a means for exercising interpretive skill. Whether the *tone* of a social interaction is formal or informal can influence how we evaluate what is said. American blacks frequently switch between different language styles depending on their motives (Apte, pp. 193-195). Sarcasm is humorous because the truth is the opposite of what is said. A mismatch between the tone and informational content is one means of producing sarcasm. Mimicry, exaggeration, and mockery often involve gestural displays and can accomplish with physical movement what tone can accomplish with speech (Apte, p. 205).

Humor can be thought of as a device for examining how and what we think, as illustrated in the following joke.

An orthodox rabbi and a Catholic priest were playing golf together and were discussing religious differences when the priest turned to the rabbi and said, "Quite confidentially, Rabbi, have you ever eaten ham?"

The rabbi in a very soft voice answered, "Confidentially, yes."

As the two continued to play, the rabbi thoughtfully asked the priest, "Very confidentially, Father, have you ever gone to bed with a woman?"

The priest blushed, and, in a whisper, answered slowly, "Yes, I have."

"Better than ham, wasn't it?" The rabbi exclaimed (Apte, p. 116).

We the viewers do not expect the Rabbi's response and are surprised by it; yet, when he gives his response, we are able to reframe the context of the discourse so that it makes sense. This anticipatory response is supported by an anthropomorphic response. The surprise works, in part, because we identify with the Rabbi who (we might believe) reframes the context of discourse to lighten the tension caused by these reciprocal confessions. We also experience the momentary surprise of the priest. My conjecture is that the surprise places the observer in a position of epistemic neutrality from which he gets a glimpse at his own notion of belief. Perhaps, laughter is a nervous reaction to belief momentarily questioned.¹

Minsky argues that *analogy*--i.e. using knowledge in one domain to explore features of an unknown domain--is a powerful means by which people learn to understand novel situations

¹ See Wolfe's *Epistemology: The Justification of Belief* for a lucid discussion of belief as assumption-testing at the deepest level.

(Minsky, 1980. p. 9). However, analogical reasoning can result in the construction of inappropriate mental links between current and past cases. For example, most common sense logic requires shifts between *frame-like* reasoning steps, Minsky's term for how previous cases are mentally represented. Frames like *A implies B*, and *B implies C* evoke a shift to the frame *A implies C*. As Minsky also points out, such frames are not always appropriate. Here, I can provide a personal anecdote.

I was visiting a friend at the University of Campinas (Brazil). One weekend night I went with him to a barbecue given by one of his students. I observed that people ate substantial quantities of meat, even by North American standards. Apparently, one of the guests caught my eye as he stacked up pieces of meat on his plate. He said to me: You know, I'm a vegetarian. Noticing that I was perplexed, he smiled and said: I eat the cow, she eats the grass, so I eat the grass. Therefore, I'm a vegetarian!

This transitivity joke works not because we are all logicians, but because logic takes transitive relations from commonsense reasoning. The vegetarian joke reminds us that transitive relations do not always work. Jokes like this can reveal the imperfections of thought by leading us to believe that a past case is relevant when another is. Learning when to substitute frames and censor others helps to minimize the negative effects of the different kinds of reasoning we use (Minsky, p. 10).

Each way of reasoning is reliable in some situations and unreliable in others. Eliminating a particular kind of reasoning because it once failed would be disastrous. Instead, when our transitivity-frame fails, as it does in the vegetarian joke, and another frame succeeds, we construct a link between the two frames with a mental note that describes under what conditions the transitivity-frame should be censored. Minsky suggests that each kind of reasoning has a collection of exceptions of this sort, what he calls "difference networks" (Minsky, 1980. p. 9). Learning how to reason better involves determining from features in the observed or mental environment what kinds of reasoning will be more productive and when. One might say that humor provides a virtual world for performing particular reasoning experiments before this reasoning is needed in real life.

3.1.1 The Pleasure of Play

Freud saw in humor's propensity for rule-breaking the triumph of the pleasure principle over the reality principle. Contemporary computing has a better idea than Freud's pleasure principle, the idea of virtual worlds. In virtual worlds—like those produced by reading novels, plays, fairy tales, pieces of music, and video games—people can project themselves into a fictional setting without experiencing any of the negative consequences of the analogous real setting. These settings provide the means to experience an artificial world in which the complexity found in the real world has been removed.

This link between the virtual and the real can be illustrated by Vygotsky's examination of children at play. The late Russian cognitive psychologist Lev Vygotsky was concerned with the

processes of culture creation. Vygotsky observed children inventing games and modifying them through continuous negotiation. He pointed out that, while play involves imaginary situations, it is still based on rules that become explicit when there are conflicts among players about the meaning of some action. Even if the rules change frequently, the way they change is negotiated in the course of play so that, at each instance, there is some guiding set of rules shaping the character of play.

If we ask why the rules of play change we get at the heart of the cognitive function of play and, by analogy, virtual worlds in general. For Vygotsky, play serves a mediating function between the child's spontaneous acts and those allowed by the game. Echoing Freud, one might say that the pleasure of the individual is restricted by the reality of the group. The child reflects on the rules that result in conflicts among his playmates because resolving these conflicts preserves the game; ignoring them jeopardizes the continuation of the game. Indeed, the conflict experienced by each child can be characterized as one between his short-term and long-term interests. The child is obliged to notice whether everyone else is having fun, not because his immediate interests demand it, but because his prolonged interests do (Vygotsky, 1978, pp. 92-104).

In McGee's thesis on play and human development, he argues that conflicts during the act of play (what he calls "expectation failures") provide players a context in which to build *middle managers*, mental mechanisms for managing conflicts. Conflicts, no matter how weak, are always generated because new situations are always a little unique. At the same time, new situations are seldom so unique that all expectations are totally inappropriate. The constraints embodied in the context of play control conflict resolution complexity by limiting kinds of conflicts. Repetitions found in play can serve as an elaboration process through which the variants of a situation are produced and associated mental schemes are made robust.

The learning is not in the particular conflicts that are resolved but the mechanisms of conflict resolution themselves, the middle managers. Middle managers acquired while constructing the virtual world of play can be re-appropriated for use in resolving conflicts in the real world (McGee).

3.2 The Context Problem

The context problem is a consequence of the reflexive nature of interpretations, the fact that an interpretative episode becomes a part of the data used in subsequent interpretations. For example, the reminders we use to make an interpretation, whether anticipatory or anthropomorphic, produce data that become the source of new reminders. Reflexivity reminds us that the context has a receding horizon and why defining context is problematic.

Reflexivity does not drown us in a sea of reminders for three reasons. For one, *there are empirical constraints*; the interpretive context always plays a limiting role. For another,

reminders have forgettings as a side-effect; being reminded of one experience prevents us from being reminded of others. For example, while we are being reminded of marching bands or wavering branches (chapter 2), a host of other experiences are being suppressed. Finally, there is a *database constraint*; an interpreter can only be reminded of things he has already remembered.

Lakoff and Johnson describe the human conceptual system as a network of experiences multiply indexed (Schank) through *metaphors* (Lakoff and Johnson, p. 36). Lakoff and Johnson assume that most concepts are defined partially by other concepts. By their definition, a metaphor provides a natural means for highlighting or hiding other metaphors. *Highlighting* builds a network of conceptual links and *hiding* protects inappropriate links from being made (Lakoff and Johnson, p. 10). Like reminders and forgettings, highlighting and hiding are complimentary functions of memory.

Lakoff and Johnson provide a number of metaphors for how we think about "ideas". Ideas are COMMODITIES ("It's important how you package your ideas"), RESOURCES ("He ran out of ideas"), MONEY ("Let me put in my two cents' worth"), CUTTING INSTRUMENTS ("That's an incisive idea"), and FASHION ("That idea went out of style years ago"). Here are a few more metaphors from their text (Lakoff and Johnson, pp. 46-48).

IDEAS ARE FOOD

What he said left a bad taste in my mouth.
I just can't swallow that claim.
That argument smells fishy.

IDEAS ARE PEOPLE

He is the father of modern biology.
Whose brainchild was that?
These ideas died off in the middle ages.

IDEAS ARE PLANTS

That idea died on the vine.
That's a budding theory.
Mathematics has many branches.

IDEAS ARE PRODUCTS

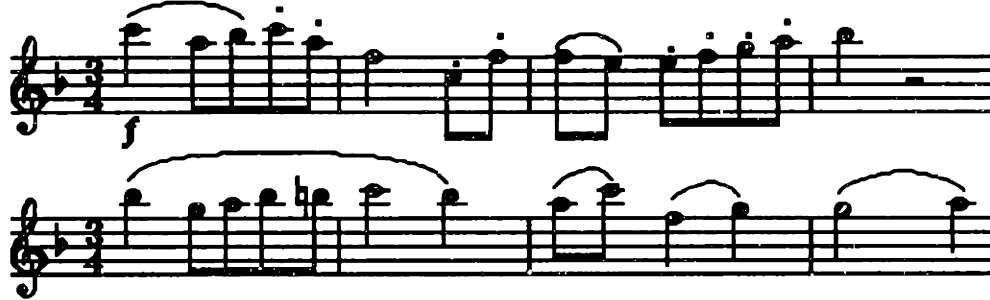
We've generated a lot of ideas this week.
He produces new ideas at an astounding rate.
It's a rough idea; it needs to be refined.

Each metaphor is connected to a network of other concepts and metaphors through which meaning, including what we are reminded of (and so on, reflexively), emerges. For Lakoff and Johnson, metaphor is "imaginative rationality" (Lakoff and Johnson, p. 193).

3.2.1 Interpretations are Context-Dependent

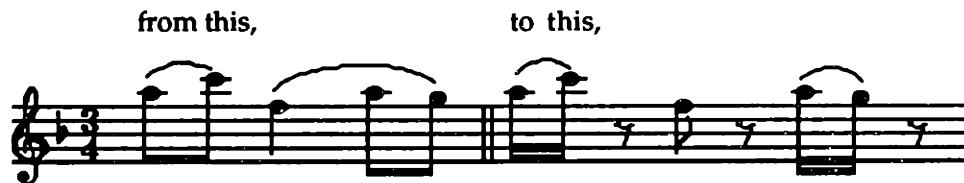
A musical event lives in several spans of time simultaneously, each a potential interpretive context. For example, the first subject at the beginning of the Beethoven's 8th Symphony (below) is interrupted again and again, Schauffler says as if "shooed away whenever it shows its face". Each interruption tells us more about what the last one meant.

Opening theme, Beethoven's 8th Symphony



In this example, the method used for producing this humor is *hide and seek* (Reti, 1961). The basic idea is that the composer first establishes a pattern in the listener's mind and then hides its parts using methods of variation. In this case, Beethoven shows only the beginning of the theme in bars 108, 120, 132, 144, 152, 164 before showing the whole theme again in bar 198.

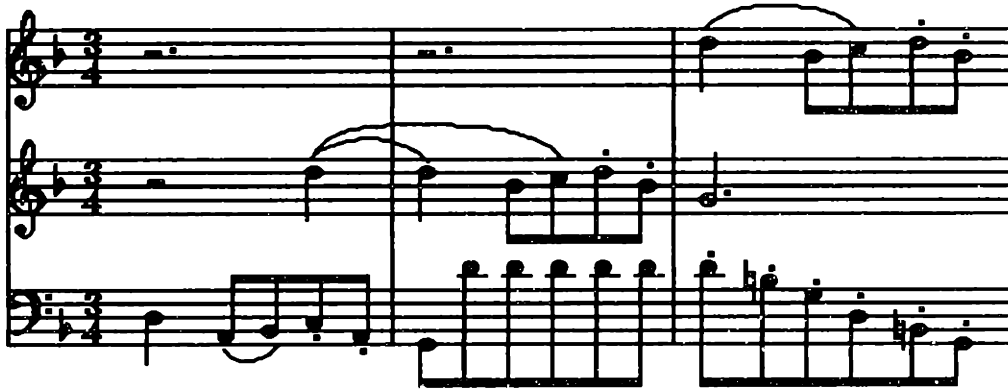
The Beethoven theme is an example of musical humor, not because the theme is humorous, nor because the method of hide and seek is inherently humorous, but because the accumulating evidence provided by the material surrounding the theme evokes humor. Three examples are: the punctuated modification of the last measure of the opening theme (measure 11),



the long duration before the abbreviated theme reappears (in measure 108) and the background in which it reappears (including harmonic modulations),



and the way the abbreviated theme chases itself around, as in measures 151-153.



Of course, even these and other bits of evidence are not entirely persuasive. In the court room of interpretation, a preliminary verdict may be negated by new evidence. What was humorous may become tragic or heroic within a larger time-span context. While these conclusions are somewhat discouraging, they sharpen our understanding of the context problem. Because interpretations are context-dependent, a previous interpretation has to be re-assessed within new interpretative contexts.

3.2.2 Strategic Violations of Interpretive Conventions

Overture is a playful piece that I wrote as one of a suite of pieces for a dramatic setting. Its duration is two minutes. It is orchestrated for flute, clarinet, two trumpets, three french horns and a trombone. Below are excerpts from *Overture* which I will use to illustrate how strategic violations of conventions can be used as a method for provoking humor.

Overture's melody is comprised of a number of *appoggiatura* (i.e. passing tones on strong beats). Some of these *appoggiatura* use chromatic notes not found in the scale (e.g. measures 17 and 19), and exaggerated durations. Exaggerating a convention can often be a source of humor.

Exaggerated use of chromatic *appoggiatura*

Melody

measure 17

measure 19



Doubling voice

Unorthodox doubling of melody starting at measure 15; in *Overture*

At measure 15 (above) the melody is accompanied by an unorthodox background. Not only does the background have a number of notes not found in the F major scale (Eg. G#, D# and B), it has a meandering shape. It would not have been possible to write these "wrong notes" in the 19th century. *Key violations* are only possible because we are used to listening to music that is *polytonal*. Nevertheless, listeners still notice them.

The melody of *Overture* would normally divide into 2 eight-measure parts. However, the first part (m1-m8) overlaps with the second part (m8-m15) at measure 8. This violation of *phrase symmetry* is another source of humor.

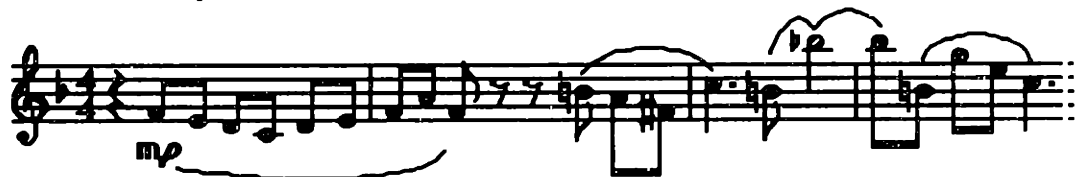
Overlapping melody parts at measure 9; in *Overture*



Accompanying eighth-note chords played by the french horns

Like the background, the counter melody (beginning in measure 15, below) introduces notes not found in the F major scale (e.g. F# and B-natural). This counter melody will be interpreted as humor rather than a mistake because the wrong notes are introduced in a systematic way. In other words, as the interpretive context grows, the listener will (presumably) change his assessment of the "wrong notes".

Counter melody in measure 15; in *Overture*



Finally, in measure 29 the lyrical melody is interrupted by an outburst of marching band music played by the brass and the percussion. Not shown is the return to the melody in measure 37, equally surprising because of its abruptness. This can be viewed as an example of *genre violation*.

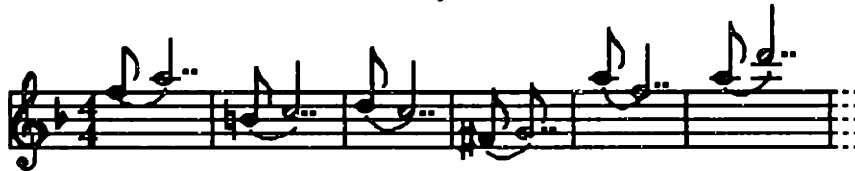
Exaggerated brass entrance (with percussion) at pick up of measure 29; in *Overture*



It is not a coincidence that I have described these sources of humor as violations of conventions (appoggiatura, key, phrase symmetry and genre). Violations are anticipatory. We expect the appoggiaturas to resolve more quickly and we expect the key and phrase structure symmetry to be preserved. We do not expect the genre to change and it does.

On the return of the melody to *Overture* (whose beginnings are shown below) the chromatic notes of the appoggiatura are brief. These durational changes do not eliminate the appoggiatura effects; they only unexaggerate them and make the violations go away.

Revised (and less humorous) melody



The conventional use of appoggiatura is present in both forms of the melody; both forms will produce anticipatory effects. The exaggerated case is measured in relation to the unexaggerated case. Similarly, phrase asymmetry depends on the recognition of phrase symmetry. Phrase symmetry is established by the fifth bar of the melody, at the point where the melody repeats (below). This repeat defines a melody subpart. The listener expects another 4-bar pattern starting at the fifth bar and is not disappointed. These bars prepare the listener for the phrase symmetry violation in measure 8 (1 measure too soon).

Melody of *Overture*; fifth bar that establishes phrase symmetry



Finally, the key is established by the use of melodic and chordal notes within the key. Key violation depends on key recognition.

While the anticipatory effects and violations of them can be locally recognized, their affective byproduct requires successively longer time-span contexts. These contexts are partially established by anthropomorphic effects that can last for long spans of time. For example, the mood

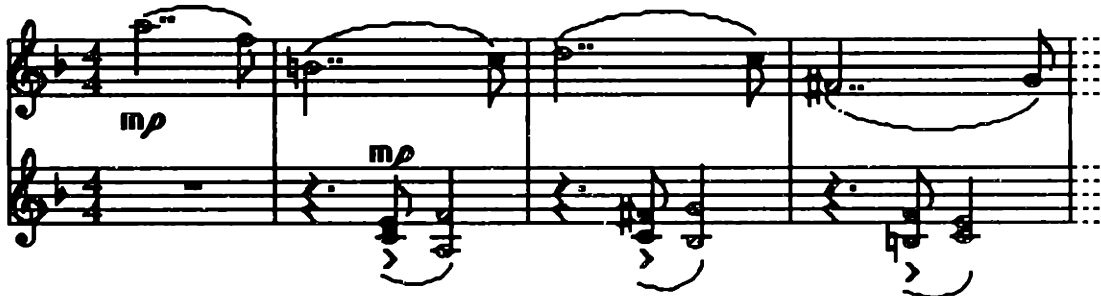
changes provoked by the marching band section and the return to the lyrical melody mark a span of time that is more than half of the music's total duration.

Tempo, orchestration, or articulation are often sources of anthropomorphism. The tempo of $mm = 180$ in the quarter notes and the use of mid-register brass playing staccato chords suggests a hurried pace and rules out certain kinds of moods. If the chords had been played by upper-register woodwinds, what felt hurried may have felt fleeting; if the tempo had been slower, what felt hurried may have felt pondering, etc. The listener experiences these effects as movements in his "mind's body", anthropomorphically.

As I have said, *Overture* shifts abruptly to marching band music in measure 30. It achieves its effect by a mixture of anticipatory and anthropomorphic effects. The previous tempo of $mm = 180$ becomes a marching band tempo of $mm = 90$ produced by emphasizing every other beat. The tempo change is a source of surprise; however, once the new tempo has been established (through repetition), the effect of the new tempo is anthropomorphic.

The music shifts from marching bands back to the more lyrical melody, now accompanied by a secondary voice that mimics it. This mimicry can be characterized as anthropomorphic with a melodic "main actor" and accompanying "supporting actor" who tries to steal the show. Mimicry combined with the faster tempo produce a playful mood.

Mimicry of the melody, starting at the beginning of measure 40; in *Overture*



One might define *mimicry* as the excessive use of imitation. From this view, mimicry is anticipatory. Imitations are recognized first. Only when they are used excessively does the interpreter need to re-assess the expressive intent of the imitative writing.

3.3 Managing Interpretive Doubt

Interpretative reliability is never guaranteed because we can always assess a composer's expressive intent using a different temporal context. Nevertheless, doubt is functionally minimized because of the constraints on reflexivity--i.e. the empirical, forgetting and database constraints mentioned earlier--and because of the progressively acquired evidence from anticipatory and anthropomorphic listening.

3.4 The Unanticipated Interpretive Utility of Rehearing

Finally, we have an additional explanation for why a piece of music can remain interesting after several rehearsals, the subject of the first chapter. Contexts not only depend on musical thought; they depend on human experience. As interpreters acquire new knowledge and experience, new partitionings of the material or projections onto it become possible. In a deep sense, rehearsals are potentially first hearings.

3.4.1 Experiencing Virtual Worlds

As listeners, we do more than engage in the immediate experience of music. The patterns recognized and the intentions we project onto them exist within progressively constructed interpretive contexts, of which the largest is the music's overall form. For the listener, the practical value of form is that it enforces *interpretive consistency*. A listener can count on the fact that previous listening will make subsequent listening easier. Piagetians would say that consistency in writing makes the recognition of invariance possible. The importance of the form is not that listeners recognize it, but that they reap the benefits of it during the interpretive process.

The patterns recognized by the listener give rise to a unique musical experience because they are as much about the listener as they are about the music. The knowledge and experiences the listener is reminded of determine what constitutes a pattern as well as its emotive force. This is why an interpretation is not a model of the *music* as some musicologists would have us believe, but a model of the interaction of music and listener.

The music serves as an interpretive context much like a traffic accident, card game or cocktail party. It provides the interpreter with constraints and the opportunity to consider what behaviors or strategies are appropriate. Unlike the pedestrian examples, music provides a place where risk-taking has only virtual consequences.

On one hand, musical interpretations are made in the privacy of one's own mind. On the other hand, these private acts of interpretation serve a social role. If a music makes us dream it is not the music but the dream that embodies the experience. Like dreams, pieces of music operate by unconscious processes that are cultural-dependent. That is why the decoding system used by Freud in *The Interpretation of Dreams* seems inappropriate today, even though using the dream experience as a virtual world remains a meaningful clinical method. In *The Uses of Enchantment*, Bruno Bettelheim shows how fairy tales serve as a source of virtual worlds for children. Through fairy tales, children are given models of conflict resolution that they can use to resolve real conflicts in their lives (Bettelheim).

Critical of Bettelheim, Jack Zipes argues that fairy tales are subversive. They produce a socialization process that reflects European attitudes towards sex in the 16th and 17th century, the

time in which many of the western classic fairy tales were written (Zipes, pp. 174-175).¹ However, Zipes is arguing against the values acquired, not that they are acquired. Socialization is occurring, just not the kind of socialization that is politically correct for Zipes and many other people. As soon as virtual worlds like fairy tales, jokes or music go public, they become objects with which interpretive communities progressively construct shared meanings like Vygotsky's children progressively constructed the rules of play. Because new meanings are possible—as exemplified by my reading of Zipes' reading of Bettelheim's reading of the function of fairy tales—virtual worlds have unanticipated interpretive utility.

* * *

In part 1 I have used the rehearing problem to examine different kinds of explanations for why a piece of music remains interesting after it has been heard several times. I contrasted anticipatory and anthropomorphic interpretive perspectives, and showed how the interpreter progressively constructs a virtual world, using these perspectives synergetically. I also argued that the cognitive function of interpretation is to give the interpreter an opportunity to take mental risks in a virtual world before taking them in the real world.

This formulation of interpretive theory provides the composer a way to take the interpreter's perspective while evaluating his emerging artifact. It suggests how people listen, what they listen too, and why they listen.

¹ [The 'beauty and the beast' tales] were and are important because they set standards for sexual and social conduct which complied with inhibiting forms of socialization and were to be internalized by the readers and auditors of the tales (Zipes, p. 33).

Part 2
Design Theory

Chapter 4

Learning by Designing

Introduction

This chapter starts cautiously, using a problem solving study to investigate the boundaries that separate conventional problem solving from designing. In this study, subjects were asked to approach a puzzle in two different ways. In the first approach they were asked to solve the problem as conventional problem solvers; and in the second, they were given the answer and asked to explore strategies for how the answer might have been obtained. I argue that the more problem solving requires strategy exploration, the more it begins to look like designing.

Strategy exploration is a typical component of design problems because they are usually *ill defined*. "Solutions" are often *provisional* because designing often leads to "solutions" that change the context of design. While goals have a role in design, they do not have the privileged status they have in conventional problem solving because designing involves the clarification of goals during the act of designing [see Appendix D: Problem Solving and Discovery].

These are reasons why designing is always also learning how to design, what I call *learning by*

designing .¹

4.1 The Four-Stone Problem

The following study helps to illustrate the boundary that separates conventional problem solving from designing. The study began as an informal activity where I tried to solve the following problem.

The Four-Stone Problem²

There is a large stone weighing 40 pounds. The stone falls and breaks into 4 smaller stones. Quite by accident, the four stones happen to have weights that make it possible to weigh objects from 1 to 40 lbs (i.e. 1, 2, 3, ..., 39, 40) using various combinations of them with a balance scale. (For example, putting all the weights on one side of the scale makes it possible to weigh a 40 lb object.) The question is: What are the weights of each of the 4 stones?

¹ I use a pencil drawing a pencil as a way of expressing graphically the reflexive nature of designing.

² L. S. Saraswathi is an educator/ethnographer working in Southern India. In recent years, she has been collecting stories (e.g. parables, "puzzles", etc.) from rural, Tamil-speaking villagers in Southern India. Villagers pass on these stories from generation to generation in an oral way. Saraswathi believes that these stories endure because they embody knowledge the villagers need for their day to day survival. The four-stone problem is one of Saraswathi's stories.

Problem Solving Assignment

1. Try to solve the four-stone problem, keeping track of the strategies you use.
2. Ask some friends to look at the problem and observe how they go about solving it. (If you want, skip steps 1 through 3 and just observe others working on the problem.)
3. Bring your "data" to our next session.

I gave this "problem solving assignment" (above) to a few of my friends outside and inside MIT and observed some of them solving it. Those I didn't observe reported how they approached the problem. However, some of the people didn't want to participate in the activity and had a number of complaints which I summarize below.

- While the problem is well-defined the way to approach it is not.
- You already have to know the answer before you can solve it.
- Because the solution is unambiguous there is no room for surprise, for something unexpected.
- There's no room for personal expression, for play.

In general, subjects who were resistant to the problem didn't like this kind of problem. But then, what kind of problem did they like? My hypothetical answer was "something more like a design problem". I reformulated the assignment in the following way to explore this hypothesis about design.

Design Problem Assignment

1. If you don't like this problem I will give you the answer.
2. The new problem is to see if you can solve it from a number of perspectives.
3. Give the solution to your friends and ask them to look for different strategies for getting the answer.
4. Bring your "data" to our next session.

Notice that I posed the problem to the MITers in the conventional problem solving form: Here's the problem, what's the answer? In the new formulation of the problem I offered the problem and the answer, and asked my subjects to explore strategies one might use to get from one to the other. In this latter formulation of the problem the focus was *strategy exploration*.

I gave this new problem to two new groups of subjects. One group was some public school teachers participating in an MIT project and the other group was Logo researchers at the University of Campinas (Brazil) working in the laboratory of Jose Valente. Prospective subjects had the option to pursue either assignment or ignore the "assignment" completely.

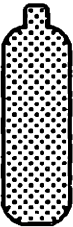
Only a few "subjects" actually solved the problem in the conventional way. The following data include these solutions, failed attempts to solve the problem in the conventional way, and strategy exploration by subjects who approached the problem as designers. In the data are the names I have given to the HEURISTICS, ASSUMPTIONS and METHODS used by subjects. I will refer to these names in the observations.

4.1.1 Data on Four-Stone Problem


One subject used the strategy of solving for weighings from 1 to 10, then 1 to 20 and 1 to 30. This subject assumed the *SIMPLIFY-HEURISTIC*, that solving the simpler problem would provide information about the more complex problem. This *heuristic* (i.e., "rule of thumb") comes right out of Polya's *How to Solve It*, a classic in the problem solving literature. Unfortunately, this strategy did not work, although the subject did begin to realize the *THIN-SPREAD-ASSUMPTION*, that with so few stones and so many things to weigh, there must be a unique solution for each weighing from 1 to 40.

The same subject also made an analogy between weighings on either side of the balance scale and the wine jug problem (below).


8-quart	5-quart	3-quart
8	0	0
3	5	0
3	2	3
6	2	0
6	0	2
1	5	2
1	4	3
4	4	0



8-quart



5-quart



3-quart

In the wine jug problem, there are two men, a 8-quart jug of wine and two empty jugs, a 5-quart jug and a 3-quart jug. None of the jugs are marked. The men want to divide up the wine evenly so that each gets 4 quarts of wine. Using the three jugs, what procedure can they follow to achieve these ends?

By making the *JUG-ANALOGY*, the subject appeared to be searching for a similar problem he had solved in the past. The *SIMILARITY-HEURISTIC* is also found in Polya.

Given that one has a collection of methods for dealing with situations, one needs knowledge about how to match methods to situations. In this case, it appeared to the subject that the transfer of weights from one to the other side of the balance scale was analogous to the transfer of wine among the available jugs.¹

* * *

¹ Actually, this analogy seems more useful in the solution which allows *multiple-weighings* (yet to be discussed). The solution involves a more complicated sequence of transfer actions than *one-weighings*.

Another subject assumed that all the stones were *prime numbers*. He chose the *PRIME-ASSUMPTION* because prime numbers exhibit "magical" properties in computer search problems. Perhaps, what forced the *SEARCH-ANALOGY* is the *THIN-SPREAD-ASSUMPTION* since both require limiting redundant action.

This subject gave himself the problem of finding a pattern of four prime numbers which added to 40 and then used them to weigh objects from 1 to 40 lbs until he located holes. When he found holes he constructed another pattern of four prime numbers adding to 40 that also filled some of the holes, and ran a new sequence of tests. Like the subject who tried weighings from 1 to 10, 1 to 20, and so on, this subject constructed the simpler problem of finding 4 prime numbers equalling 40. With the prime number assumption, the number of possible trials (i.e. the search space) is greatly reduced. Unfortunately, in this case, the subject was reducing choices in the wrong search space.

* * *

One subject decided to try four stones each weighing 10 pounds (40 pounds / 4 stones = 10 pounds). The subject was discouraged by the *EQUAL-WEIGHTS-ASSUMPTION* because the result of using it provided her no clues on how to continue. In fact, she admitted that she did not like puzzles and was hoping to solve the problem like one takes medicine, as quickly and as painlessly as possible.

I found this guess humorous—a kind of mathematical joke—since this pattern results in the least number of weighable objects. What the subject didn't notice is that even this is useful information. The subject could have concluded that the stones should have different weights in order to increase the number of weighable objects. This would surely have led to an improved guess.

* * *

Symbol-oriented subjects saw the four-stone problem as a number system problem, what I will refer to here as the *NUMBER-SYSTEM-ANALOGY* which, in turn, is based on the *SIMILARITY-HEURISTIC*. One subject was led to powers of two (1, 2, 4 and 8) and changed strategy when he found that the result was short of 40. Another subject moved from powers of two to powers of three and "lucked out" with the answer.

One subject used the following equations as a way for him to formulate the problem in a familiar symbolic form.

$$a + b + c + d = 40$$

all the stones add to 40

$$\pm a \pm b \pm c \pm d = 1...40$$

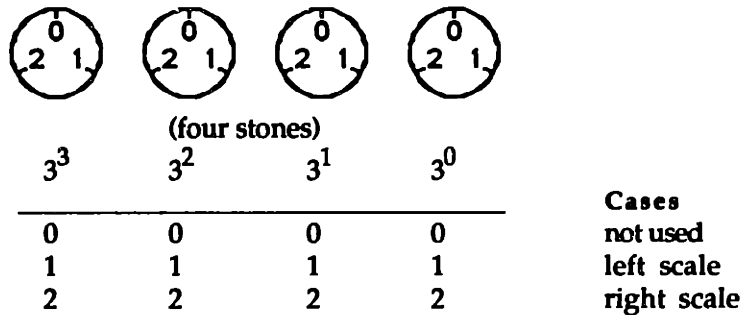
stones can be placed on either side of the scale

From here the same subject went to a visual form in which each stone is represented as a kind of "dial", as shown below.



Moving from right to left, the most-right dial handles cases 0 to 2. For a weighing of 3, the next dial is set at 1. The first two dials handle cases 0 to 8. For a weighing of 9, the next dial (second from the left) is set at 1. The three dials handle cases 0 to 26. And so on for the last dial.

It was difficult for me to see how this subject went from the equations to these dials until another subject offered the *CASE-ANALOGY*. He argued that each stone had three cases; it could either not be used, be placed on the left side of the scale, or placed on the right side of the scale. Given these three possibilities for each stone, base 3 could be seen as a candidate means for solving the problem. This idea is illustrated below, where one can see the connection between cases and dials.



* * *

Some of the facts of the four stone problem were obvious; for example, everyone knew that there were four stones (*FOUR-STONE-ASSUMPTION*) and that the sum of the four stones was 40 lbs. (*SUM-40-ASSUMPTION*). Other facts were less obvious. For example, the story says that a balance scale is used in the measuring of objects. Still, many subjects considered it a breakthrough when they realized that stones could be added to the weight of the object being weighed or placed on the opposite side of the balance scale, the *BALANCE-ASSUMPTION*.

* * *

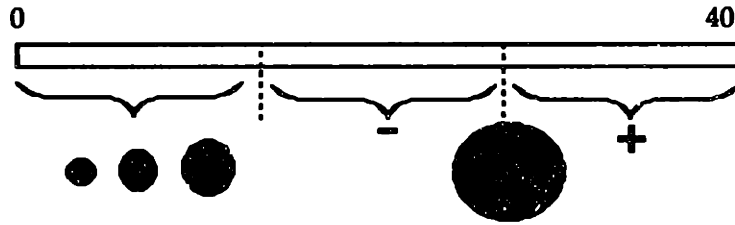
Many subjects assumed that the four stones had to have odd numbered weights, the *ODD-NUMBERS-ASSUMPTION*. The argument was that odd numbers can add to even numbers (e.g. $1 + 5 = 6$) but the reverse is not true.

* * *

Many subjects used the *HEAVY-STONE-ASSUMPTION* which can be described in the following way. The three "lighter" stones measure objects which are relatively light. When the object being weighed is heavier than the three light stones added together, the heavy stone can be used in their place. If the heavy stone is heavier than the object, the lighter stones can be added to the

weight of the object. If the heavy stone is lighter than the object, the light stones can be added to the heavy stone.

This argument can be illustrated by the picture shown below. A weight scale is shown from 0 to 40 lbs. It is partitioned into three parts.



The three light stones cover weighings in the most left part of the scale. These light stones are subtracted from the heavy stone (i.e. added to the object being weighed) to cover weighings in the middle part. The light stones are added to the heavy stone to cover weighings in the most right part of the scale.

The *HEAVY-STONE-ASSUMPTION* doesn't give an answer, but it helps to narrow the search space. For example, it helped some people to get to a simpler question, namely: What should the numbers be for the three light stones in order to cover weighings in the most left part of the scale? Answering this question results in the weight of the heavy stone (i.e. $40 - \text{light stones} = \text{heavy stone}$). One might begin to guess that each lighter stone has a relationship to its lighter neighbor that the heavy stone has to it.

* * *

Some people used the *THIN-SPREAD-ASSUMPTION* in an evaluative way. As soon as they found that a proposed pattern of stone weights produced the same weight twice, they tried a different pattern of stone weights. For example, if the proposed pattern of stone weights was 1, 9, 10 and 20, an object of 10 lb. could be weighed using a 10 lb. stone or by adding two lighter stones ($1 + 9$). Duplicate weighings would be hint that the pattern of stone weights was wrong and must be abandoned.

* * *

Most of the people who worked on the four-stone problem used the *TRIAL-AND-ERROR-METHOD*; they guessed four numbers which would correspond to the weights of the four stones, evaluated their guess and guessed again. The difference between subjects was the context in which this method was used, including the assumptions they made.

* * *

I like the *PROCEDURAL-METHOD* because it shows systematic reasoning with only a minimum of mathematics knowledge. A couple of people used this approach. First, this approach assumes the *THIN-SPREAD-ASSUMPTION*. Second, it assumes that one of the stones has a weight of 1, the *STONE-OF-ONE-ASSUMPTION*. But wait! Where does this assumption come from? Many people

made this assumption without being able to defend it. Some said that the only way to weigh an object of weight 1 is by having a stone of that weight. Actually, this is far from the truth. Many combinations of stones with a weight difference of 1 will accomplish this. Only one person argued that it isn't a weight of 1 but a weight of 39 which requires it.

Using the *PROCEDURAL-METHOD*, given a stone of weight 1, it can weigh an object with weight 1. We need an additional stone to weigh an object of weight 2. The *THIN-SPREAD-ASSUMPTION* says that the second stone cannot also be 1. It shouldn't be 2 either because we can get 2 by using a stone with weight 3 (i.e. $3 - 1 = 2$). However, we cannot measure a 2 lb. object with a stone weight of 4. Therefore, the first two stones are 1 and 3. Notice that this is also the reasoning used in the *HEAVY-STONE-ASSUMPTION* but applied to the lighter stones.

The third stone will not be 4 because we can get 4 by adding 1 and 3. It won't be 5 either because we can get 5 by subtracting some third weight from those we already have. The *THIN-SPREAD-ASSUMPTION* enforces this thinking. Since the first two weights add up to 4, a stone weight of 9 allows the weighing of 5 lb. objects ($9 - 4 = 5$). Therefore, the first three stones are 1, 3 and 9.

At this point it is possible to add up the first three stones and subtract their combined weight by 40 (i.e. the weight of all the stones all together). But it is possible to continue using the above reasoning. For example,

$$\begin{aligned} 6 &= 9 - 3 \\ 7 &= (9 + 1) - 3 \\ 8 &= 9 - 1 \\ \text{etc.} \end{aligned}$$

Continuing in this manner leads to a weight of 13 (i.e. $9 + 3 + 1$). The next weight one wants to weigh is 14. Once again, we don't want a stone of weight of 14 but a stone which can be used with the others to get that weight. $13 + 14 = 27$. The fourth stone is 27. $1 + 3 + 9 + 27 = 40$.

The above manner of thinking places the least importance on one of the most obvious facts, that the stones must add to 40 (the *SUM-40-ASSUMPTION*). Since there are so few facts in problems of this kind, it would seem important to embrace them. Paradoxically, in order to give oneself a chance to explore the *PROCEDURAL-METHOD*, it is desirable to ignore the fact that all stones add to 40 even though one knows that violating it would produce an inadequate solution to the problem.

* * *

Some facts in the four-stone problem were debatable. For example, I never said that an object's weight must be determined in one weighing (*ONE-WEIGHING-ASSUMPTION*), though I assumed it when working on the problem myself. One of the subjects did not make this assumption; indeed, he thought it was impossible to find a solution based on it. Instead, he thought that it would be easier to determine whether an object was less than or greater than some collection of stones than it would

be to determine the object's precise weight. His strategy was to use stones of even numbered weights and to use them in two weighings to find all objects with odd numbered weights, the *MULTIPLE-WEIGHINGS-ASSUMPTION*. For example, if two of the stones had the weights 2 and 4, and the object being weighed was 3 lbs, the first weighing with a stone weight of 2 lb would show that the object was a little heavier than 2. The second weighing with a stone weight of 4 would show that the object was a little lighter than 4. The answer would then be 3.

The new problem organized by the *MULTIPLE-WEIGHINGS-ASSUMPTION* was to guess stone weights that would cover objects with only even numbered weights. This is another example of the *SIMPLIFY-HEURISTIC*.

Two stones of weights 2 and 6 get you: 2, 4 (i.e. $6-2$), 6 and 8 (i.e. $2+6$). Adding a third stone of weight 12 gets you: 10 (i.e. $12-2$), and 12 through 20 (using stone of weight 12 and the first two stones). Adding a fourth stone of weight 20 gets you 20 through 40 (i.e. 20 plus the possibilities with the first three stones). Under the *MULTIPLE-WEIGHINGS-ASSUMPTION*, only one weighing is necessary for objects with even numbered weights. Only objects with odd numbered weights require two weighings.

The *MULTIPLE-WEIGHINGS-ASSUMPTION* does not require a great commitment to the *THIN-SPREAD-ASSUMPTION* since it is possible to weigh the same object in more than one way using two weighings. For example, with the pattern [2 6 12 20] you can get a weight of 10 by subtracting 2 from 12 (i.e. $12-2$) or by subtracting 12 from the addition of 20 plus 2 (i.e. $(20+2)-12$.) There are also other correct answers with the *MULTIPLE-WEIGHINGS-ASSUMPTION*. For example, the pattern [2 6 14 18] will also work.

4.1.2 Observations on Data

The *SIMILARITY-HEURISTIC* was expressed by the analogies subjects made between the four-stone problem and others they had encountered in the past: the *JUG-ANALOGY*, the *SEARCH-ANALOGY*, the *NUMBER-SYSTEM-ANALOGY* and the *CASE-ANALOGY*. An analogy makes knowledge gained from past experience reusable in current experience, though it can also have adverse effects as it did with the subject who used the *SEARCH-ANALOGY* to make the *PRIME-NUMBER-ASSUMPTION*. The *PRIME-NUMBER-ASSUMPTION* provided the wrong problem solving context for the four-stone problem.

At the same time, the subject who used the *PRIME-NUMBER-ASSUMPTION* learned the importance of challenging an assumption in the face of counterevidence, regardless of his investment in the assumption. This is a subtle practice to learn since it depends on the ability of the designer to weigh "objective" strategies against "subjective" assumptions. Managing this tension is at the core of the art of problem design.

Why is there such a tension? Because most "problems" worth "solving" are too complex to solve all at once; the *SIMPLIFY-HEURISTIC* reminds us of this. By committing to an assumption, the problem solver constructs components of the problem's context so that it becomes simple enough to solve.

Of course, simplicity is not everything. The *SIMPLIFY-HEURISTIC* can lead to problems. Recall that some subjects did not begin with the *BALANCE-ASSUMPTION*, the fact that stones can be placed on either side of the balance scale. Without the *BALANCE-ASSUMPTION*, the problem is impossible to solve! In other words, a designer needs to learn how to deal with failures in the use of the *SIMPLIFY-HEURISTIC*.

The *MULTIPLE-WEIGHINGS-ASSUMPTION* makes the problem easier to solve than the *ONE-WEIGHING-ASSUMPTION*, though from the latter perspective, *MULTIPLE-WEIGHINGS* makes it too easy to solve.

Right or wrong, assumptions structure the problem context by providing evaluative strategies (*THIN-SPREAD-ASSUMPTION*), constraints (*SUM-40-ASSUMPTION*, *FOUR-STONE-ASSUMPTION*, *ODD-NUMBERS-ASSUMPTION*, *ONE-WEIGHING-ASSUMPTION*), or qualitative relationships between problem parts (*HEAVY-STONE-ASSUMPTION*).

Of course, the subjects who used the *PRIME-NUMBER-ASSUMPTION* or the *EQUAL-WEIGHTS-ASSUMPTION* structured the problem context in an unproductive way. These kinds of failures provide valuable experience as well. As with the *SIMPLIFY-HEURISTIC*, knowing when to abandon a particular assumption is also a kind of knowledge.

In general, one of the reasons for constructing a problem-solving context is to reduce possible choices so that the *TRIAL-AND-ERROR-METHOD* is applicable. This seems to be the preferred method for either problem solver or designer. Even the *PROCEDURAL-METHOD* uses the *TRIAL-AND-ERROR-METHOD* within a problem solving context structured by the *THIN-SPREAD-ASSUMPTION*, *FOUR-STONE-ASSUMPTION*, *BALANCE-ASSUMPTION* and the *STONE-OF-ONE-ASSUMPTION*.

4.1.3 Design Problems as Problem Design

Recall from the introduction that design problems are problems that operate within a dynamic problem context. I have tried to look at conventional problem solving from the designer's perspective by highlighting data that relates to problem design rather than problem solving. Several points stand out.

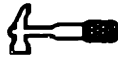
1. The problem context is constructed. Even in conventional problems, the difficult part is setting up the problem. If possible, everyone wants to "solve" problems using the *TRIAL-AND-ERROR-METHOD*. Context construction has this as its goal.

2. Context construction is reflexive. "Solving a problem" is, in part, getting a feeling for what the problem is.



3. Reusable cases are constructed. Through the use of analogy, subjects construct links between past experiences and current events. Even analogies that fail are informative since they resulted in negative links between cases and possible events.

4. Representation skills are acquired. "Problems" that are worth "solving" are usually too complex to solve at once and require restructuring. Through the use and examination of different assumptions, one learns different ways to represent events and how to examine the productivity of these representations.

5. Learning is reflexive. Subjects used the four-stone problem to reflect on their case knowledge, the function of analogy, the function of assumptions, and their commitments to assumptions. In other words, learning how to learn is a kind of knowledge, *meta-knowledge* that (presumably) is useful for future problem design. That there is meta-knowledge is, itself, an example of meta-knowledge at a higher level.



4.2 Skill

I have suggested that problem design requires knowledge that the designer uses to take action, *operational knowledge*. I call the components of this operational knowledge *skills* and define them as tools  (material, conceptual, or computational) plus knowledge about the situations  in which they can be productively employed. Tools can be material (e.g. rulers, hammers), conceptual (e.g. formula, methods, techniques), or computational (e.g. algorithms, search methods). Tools are know-how. The HEURISTICS, ASSUMPTIONS and METHODS are all examples of know-how. Skill requires experience in knowing when to use know-how, in linking know-how to case knowledge.

The purpose of skill is to reduce the field of possible options so that the few options that remain can be tried out and tested. This is what I mean by the *TRIAL-AND-ERROR-METHOD*.

4.3 Environment Design vs the Design Environment

Within a design context, "solutions" are seldom answers to puzzles like the four-stone problem. Rather, a "solution" is usually an artifact that is progressively constructed for use by others. What I call *environment design* is the process of customizing skills and their organization in order to shape the space of discovery in which an artifact is designed. The result of environment design is the *design environment*, the conceptual interface between the internal world of the designer and the external world in which the emerging artifact resides.

A magnificent example of a design environment in architecture is found in *A Pattern Language* by Alexander, Ishikawa, and Silverstein. This pattern language is comprised of 253 kinds of design cases synthesized over many years, what the authors call *patterns*. Each pattern offers advice on how to build kinds of physical spaces that are rewarding to live in.

What follows is a sample of patterns. One can imagine that these patterns focus decision-making during space design and, as such, help to shape the space of discovery. But they do more. They incorporate thinking about the utility of designed spaces for their users. These are two different kinds of design thinking, both explored in chapter 5.

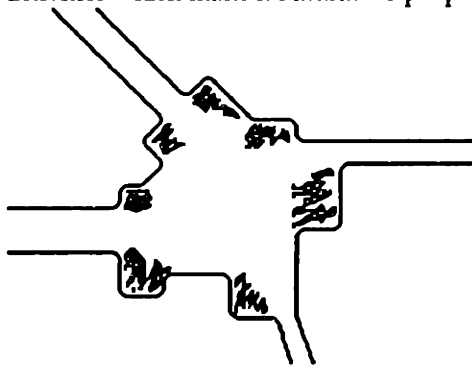
Pattern 109: Long Thin House

The shape of a building has a great effect on the relative degrees of privacy and overcrowding in it, and this in turn has a critical effect on people's comfort and well being. In small buildings, don't cluster all the rooms together around each other; instead string out the rooms one after another, so that distance between each room is as great as it can be.



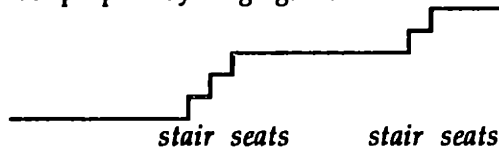
Pattern 124: Activity Pockets

The life of a public square forms naturally around its edge. If the edge fails, then the space never becomes lively. Surround public gathering places with pockets of activity—small, partly enclosed areas at the edges, which jut forward into the open space between the paths, and contain activities which make it natural for people to pause and get involved.



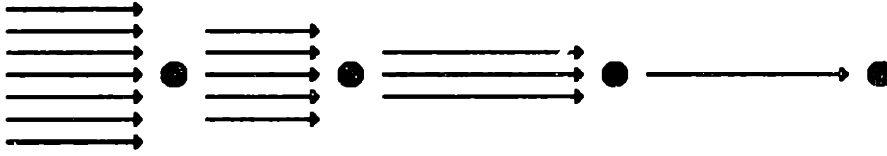
Pattern 125: Stair seats

In any public place where people loiter, add a few steps at the edge where stairs come down or where there is a change of level. Make these raised areas immediately accessible from below, so that people may congregate and sit to watch the goings-on.



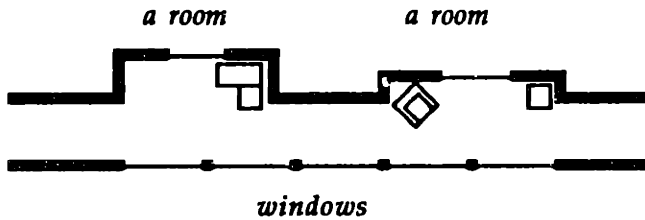
Pattern 127: Intimacy Gradient

Lay out the spaces of a building so that they create a sequence which begins with the entrance and the most public parts of the building, then leads into the slightly more private areas, and finally to the most private domains.



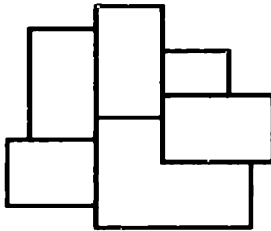
Pattern 132: Short Passages

Keep passages short. Make them as much like rooms as possible, with carpets or wood on the floor, furniture, bookshelves, beautiful windows. Make them generous in shape, and always give them plenty of light; the best corridors and passages of all are those which have windows along an entire wall.



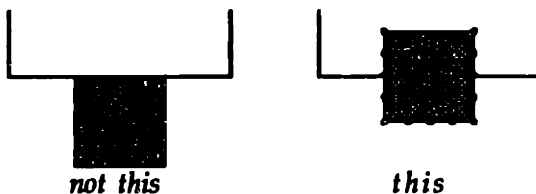
Pattern 159: Light on Two Sides of Every Room

Locate each room so that it has outdoor space outside it on at least two sides, and then place windows in these outdoor walls so that natural light falls into every room from more than one direction.



Pattern 167: Six-Foot Balcony

Whenever you build a balcony, a porch, a gallery, or a terrace always make it at least six feet deep. If possible, recess at least a part of it into the building so that it is not cantilevered out and separated from the building by a simple line, and enclose it partially.



Alexander *et al* feel that many of their patterns are "archetypal" and offer "a core of any reasonable human pattern language". Their pattern language exemplifies what I am calling a design environment, and their patterns my notion of fully developed skills. Rarely is it documented with this thoughtfulness.

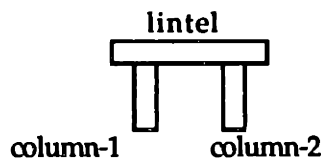
However, Alexander's *et al* pattern language hides the developmental process that gave rise to it. I have already pointed out that each of the patterns include two different concerns, that of process complexity and user utility. During development, these concerns are not necessarily linked. Moreover, development never stops; designing is always also learning how to design, constructing tools to deal with unanticipated problems, constructing skill (i.e., learning when to use tools), and constructing systems of skill management to serve goals dictated by the emerging artifact i.e., learning by designing.



4.2.1 Technologies to Support Learning by Designing

The pattern language of Alexander *et al* serves as a good example of fully developed expertise. I am concerned with the thinking that goes into its development and how tools might be designed to support development.

Consider Gross's *Constraint Explorer*, a computational environment for architectural designing in which the designer explores the degrees of freedom found within different sets of *constraints* (rules, trade-offs, etc.). For example, using the Constraint Explorer, the arch (below) might be described in the following way.



Given constraints

1. Column-1 supports lintel. (a relation)
2. Column-2 supports lintel. (a relation)
3. The minimum distance between columns 1 and 2 is 4 feet. (a restriction)

The Constraint Explorer will then deduce the following constraint from those given by the designer.

Deduced Constraint

4. The lintel is longer than the distance between columns 1 and 2. (a restriction)

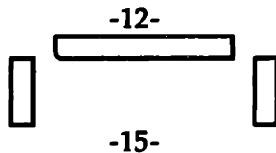
If asked to report the constraints operating on column 2, the Constraint Explorer will give the following.

Reported constraints on column-2

1. It supports lintel.
2. It is at least 4 feet from column-1.
3. Its distance from column-1 is at most the length of the lintel.

Because the Constraint Explorer makes it possible for the designer to receive reports on the constraints operating on a particular aspect of the design (e.g. column 2), the reporting reflects the design focus of the designer.

Assuming the above constraints, if the designer sets the length of the lintel at 12 feet and the distance between the columns at 15 feet, the Constraint Explorer will complain that the columns are further apart than the lintel is long (based on deduced constraint #4).



According to Gross, during the design process objectives can lead to conflicting constraints (e.g. "I want a large space that is inexpensive to build"). For this reason, a designer needs to be able to describe a set of constraints and explore variants within them. Based on the results of these explorations the designer might change some of the constraints and try variants within the new set of constraints, and so on, recursively. Through this process the designer learns which set of constraints are productive in a given situation. In short, he acquires skill.

Gross contrasts the notion of design embodied in his Constraint Explorer with Simon's notion of design. For Simon, designing is an optimization process in which solutions are produced within a set of unchangeable constraints. For Gross, designing is more exploratory. Constraints can be changed dynamically, allowing different sets of constraints and different views of the emerging artifact. A designer can optimize over pieces of a design ("suboptimize") rather than over the whole design. Finally, he can resolve local design conflicts by relaxing a constraint temporarily.

For Gross, *expertise* depends on the designer's ability to predict the consequences of a design action on the rest of a design and to develop debugging strategies for making "sequences of fixes". Based on past results, designers usually acquire design preferences (e.g. long rooms, square rooms), and evoke certain constraints automatically ("default constraints"). The Constraint Explorer helps the designer to manage constraints he has defined so that he can investigate different theories of design, his preferences and default constraints. Through this process, the designer constructs a history of design cases and how to handle them (Gross).

With practice, designers become better at matching sets of constraints with design cases, and better at predicting which constraints can be relaxed during the debugging process. Gross's Constraint Explorer supports this process by providing an environment of design in which learning and designing are integrated; it supports learning by designing. Gross's Constraint Explorer provides an example of the kind of tool that might support the development of a pattern language like Alexander, et al.

* * *

Using the four-stone problem I have argued that designing is always also learning how to design. I introduced the notions of skill (i.e., the product of using tools) and design environment (i.e., the product of environment design). In the next chapter I will outline several perspectives on designing that support the development of skills and design environments.

Looking ahead, this chapter offered the pattern language of Alexander *et al.* as an example of a fully developed design environment. In part 3, I will examine the development of such environments by composers. I also offered Gross's Constraint Explorer as an example of a computer-based tool for supporting skill and environment design. In part 4 I will examine the development of computer-based tools of my own design, one for music composition and another for textile design.

Chapter 5 Perspectives on Designing

I want to write about poetry not as a pedant, but as a practitioner. My article has no scholarly significance. I write about my work, which, by the light of my observations and convictions, I see as differing very little from the work of other professional poets.

...I want to insist that I offer no rules to make anyone a poet, by following which he can write poetry. Such rules simply don't exist. A poet is a person who creates these very rules.

In Vladimir Mayakovsky's *How are Verses Made?*

The above quote is from *How are Verses Made?*, a beautiful little book published in 1926 by the Georgian poet Vladimir Mayakovsky.¹ Mayakovsky's motivation for writing *How are Verses Made?* was to bridge the gap he observed between theory and practice. "Almost all editors complain to me that they don't know how to turn away a poetry manuscript, they don't know what to say about it" (Mayakovsky, p. 14).

Experts are often unaware of the skills they have learned; they simply use them. Consider the following rather recursive example from Cheney's book *Getting the Words Right*. In it he uses a sample of his own writing to demonstrate the "creative process" (below).

Just as we are subconsciously satisfied by rhythm in what we read, we are additionally satisfied by sound.

Cheney says that the following progression of edits led to the above sentence.

the following

"rhythm satisfies our subconscious"

became

"subconsciously satisfied by rhythm in what we read"

the following

"we are moved by sound"

became

"we are satisfied by sound"

became

"we are also satisfied by sound"

became

"we are additionally satisfied by sound"

Cheney says that he was unaware of the reasons for this progression of edits until he began to write about editing. Only then was he able to see that there is alliteration in the repetition of the initial consonant *s*'s; assonance in the final vowel sounds *satisfied* and *by*; delayed alliteration in the *r* sounds of *rhythm* and *read*; alliteration in the string "what we read, we"; additional

¹ Mayakovsky was born in 1883. He was active in revolutionary politics, working on propaganda poems. He was also a leader of the Russian Futurist group.

assonance in the long *e* in "we read, we"; "additionally" was added to "satisfied" to echo "subconsciously satisfied"; and the repetition of "we are" added coherence and rhythm (Cheney, pp. 166-167).

* * *

The central question to this chapter is: How can a designer know whether he is making progress? There are two kinds of answers, each reflecting a different perspective on designing.



One kind of answer has to do with how the designer keeps design process complexity from getting out of hand. By *controlling process complexity*, the designer keeps the emerging artifact from requiring skills he does not have or cannot construct "on the fly".



Another kind of answer has to do with how the designer evaluates the expressive utility of the artifact he is making.¹ By promoting user utility (or interpretability), the designer keeps the emerging artifact from becoming unusable.

There is also the distinction between using a perspective and constructing it, a distinction that is important if one is concerned with the acquisition (as well as the use) of design skill.



Sometimes the designer is engaged in *environment design*, constructing skills and organizations of them that he thinks he will need.



Sometimes the designer is engaged in *artifact design*, using the skills he has already constructed.

What seems to distinguish the best designers from the rest of us is their ability to take charge of the skill construction and skill management processes. I argue that the perspectives on designing support these processes.

5.1 Controlling Design Complexity: Designing as ReDesigning



Designing is in large part redesigning (editing, debugging, or refining). It is concerned with problems Anne von der Lieth Gardner describes as *open-textured*. In her study of legal reasoning, Gardner argues that lawyers are not governed but *guided* by rules. This is especially true in hard

¹ Most things are not like puzzles, discarded after the problems associated with them have been solved. Most designing involves the production of an artifact (a piece of music, a poem, a building, a computer chip, etc.) that is used by others. A piece of music or poem is used by an interpreter to have an experience, people live and work in buildings, and programmers use computer chips as roads to traffic bits of information.

legal cases where a large part of the task is to determine the true state of the world (Gardner, p. 61).¹ The selection of facts is critical because it determines which legal *precedents*² might be applicable (Gardner, p. 56). Consider the following case.

Let us suppose that in leafing through the statutes, we come upon the following enactment:

IT SHALL BE A MISDEMEANOR, PUNISHABLE BY A FINE OF FIVE DOLLARS, TO SLEEP IN ANY RAILWAY STATION.

Suppose I am a judge, and that two men are brought before me for violating this statute. The first is a passenger who was waiting at 3 A.M. for a delayed train. When he was arrested he was sitting upright in an orderly fashion, but was heard by the arresting officer to be gently snoring. The second is a man who had brought a blanket and pillow to the station and had obviously settled himself down for the night. He was arrested, however, before he had a chance to go to sleep.

In the above case, what does *sleep* mean? It might mean "to spread oneself on a bench or floor, or as if to spend the night". Similarly, *person* might mean "someone who is not a passenger". These interpretations of *sleep* and *person* make certain facts relevant and others irrelevant, and will result in the passenger being innocent and the vagabond guilty. However, a different interpretation of *sleep* as "the physical state of sleep", and *person* as "any person", will result in the passenger being guilty and the vagabond innocent (Gardner, pp. 39-40).

Designing is open-textured because the way one interprets a problem (legal, musical, or otherwise) has implications for what facts are relevant or irrelevant, what previous experiences one uses to evaluate it, what new facts these previous experiences uncover, and so on. What is relevant about legal cases are those elements which have multiple legal indices. Hard legal cases are those that are so ambiguous, so richly indexed, that they allow lawyer's the opportunity to evoke different kinds of precedents in the "design" of different, often opposing, arguments.

The highly successful money manager George Soros "plays the market" aware that markets are inherently reflexive. *Reflexivity* is present whenever interpretations of human action can change the course of subsequent action and interpretation. A market player can make money if he spots a reflexive cycle in which the perceived and real market value is different. Soros puts it this way in his book *The Alchemy of Finance*.

The participants' perceptions [of the stock market] are inherently flawed, and there is a two-way connection between flawed perceptions and the actual course of events, which results in a lack of correspondence between the two. I call this two-way connection reflexivity (Soros, p. 14).

¹ Presumably, lawyers would rule in the same way in clear cases.

² As an aside, for me, legal precedents play the same interpretive role in law as musical conventions do in music.

For example, stock prices are determined by both underlying trends and prevailing biases, and since both of them are influenced by stock prices, decisions are highly interactive. Reflexivity explains why there are disparities between the perceived and real value of a stock. It is for this reason that Soros is interested in *emergent* effects.

I did not play the financial markets according to a particular set of rules; I was always more interested in understanding the changes that occur in the rules of the game (Soros, p. 15).

Gardner's lawyers design legal arguments in a similar way. Lawyers apply a variety of precedents in an attempt to explore different patterns of facts which, in turn, provide new precedents and, reflexively, uncover new facts and precedents. Lawyers are often trained in legal reasoning by being given *issue spotters*, narratives so constructed that the facts embodied in them straddle the boundaries of several legal categories (Gardner, p. 7). By reinterpreting a case in several ways, lawyers gain skill in constructing durable legal arguments.

A final example. The sociologist of music Simon Frith describes how popular taste develops. His notion of beauty operates in ways similar to Soros' notion of value or Gardner's notion of truth. Frith argues that "popular music is popular...because it creates our understanding of what popularity means". And again: "What we should be examining is not how true a piece of music is to something else, but how it sets up the idea of "truth" in the first place" (Frith, p. 137). Frith is not avoiding the issue with a tautology; rather, he is describing a dynamic process in which future judgments are progressively adjusted to accommodate the effects of past judgments.

These examples illustrate the reflexive nature of designing. A designer expects unanticipated problems and learns how to construct and use recovery strategies. This is why designing is always redesigning.

5.1.1 Creative Solutions: Strategies for Acquiring Strategies

In designing there is no way to plan a path towards a solution if what constitutes a solution is, itself, under debate. The solution to designing is *emergent* rather than planned because the designer is learning what a "problem" is about during the design process. Moreover, he is developing new skills for improving his design process as the following short study illustrates.

While in Brazil in the summer of 1990 I asked a young popular folk singer, who I will call Jose, whether I could observe him compose a folk song on his guitar. He agreed. Jose tried some things out on his guitar while I observed and asked questions. After about an hour and a half of this, I told him what I thought he was doing and corrected my description based on his response until he and I were both satisfied. The following is a schematic description of Jose's "compositional method" based upon this session. It serves as an illustration of creative solutions in music composition.

Jose said that he usually started with a poem which he liked (step 1). He then would try out a simple repeating rhythm on his guitar to accompany these words. This ostinato rhythm was for the guitar chords yet to be chosen (step 2). Next, Jose would try out different sequences of chords which could be used as the underlying harmony to mark each of the phrases of the poem and music. The combination of ostinato and chord patterns defined the duration of the phrase. He would either "borrow" chords from other Brazilian folk musicians—he favored the Brazilian folk musician Caetano Veloso—or use chord patterns that worked in his own previous songs (step 3).

Jose's songwriting steps

1. Select text.
2. Decide on ostinato beat for chords
3. Find pattern of chords
4. Suppress chord rhythm, play with *generic* melody (i.e. notes that fall within the notes of the current chord).
5. Use "syncopation" to fit text syllables to notes in the generic melody.
6. Put everything together.

After finding a pattern of chords, Jose would suppress the chord rhythms he had decided on earlier (i.e. the ostinato pattern) and concentrate on finding melody notes which fit each of the chords in the pattern (step 4).¹ These melody notes wouldn't be the final melody but a *generic* melody having the minimum requirement that the notes fall within the current chordal context. With this generic melody Jose would explore possible rhythms for the text (5). Finally, Jose would re-introduce the ostinato pattern to complete the song (6).

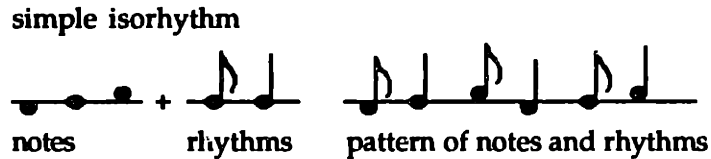
Jose said that he especially liked the melody to be "syncopated". Sometimes what he meant was the conventional notion of syncopation: accented weak beats, de-emphasized strong beats, or rests on strong beats. At other times what he meant by "syncopation" was a more elastic notion of time in which notes rushed ahead or lagged behind the clock-like meter underlying a phrase. The amount of rushing and lagging was substantially influenced by the number of syllables in the Portuguese text. Jose had to allocate text syllables to phrase elements. When a line of text was sparse he had to stretch syllables over the duration of the phrase; conversely, when a line of text was dense he had to shrink syllables into the duration of the phrase.

Only after the ostinato pattern and chord sequence had been decided did Jose specify the phrase lengths. Of course, it was still possible to revise the chord sequence but, at each revision, what resulted was something equally constraining.

According to Jose, the tricky part of the songwriter's craft was fitting text syllables to melodic elements (step 5). After some probing Jose mentioned some isorhythmic exercises he was given by his




¹ To simplify a bit, a chord implies a musical scale of 7 notes. To say that a melodic note "fits" a chord means that it is one of the scale notes implied by the chord.

composition teacher to deal with this problems. An *isorhythm* can be defined in the following procedural way. Given some collection of notes and some collection of rhythms, each with different numbers of elements, it is possible to construct a pattern of note-rhythms (i.e. a melody) using them in an ordered way. The following illustrates by using 3 notes and 2 rhythms to produce a 6 note melody (2 x 3).



In fact, the assignment included an additional step. Each time the constructed pattern had been completed (i.e. when all orderings of both notes and rhythms had been made), Jose was asked to introduce either an additional note or rhythm. In this way, the component patterns and the resulting isorhythm would continuously expand. A side-effect of these expansions would be the production of different metric frameworks.¹

When I asked Jose how this activity became useful for text-fitting problems he said that since all the patterns except the melody are rigid, the isorhythms helped him to "unlearn" his notion of meter. What he meant was that he learned to re-represent the music's meter in different ways. This gave him the mental elasticity he needed to explore different text-fitting solutions. He had

acquired a new skill , a technique  (e.g. metric re-representation) plus the kinds of cases  in which it could be productively used (e.g. text-fitting).

Of course, the exercise Jose's teacher gave him, Jose might have constructed for himself. Composers do this all the time,² all the more reason to view environment design as an important aspect of artifact design.

5.1.2 Two Meta-Skills

Freedom in Restrictions. Designing requires restricting design. Without restrictions, a designer would be unable to choose from the possible actions he could take; he would be paralyzed.

¹ A similar method is used by the composer Steve Reich and described by him as the *process of gradual change*.

² Beethoven's sketch books are full of self-imposed "assignments". In his study of Beethoven's sketches for the *Diabelli Variations*, Kinderman remarks that:

"Most of the sketches, if they do not obviously relate to one of the finished variations, are related clearly enough to the development of ideas used in one, or, most often, several of the finished variations" (Kinderman, p. 29).

Moreover, an action has little value if there is no way to evaluate the effect of the action. What I call *freedom in restrictions* is the counter-intuitive notion that restrictions—like the assumptions used by those who did the four-stone problem or the pattern language of Alexander, Ishikawa and Silverstein—provide the designer freedom rather than enslavement. Within a restricted collection of choices, a designer can explore possible choices using trial and error or algorithmic methods.

For example, Gross's Constraint Explorer (chapter 4) was developed under the assumption that an architectural designer works with rules (e.g. beams should be no less than 12 times their depth), conventions (e.g. architectural style), laws (e.g. gravity) and principles (e.g. a room should have windows). The *design context* is the set of rules, conventions, laws and principles that restrict current designing as well as relations among design parts and other requirements like materials and codes (Gross).¹

Confidence Building. Reflexivity explains why designing—in search of truth, value or beauty—is a process in which provisional solutions serve as a means of further discovery. Still, designing imposes restrictions which become intractable. For this reason, designers are continually evaluating the restrictions they impose on their process. *Confidence building* is about how restrictions earn their credentials through use.

The psychologist John Sloboda has observed that composers tighten or loosen compositional constraints depending on the difficulties they encounter in their design problems (Sloboda, pp. 123-138). Sloboda's constraints are my restrictions. However, Sloboda keeps implicit the ranking of constraints/restrictions based on their productivity, my confidence building.

Once constraints are ranked, they offer different *degrees of freedom*. I think of the degrees of freedom found in the joints of the body. There are several ways one can reach for a glass: for example, by extending the arm using the elbow and shoulder joints, walking forward while lifting the arm from the elbow, leaning forward from the waist, twisting from the waist, or some combination of these movements. The movements chosen depend on physical restrictions created by the context. Whether one is sitting at a dinner table or standing among people crowded around a buffet table will determine the combination of movements one is free to use. While designing, there is also a context made up of a number of constraints, they are ranked according to their productivity and this ranking restricts design choices.

Alexander's idea of design *fitness* is a similar idea. Design fitness is the harmony created between an ensemble and any of its parts. He offers the simple case of a suit and tie. A suit is the

¹ For Gross, designing does not happen without design rules; only "free expression" can happen in the absence of rules. I will argue that "free expression" is never "free" because of the need for methods to manage the complexity of decision-making and because of external constraints like conventions, laws of perception, or user utility.

ensemble in which a tie is a part. A different suit requires a different tie. If the suit and tie do not match, it is the tie, not the suit, that must be replaced. This is because the design investment is greater in the suit; it is ranked higher, less intractable, than the tie.

In complex ensembles there are many ways the ensemble can be broken into parts and different ways to rank the parts. The designer may have nothing at the outset on which to substantiate a particular strategy for producing harmony. Fitness may be achieved indirectly, through a process of removing factors leading to misfit (Alexander, 1964. pp. 15-27).

The designer needs strategies for identifying factors that restrict the degrees of design freedom. Sometimes the factor defining misfit is identified through a process of perspective taking. Through this process, a certain factor may emerge as particularly important because it is important from all perspective. At other times the factor defining misfit may come with the design problem. Using the suit-tie example, one can imagine that the ensemble's most important element is a particular tie (perhaps, a gift which one wishes to wear on a special occasion to please a loved one). The tie must fit and anything that does not match with it is a misfit.

In either case, growing confidence makes some restrictions rigid and certain solutions decreasingly provisional. Proof that artifacts become increasingly permanent is that they eventually get made.

5.2 User Utility (or Interpretability) Making Artifacts "User-Friendly"



The designer knows that he has privileged access to the thinking that gave rise to his designed artifact and takes this into account by considering its interpretive utility. This can be seen most clearly in artifacts that have day-to-day utility. Our success or failure to interact with doors, keys, VCR displays, washing machines, telephones, or watches depends upon how well the designers of these objects understand the way we interact with them. Everyday things are tools that we want to use, not contemplate. We don't want to think about doors, we want to go through them; we don't want to contemplate watches, we want to know the time.

According to the cognitive psychologist Donald Norman, our understanding of everyday objects requires either shallow or narrowly structured knowledge. Norman gives an ice cream menu as an example of *shallow knowledge*. "Difficulties arise from competing alternatives, not from any prolonged search, problem solving, or trial and error. In shallow structures, there's no problem of planning or depth of analysis" (Norman, p. 121). *Narrowly structured knowledge* does not require extensive planning either. Such knowledge is comprised of "a long series of steps, but at each point, there are few, if any, alternatives to consider (Norman, p. 123). Norman gives a cookbook recipe as an example of narrowly structured knowledge. Shallow structures, like ice cream menus, are wide but not deep while narrow structures, like recipes, are deep but not wide.

Because music is both deep and wide it may not be subject to any of the criteria of design mentioned by Norman.

In general, we find wide and deep structures in games and leisure activities, where the structure is devised so as to occupy the mind or to make the task deliberately difficult (Norman, p. 124).

Unlike Norman, I argue that many everyday objects (like software environments) are capable of supporting fairly complex activities. We judge the utility of these objects based on whether shallow or narrow initial access provides the means for deeper or wider subsequent access. In other words, the full utility of the artifact is something that is gradually discovered: Using it becomes a means of learning how to use it. One might say that a successful piece of software (or by analogy, a piece of music) is "user-friendly" when it is designed so that subsequent encounters (or rehearsals) build on previous encounters.

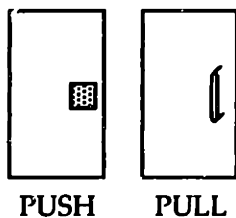
I have already argued that art objects have unanticipated interpretive utility (chapter 3). But so do software environments to some extent. To this extent, Norman's evaluative stance can serve as a bridge between these different kinds of designing.

5.2.1 Natural Mappings and Feedback

Norman argues that the primary source of problems with designed things is that there is a gap between the designer and the user of designed objects.

For a surprisingly large number of everyday tasks, the difficulty resides entirely in deriving the relationships between the mental intentions and interpretations and the physical actions and states (Norman, p. 50).

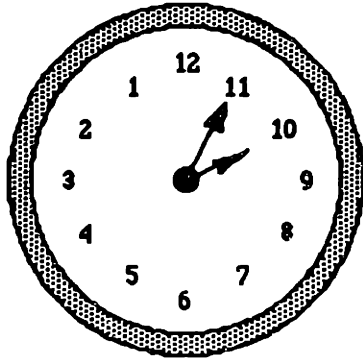
Norman attributes these difficulties to (1) unnatural mappings between mental and physical states and (2) inadequate feedback of the effects of user actions. *Natural mappings* take "advantage of physical analogies and cultural standards" (Norman, p. 23). For example, it is clear from the design of some doors what the user should do to open them. The following illustrates that a small rectangular plate invites the user to PUSH, while a narrow protruding bar invites the user to PULL.



Even this simple case is problematic because there is more than one way to open a door. For more complex objects the number of ways we might interact with them can be quite large. "The difficulty of dealing with novel situations is directly related to the number of possibilities"

(Norman, p. 81). Finding natural mappings helps to reduce the possibilities through design rather than by taxing the user.

Natural mappings can rely on conventions. "Red means stop", or "walk on the right side" are two examples. The following backwards clock (Quick? What's the time?) is another vivid example (Norman, p. 201).



A Backward Clock

There is nothing about the world that demands clock time to move in clockwise fashion. Nevertheless, making clock motion standard reduces interpretive work and, thus, makes telling the time almost effortless. "If you can't put the knowledge in the device, then develop a cultural constraint: standardize what has to be kept in the head" (Norman, p. 170).

Feedback sends "back to the user information about what action has actually been done" (Norman, p. 27). The "zzz" of a zipper, the whistle of a tea kettle, and the increase in pitch when a vacuum cleaner gets clogged are all examples of designed objects that provide immediate and obvious feedback (Norman, p. 102). We also get immediate feedback when doors we should have PUSHed rather than PULled do not open.

Musical objects are like everyday objects in these respects. They, too, are more or less "user-friendly" depending on a composer's understanding of how listeners are likely to interact with them. Musical conventions, like our clockwise clock, standardize arbitrary pattern choices and by doing so reduce interpretive difficulty.

5.2.2 Interpretability

From a cognitive perspective, musical thinking is neither especially privileged nor are everyday concerns especially mundane. What is special about the musical experience is its interpretive potential. One understands how to open a door in order to open it. Musical objects, unlike everyday objects, are a source of virtual worlds in which observers live-out an interpretive experience (chapter 3). The function of these interactions is to engage in the process of interpretation itself, a process that is also crucial in everyday life. Norman ignores this valuable

function of music. "Games and leisure activity" are difficult not only because they "occupy the mind" of the observer as Norman says, but because they give us the opportunity to exercise and acquire interpretative skill. (Programming environments that are powerful give "designers" the ability to make tools for addressing unanticipated problems. Programming is also learning how to program, learning by designing.)

In music, interpretability is a necessary but not sufficient condition for "beauty". A piece of music is beautiful because it is interpretable and more (e.g. moving, involving, etc.). It is like user-friendly, itself, an elusive idea. The following ideas—of interpretive consistency and learnability—add more meat to interpretability, though even they are not sufficient for determining beauty.

5.2.3 Conventions and Interpretive Consistency

My notion of a musical convention is much like Norman's notion of a natural mapping. The clockwise clock is an example in everyday objects, and the traditional rules for chord progressions is an example of a convention in musical "objects".

What I call the principle of interpretive consistency is much like Norman's notion of feedback which, in turn, depends on natural mappings. Composers give interpreters the means to confirm or refute their interpretations by being consistent about the conventions they use in producing the artifact in the first place. Consistency restricts musical novelty and makes listening easier to do. A work that is difficult to interpret exercises interpretive skill. A work that is impossible to interpret discourages one from making an interpretation at all!

5.2.4 The Problem of Learnability

From a cognitive perspective, listening to a foreign music for the first time is like listening to an experimental piece for the first time. The problem in both cases is whether the unfamiliar is learnable. In general, *learnability* becomes an issue when something is too complex to grasp in one setting. Here we move beyond Norman's prescriptions for the design of everyday objects. A listener will engage in repeated hearings of a piece of music because initial hearings are rewarding and subsequent hearings are likely to profit from them. During rehearings, the listener will take advantage of conventions of listening he has previously acquired in order to learn new ones.

Only when we are confronted with the unfamiliar do we begin to appreciate that our musical experience is informed by musical knowledge that we have learned. When ethnomusicologists examine the music of an unfamiliar culture, one of their tasks is to identify the conventions of listening operating in that music. The same task is required of listeners of experimental music.¹

¹ Of course, the experimental composer can help the interpreter by providing him interpretive aids. However, this assumes that the composer has some theory of interpretability.

Among musicologists, the idea that the interpretive process is a learning process is embedded in discussions about absolute music. *Absolute music* can be described as music which is defined in musical rather than extra-musical terms (Apeil, pg. 2).¹ Even though the phrase absolute music is attributed to Wagner, according to the musicologist Ian Bent, the notion of absolute music was born in the 18th century, around the same time as phrase structure analysis and formal musical modelling began to develop within the western music community. These developments were important because they resulted in explicit statements about how musical elements are linked to each other through musical norms (Bent, pgs. 12-16). It was no coincidence that the idea of absolute music and work in musical norms were co-dependent. With musical norms identified, it was no longer necessary for music to make reference to extra-musical criteria. Music could now be *self-referencing*, evaluated exclusively in terms of musical norms.

In reading Carl Dahlhaus' account of the idea of absolute music, one gets the impression that, at the birth of "pure" instrumental music, composers and theorists were truly puzzled by the fact that instrumental music was able to achieve its expressiveness without degenerating into noise. What could it mean for there to be a musical "idea" or "thinking with sounds"? How could one account for the affective side of music without a narrative reference?

According to Dahlhaus, there were two sorts of arguments. One argument, reflective of Rousseau's naturalism, was that music has its origins in the emotions produced by the "natural" inflections of passionate speech; i.e., music is a language. A second argument, reflective of Rameau's scientism, was that music had its origins in the Pythagorean proportions; i.e., music is a mathematics. Both arguments assumed that in order for music to be absolute it must be rooted in some universal principle (Dahlhaus, p. 47-53).

A different idea began to emerge, the idea that one's experience of music is learned. This idea put in question the absoluteness of music. By admitting learning into the discussion, theorists had to give a higher intellectual status to the interpretive process. Dahlhaus places the awareness of the role of interpretation in western musical experience in the romantic aesthetics of the late eighteenth century which attempted to reconcile the particularity of art works with more universal criteria of beauty.

For insofar as music does not exhaust itself in the acoustical substrate that underlies it, but only takes shape through categorical ordering of what has been perceived, a change in the system of categories of reception immediately affects the substance of the thing itself (Dahlhaus, p. 63).

The new challenge was to find a way to evaluate a "learned" music on absolute grounds. Music theorists became increasingly interested in principles of music organization, seeing in the fugue an illustration of "thinking with sounds", and in symphonic forms (e.g. concerto and sonata forms) a

¹ What we mean by *absolute music* is what some musicologists prefer to refer to as *abstract music*.

coherent system of harmonic control. What gradually became of evaluative interest was how the composer demonstrated near the beginning of a work the musical elements the listener should pay attention to while listening to the remainder of the work (e.g. themes, harmonic "plan", etc.).

Language is the garment of thought, just as melody is the garment of harmony. In this respect, one may call harmony a logic of music, because it stands in approximately the same relationship to melody as logic in language stands to expression, namely, it corrects and determines melodic writing so that it seems to become a real truth to one's sensations (Johann Gottfried Herder, in Dahlhaus, p. 105).

The ideas of absolute music and interpretation continue to be debated until this day. One insightful critic of twelve tone music, himself a twelve tone composer and theorist, is Milton Babbitt. He argues that one of the primary difficulties people have with twelve tone music is that the music takes the ideas of absolute and interpretive music to an extreme. According to Babbitt, twelve tone music establishes more than its "thematic" or "harmonic" premises within itself. What is normative is also a component of a music's premises. In the twelve tone framework, listeners have to learn what is normative as they are listening--including what "theme" and "harmony" mean--and then continue to listen using these norms as interpretive instruments (Babbitt). Babbitt reminds us that the interpretive process and the resulting musical experience suffers when too much has to be learned too quickly.

Part of the composer's design problem is to make the music learnable by the listener. As I see it, the learnability of complex knowledge requires the satisfaction of at least two criteria.

Learnability Criteria

- 1. Learning is incremental.** Knowledge must be learnable in discrete steps; a little knowledge gets the learner to a little more knowledge, and so on.
- 2. The pathways to knowledge are different for different people.** The steps in the learning progression must be rewarding in themselves. Point 2 reminds us that the learner's receptivity to knowledge must be taken into account.

Criteria 1 asks the designer to deconstruct the knowledge into knowledge steps, each requiring the cognitive effort of Norman's everyday objects. Criteria 2 puts in question any pathway to knowledge that ignores the learner. In a sense, without criteria 2, any application of criteria 1 is arbitrary outside of a cultural context.

5.2.5 The Learnability of Music's Protean Forms

Good composers respect the criteria of learnability by providing listeners several rewarding pathways to knowledge. There is little else composers usually do except modify previously stated material, or introduce a little new material. Regardless of the stated form of a piece, most

composers use either *theme-and-variations* or *theme-and-contrast* as a means for extending the musical material. These are the two protean musical forms (Reck, 1977; Rowel, 1983; Schoenberg, 1970).

In *theme-and-variations*, changing the harmonies associated with a melody results in *harmonic variation*, changing the details of a melody while preserving its overall contour results in *melodic variation*, and adjusting the rhythms of a melody so that it can fit in a different meter results in *rhythmic variation*. Listeners change their understanding of a piece of music through repeated hearings because repeated hearings offer the listener a chance to use previously identified elements to gain access to related and unidentified elements. In addition, listeners mentally construct different degrees of relatedness (Pollard-Gott, pp. 66-93).

Theme-and-contrast is a kind of *phantom-form* because whatever a composer needs to do in order to make the theme recognizable he must do to make contrasting material recognizable; namely, he applies variation methods to the contrasting material. For the listener, recognizing contrasting material is not unlike hearing a theme for the first time and requires the same pattern recognition strategies that were needed then.

5.3 Environment Design vs Artifact Design




During the early phases of the design process there is no data on which to build confidence. Sometimes composers use strategies like *composing by example*, a strategy that makes it possible for the composer to re-appropriate elements from previously successful artifacts. Other times composers develop so-called precompositional methods to support compositional decision making. However, "pre-composition" is also composition. For most composers, "pre-composition" is the exploratory aspect of composition. Moreover, "pre-composition" is ongoing and, therefore, inappropriately named.


My notion of environment design makes the distinction between composing and pre-composition unnecessary. However, there is an important distinction to make, illustrated by Jose's re-appropriation of isorhythmic thinking to address text-fitting problems: namely, a distinction between working on the design environment and working on the artifact.

Sometimes the designer is engaged in environment design, constructing skills and new organizations of them so that particular skills can be found. At other times, the designer is constructing the artifact itself, selecting the organizations of skills from which particular skills are then selected and applied. These two perspectives on designing need to be added to those already discussed.


5.4 Six Perspectives on Designing

In total, I have identified six broad perspectives on designing.

 In *managing design complexity* the designer constructs and ranks the restrictions he imposes on his process based on their past or anticipated productivity. Ultimately, this process leads to an emerging notion of design fitness for the design environment.


 In *promoting user utility* a designer re-appropriates "user-tested" conventions, or invents new ones that can be learned by the interpreter. An interpreter can learn that something is a convention because he has encountered many patterns that operate by it; he can recognize that a "law of invariance" (as Piagetians would say) applies for a number of pattern-cases. The notion of interpretive consistency says that a new convention can be learned if a composer applies it consistently. Ultimately, this process leads to an emerging notion of design fitness for the artifact.


While operating within the perspective of promoting user utility, the designer uses the interpretive perspectives presented in part 1.

 User utility is promoted by making anticipatory listening easier to do.

 User utility is promoted by making anthropomorphic listening easier to do.

Finally, the designer alternates between the perspectives of environment design and artifact design..

 Sometimes the designer is engaged in environment design, constructing skills and organizations of them so that they can be easily found.

 Sometimes the designer is engaged in artifact design, selecting the organizations of skills from which particular skills are then selected and applied.

Part 3
Design Practice

Chapter 6

Skills Supporting the Perspectives

Introduction



I use the six perspectives from chapter 5 as a means of organizing 37 skills that I have identified through self-reflection. My investigative approach was informal, but deliberate. I began by teaching myself a way of writing music that was simple enough so that the skills used to write would be unambiguous, yet complex enough so that a variety of skills would be necessary. It was also important that artifacts produced by this process would have musicality. While composing, I would reflect on what I had done or was about to do, occasionally writing down my thoughts. Skill identification was easiest when the application of a skill failed or produced a new problem.

Readers will notice that more than one perspective may be in operation at the same time. For example, artifact design (one perspective) may have the objective of managing design complexity (a second perspective) or the objective of promoting user utility (a different second perspective). Some skills could be placed under a different heading. For example, *designing by example* (HYPOTHESIS 10) and *self-referencing* (HYPOTHESIS 13) are two skills that could have different objectives, depending on the nature of the example or the referenced material.

I call these skills "hypotheses" for two reasons. For one, some skills are little theories about skills, meta-skills. For another, I do not argue that the skills are necessarily true for all composers, nor do I argue that the set of skills I have identified are complete. What I do wish to defend is the general applicability of the perspectives on designing in learning how to design, a point that will be relevant when I start considering computer-based design environments in part 4.



environment design

Hypothesis 1: Environment Design

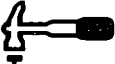


In order to manage the design process, a designer not only designs an artifact, he designs the box of tools with which he designs the artifact.

Environment design is similar to the notion of *language design* in computer science. In designing a particular software application, a programmer designs a set of programming tools that offer actions relevant to that application domain. For example, a paint program requires drawing tools, a word processing program requires text editing tools, and a music sequencer requires note editing tools (Eisenberg).

The function of environment design is to organize these tools. For example, word processors provide page layout, numbering, footnoting, indexing and sometimes the ability for the user to produce customized macros. Computer aided design (CAD) environments offer customized design templates that embody pieces of other designer's experience in specific application areas. Environment design results in a "box" of design tools. Each tool has a particular function. When situations call for new tools they must be designed and added to the "box" of tools.

Thinking about the environment of design is a way of addressing the theme of "creativity". Novice designers do not appreciate that experts have control over the shape of the design environment itself. Experts are not more imaginative than novice designers. The tools they design help them to think of things they would not normally imagine. Being able to control the shape of one's design environment facilitates the mind-stretching we associate with creative activity.

Hypothesis 2: Skill Design

Skills  require know-how  (i.e., tools) and know-when  (i.e., knowledge of the situations in which know-how can be productively employed).

Even before computers, when design "templates" and writer "macros" resided in the designer's mind, designers tried to externalize these design aids. The composer Igor Stravinsky wrote his musical sketches using different colored pens so that he could keep a trace of the chronology of his design decisions. The author Vladimir Nabokov used 3 x 5 cards (one sentence per card) as a tool for keeping his prose modular during the writing process. Early Western perspective painters used to look through a grid at their subjects to help simplify the problem of coordinating the relative scale of objects in the foreground or background. These are all examples of tools that support the design process.

Some tools embody design decisions found within a cultural group. For example, with many folk instruments, like the Senegalese *kora* (21-stringed harp), the way it is tuned remains fixed within a family of practitioners. Moreover, the *kora* is not a chromatic instrument. Its "scale" (or mode) is

determined by the tuning system and "key" is determined by the tuning of its lowest note, an octave lower than its physical neighbor. A kora musician inherits these tuning decisions from the past much like a contemporary CAD designer inherits past design decisions by purchasing a template.

The piano, like the kora, has a tuning system fixed by cultural tradition. Unlike the kora, its chromatic possibilities allow a large number of scales. These scales are not organized by the physical object but by a conceptual tradition, a common practice.

Computing has taught us that we can soften the line between physical and other design tools. Colored pens, 3 by 5 cards, rulers, and hammers are physical tools; CAD templates and macros are computational tools; musical scales are conceptual tools. These cultural artifacts are all the result of environment design, either inherited from past designers or invented by current designers.

* * *

Perpetua (a name to suggest "perpetual motion") is a piece I wrote for string ensemble. While *Perpetua* is a simple piece, it is not a "toy piece". It lasts several minutes and some people find it pleasurable, even after several hearings.

An unusual aspect of *Perpetua* is its use of copy, cut and paste operations. Chunks of music, what I call *frames* (examples 6.6a-d), were copied and pasted several times to produce musical cycles. These cycling frames were then "sculpted" using *deletion strategies* for removing notes. These deletion strategies are examples of tools. What follows are three kinds of situations in which they could be productively employed.

- By deleting notes in a patterned way it was possible to produce a metric organization not found in the original material. For example, deleting every other eighth beat would produce a meter, in this case a duple pattern, contrasting with the original pentameter.
- By deleting notes before and after a beat where two or more voices were sounding, it was possible to make chords or accents not found in the original material. These accents could be used as a source of phrasing or surprise.
- By deleting pizzicati in the third voice it was possible to emphasize the more lyrical effects of the other two voices. Conversely, by deleting sustained notes in the third voice I could emphasize pulsating effects.

While the above strategies were used to "sculpt" a cycling frame, the following *smoothing strategies* were used to make smooth transitions between cycles of frames. The smoothing strategies are more examples of tools; they are used in the following kinds of situations.

- *Voice as pivot*. All voice 1s have a similar contour. So do all voice 2s and 3s. One way I could promote smooth transitions was to feature the same voice at the end of one frame and at the beginning of the subsequent frame.
- *Counter-rhythm as pivot*. If a counter-rhythm had been established at the end of one frame (using deletion strategies), the same counter-rhythm could be used in the subsequent frame.

- *Shared notes as pivot*. If two neighboring frames had notes in common, I could use shared notes at the transition.

Hypothesis 3: Coherent Design

Through environment design, designers determine the kinds of thinking they allow themselves as they work, while protecting themselves from the ever-present inconsistencies found within their design tradition.

Designing is systematic even though it is not homogeneous. This flexibility provides the designer the necessary room to construct and organize tools in unanticipated ways.

Coherent design helps to clarify what musicologists mean when they speak of musical "coherence" or a composer's "language" or "logic". I attribute the remarkable consistency in particular pieces of music to the coherence of the design environment and not the coherence of a musical tradition.

Hypothesis 4: Design analysis

Designers use analysis as a method for selecting skills.

In constructing his design environment, the composer selectively draws techniques from his musical tradition and re-appropriates them in new ways. According to Charles Rosen, twelve tone ideas were largely present along the frontiers of the tonal music "system". As examples, instead of using the orchestra in full force, Mahler¹ tended to use the orchestra as a resource for constructing a variety of chamber ensembles with contrasting instrumental color. Instrumental color reached new heights in the twelve tone notion of *klangfarben* melodies (or "tone color" melodies). Beethoven² had the ingenious idea of drawing thematic material from the details of tonality, causing musical detail to reflect the whole. By Beethoven using a musical scale as a melody, any time that scale occurred for any local reason, it would automatically serve a more global associative function. Schoenberg's *grundgestalt* ("basic shape" or "premise") is primarily about reflecting the whole in

¹ An invective:

It is a matter of extreme difficulty to detect tangible themes in the second movement of Mahler's Fifth Symphony, and it is an almost impossible task to follow them through the tortuous mazes of their formal and contrapuntal development. One has to cling by one's teeth, so to speak, to a shred of theme here and there, which appears for an occasional instant above the heavy masses of tone, only to be jumped upon immediately by the whole angry horde of instruments and stamped down into the very thick of the orchestral fray. The fighting grows so furious towards the finish that one is compelled to unclose one's teeth on the morsel of them, and lo and behold! it is seized upon, hurled through the screaming and frenzied ranks of the combatants, and that is the last seen or heard of the poor little rag of a theme. Musical Courier, New York, February 21, 1906; in Slonimsky

² An invective:

The merits of Beethoven's Seventh Symphony we have before discussed, and we repeat, that...it is a composition in which the author has indulged a great deal of disagreeable eccentricity. Often as we now have heard it performed, we cannot yet discover any design in it, neither can we trace any connection in its parts. Altogether, it seems to have been intended as a kind of enigma--we had almost said a hoax. The Harmonicon, London, July 1825; in Slonimsky

the parts (Epstein). Brahms¹ introduced many new techniques for motivic construction which became, in the twelve tone tradition, the source of new ideas on how to derive new "sets" from old ones (Rosen, 1981, pp. 48-52).

Like his Viennese counterparts (i.e., Schoenberg, Berg, and Webern), Bartok sought to break loose from the "tyranny of diatonic music". This is reflected in Bartok's 1920 essay on the problems of new music.

It would be desirable to have at one's disposal a notation with twelve similar symbols, where each of the twelve tones would have a comparably equivalent symbol, in order to avoid the necessity of notating certain tones exclusively as alterations of others (Bartok, in Antokoletz, pg. xv).

Rather than look to the German chromatic tradition for guidance, Bartok took his cue from the Eastern European folk musics he had been analyzing for many years.² Bartok observed that musicians working in the old Hungarian folk style primarily used a pentatonic scale while those working in new style introduced new scale notes, producing a quasi-major or mixolydian scale as in example 6.1.

Antokoletz shows how Bartok's harmonization of the *Eight Hungarian Folk Songs* extends this folk practice. The *Second Song* can be "harmonically" analyzed as an E-pentatonic scale (i.e., pentatonic scale starting on E, example 6.2) extended by the addition of a C#, resulting in a quasi E-Dorian mode. In example 6.2, adding a C# and F# to the E-pentatonic scale results in the E-Dorian mode. Replacing the C# and F# of the E-Dorian with a C and F results in the E-Phrygian mode. Subtracting the C# and F# from the E-Dorian mode results in the recovery of the E-pentatonic scale. So does subtracting the C and F from the E-Phrygian mode (Antokoletz, pgs. 36-38).

We see the beginnings of a "harmonic" system in this method. We can imagine Bartok thinking of the E-pentatonic scale as the point of reference (i.e., a functional "tonic") and scale expansions and contractions as serving a *modulatory* function. While notions like "tonic" and "modulation" undergo a conceptual change in the process, the newer concepts retain their design function of restricting note-sets and relating different ones to each other.

¹ An invective:

The Brahms C minor Symphony sounds for the most part morbid, strained and unnatural; much of it even ugly...Melody has become, by this time, a pretty vague term...but when it comes to an oboe and a clarinet making absolute speeches at each other (vide, for instance, a passage in the Andante), the listener's mind is at so great trouble to remember what the first has said, that it is impossible to appreciate whether the reply of the second is pertinent or not.

W. F. Athorp, *Boston Courier*, January 20, 1878; in Slonimsky

²Bartok believed that the use of pentatonic scales by Debussy and Stravinsky were both influenced by Russian classical and folk music. For example, the whole-tone scale appears as early as 1842 in Glinka's opera *Ruslan and Ludmilla*. There is evidence that Debussy was influenced by Mussorgsky, another Russian composer (Antokoletz, pg. 8).

Bartok took this thinking into his compositions.¹ One of the observations in which he delighted was the *intervallic symmetry* of the pentatonic scale (example 6.3), the fact that the pattern of interval distances between successive notes along the lower end of a scale are mirrored along its upper end.

Bartok combined intervallic symmetry with the scale expansion and contraction idea by using intervally symmetric scale parts--what Bartok called *tone cells*--as building blocks for new kinds of scales. For example, each tone cell might be comprised of 4 symmetrically related notes. In example 6.4, the tone cell [G# C# D G] has the interval pattern [P4 m2 P4]². When the left most note is moved to the right most position, the interval pattern is [m2 P4 m2]. This procedure can be repeated until the first tone cell is recovered. (The points of symmetry are shown by the dotted lines in example 6.4).

As in the earlier Bartok harmonization example, notes could be added to or subtracted from a tone cell in a systematic way. Example 6.5 shows two tone cells combined into an eight-note "scale" (Antokoletz, pgs. 67-77). Each of these tone cells have intervallic symmetry. Tone cell 1 [C# F# G C] has the interval pattern [P4 m2 P4]. Tone cell 2 [D# E A A#] has the interval pattern [m2 P4 m2]. Combining these cells also results in a "scale" with intervallic symmetry.

Antokoletz is engaging in a kind of music analysis similar to sketch analysis where the focus is on the evolution of the composer's thinking, of the design process rather than the design product. I argue that a similar approach to analysis is performed by the composer while he is working.

Hypothesis 5: Meaning is Negotiated (Vygotsky)

Neither artist nor interpreter are entirely free to make the meanings they choose, nor are they entirely prisoners of their culture.

A music cannot be expressive unless there is shared knowledge between composer and listener. This is why the composer has some confidence that what he intends to express is expressed. Nevertheless, the listener is a co-creator, projecting experiences onto the music that the composer could not have anticipated. (Kivy is right to think of music as a "protean expressive clay".)

The listener has the right to interpret a piece of music any way he chooses. However, if anything goes, one would be hard put to explain the benefits of music listening. I have argued that

¹ An invective:

Mr. Bartok elected to play his composition dignified by the title Concerto for Pianoforte and Orchestra. Note the omission of key. Ultra-moderns cannot be bothered with such trifling designations. Bartok plays the piano part from memory. How does he do it? And would it make any difference if memory failed and different notes were substituted for those written in the score? Perhaps the unaccountable chaos of sound was caused by an incorrect distribution of the parts to the musicians...Is Bartok making fun at our expense? If so, the laugh is on us.
Cincinnati Enquirer, February 26, 1928; in Slonimsky

² The notation I am using is *m2* stands for *minor second*, *M2* for *major second* and *P4* for *perfect fourth*.

a piece of music is used by an interpreter to construct a virtual world in which he can exercise the kinds of reasoning needed in the less forgiving real world. If music has this function than the interpreter is neither free-man nor prisoner, but negotiator.

I think of Iser's notion of entanglement and Vygotsky's observations of children at play. Iser suggests that, as interpreters, we do not want to be in total control. We want commitments established early during the interpretive process to lead us along paths of reasoning we have not previously followed. Vygotsky suggests that our long-term pleasure demands that we play an interpretive game that is salient for all players, provoking the construction of shared understandings. Neither artist nor interpreter is entirely in charge.



managing design complexity



environment design

Hypothesis 6: Design Environment Evaluation

A designer evaluates the productivity of his design tools.

In *Perpetua*, I anticipated that I would have a problem coordinating note-pattern and rhythmic-pattern changes (caused by frame changes during the repeating cycles of frames), though I did not anticipate a particular solution. The *deletion* and *smoothing* strategies, discussed earlier, were the tools I built into the environment to make the music interesting and coherent.

Hypothesis 7: Design Style

A design style might be partially described as the skills found across a designer's environments of design; i.e., his common practices.

In *Perpetua* (example 6.6), when frame changes were infrequent, deletion strategies dominated the compositional process; conversely, when frame changes were frequent, smoothing strategies dominated the compositional process. These observations illustrate why the notion of skill is recursive; there is skill in knowing when to use skill.

I became an expert at writing *Perpetua* only at the end. It took me quite a while before I discovered that there were two types of strategies, deletion strategies and smoothing strategies. If I was to write a second piece in the "style" of *Perpetua*, I would be able to use the skills intuitively, as part of my personal common practice.



Hypothesis 8: Learning by Designing

Tools take the designer into new design regions and new design regions necessitate the design of new tools.

Designing can be viewed as a kind of learning that moves in two directions. First, acquiring skill in the use of a tool means that there are many variants of the case for which the tool can be used. In Piagetian terms, the designer has assimilated the tool because he has constructed a stable

mental scheme linking the tool to many experiences. To say that a mental scheme is stable is to say that it operates at a subconscious level; what was rational has become intuitive. Second, by the designer having new tools that he can use intuitively, new kinds of rational thought becomes thinkable.

Hypothesis 9: Forms as Guides (Suchman)

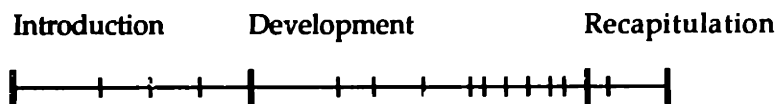
Design forms are not prescriptive but a way of keeping track of one's progress.

In *Perpetua*, the guiding plan was to introduce each of the four frames, produce varied mixes of frames in the middle, then bring the music to a close. The following chart shows the results of using this guiding plan to group frames into the three large parts of introduction, development and recapitulation.

Guiding Plan	Resulting Pattern of Frames	
	Frame	Duration in seconds
Introduction (Introduce frames)	1	32
	2	18
	3	18
	4	18
Development (Mix and vary frames)	1	32
	2	13
	4	18
	3	17
	1	5
	3	8
	4	8
	2	8
	1	5
	3	8
Recapitulation (Endgame)	4	8
	1	21

As part of the guiding plan, I also assumed that frame-cycle changes should speed up through the "development" section and slow down towards the end of the piece. The following graph provides a visualization of the actual rate of frame-cycle change over the duration of the entire piece. Dark hash marks divide the piece into its 3 sections. These dark hash marks plus the thin ones mark off the 16 points in time where frames changed (i.e., the points are given in the above chart).

(Dark hash marks are form parts. All hash marks represent frame change points.)



(Time moves from left to right in dots/second)

* * *

Next Morning is a piece within the suite *The Twins Who Forget Themselves*, including *Chin Music* and *Skeleton Man*, discussed later. The 40 measures of *Next Morning* found in example 6.12a-g are used to illustrate a number of design hypotheses. Regarding forms as guides, the sequence of solutions to *Next Morning* required a change in its form. Instead of being *through-composed* where one pattern leads to another, the sequence was re-organized into a *binary* form.¹

Through-composed

Revised Beethoven theme -> Harmonic Theme -> Harmonic Theme + Piano Arpeggios
(Counter-theme 1)

Binary

Revised Beethoven theme -> Harmonic Theme ->
(Counter-theme 1)

Revised Beethoven theme -> Harmonic Theme + Piano Arpeggios
(Counter-theme 2)



managing design complexity



artifact design

Hypothesis 10: Designing by Example (AI)

Designing does not happen in a vacuum but gets its start in previous design examples. Designing by example can promote user utility, depending on the example material.

Designing by example refers to the simple idea that a composer can take some previous pattern or idea and use it in the same way he would use *self-referenced* material (HYPOTHESIS 13). *Designing by example*, like *self-referencing*, is a way to avoid constructing problem settings from scratch.²

What follows are a few ideas that informed *Perpetua's* preliminary design. These ideas need not be recognizable to the listener. They were only conceptual aids for me. Notice that they also illustrate *design analysis* (HYPOTHESIS 4).

Subtractive Composition Influenced by the Tool

Perpetua used cut and paste operations available in the software environment in which it was written, *Performer* (by Mark of the Unicorn).

¹ According to Kinderman, Beethoven wrote two-thirds of the Diabelli Variations by 1819, set the work aside, and then finished it in 1823 when he added several new variations: variations 1 and 2, several new variations at the end and one new one in the middle. These additional variations imposed a new asymmetrical plan on the work, previously in a quasi-Sonata form (Kinderman).

² I recall Stravinsky's reply when asked whether he borrowed ideas from other composers: "I don't borrow ideas, I steal them".

Cyclic Thinking

In gamelan music the ensemble sound is produced by the interaction of repeating musical voices of unequal durations. Because voices have unequal durations they align differently as they repeat, producing dynamic results from static beginnings.

Minimalist Thinking

The minimalist composer Steve Reich uses a cyclic approach where material is added or subtracted from each voice at each repetition of the cycle, what he calls the *process of gradual change*. The cut and paste operations were used to support both cyclic and minimalist thinking.

Stravinsky's Start-and-Stop

Stravinsky frequently found it expressive to emphasize material by bracketing events in silences, or by drawing attention to the meter by making the downbeat less ambiguous.

The Opposition Aesthetics of African Drumming

In much African drumming rhythm one finds two simultaneous meters sharing a common pulse. The pulse and meters exhibit varying degrees of audibility. It is the possibility that a rhythm will be weaved between opposing meters that makes the silences so potent. I planned to use this kind of thinking to support Stravinsky's start-and-stop strategy.¹

Simplified Harmonic Thinking

In the simplest case, harmony can be defined as a pattern of scales, each related to the other by way of shared notes among scales. I intended to use frame-cycle changes to serve the functional role of harmonic modulation.

Of course, I was not planning to write gamelan or African music, nor was I planning to write in the style of Stravinsky. I was only interested in certain features of these musics as a means for selecting tools for my tool box.

* * *

In *Perpetua*, an idea common to all the smoothing strategies (used at junctions where frame-cycles changed) is the notion of a "pivot", taken from tonal music. *Pivot chords* are chords that have meaning in two different keys and are used for harmonic modulation. This traditional concept of a pivot was redefined. *Pivot* now meant any musical feature that could remain constant across frame-cycle changes.

* * *

I decided to tackle the problem of writing a melody for the harmonic theme in *Next Morning* (example 6.12c), what I call the Schoenberg² theme (example 6.12f). Trying to write a traditional western melody within an harmonically slippery context, I began to feel what I imagine

¹ The opposition aesthetic is about producing a chain of local tensions as in African drumming. In contrast, the resolution aesthetic is about building an arc of tension that is resolved at the end of the piece as in Western *common practice* writing.

² An invective:

The music of Schoenberg's Five Orchestral Pieces resembled the wailings of a tortured soul, and suggested nothing so much as the disordered fancies of delirium or the fearsome, imaginary terrors of a highly nervous infant.

London Globe, September 4, 1912; in Slonimsky

Schoenberg must have felt when he was inventing twelve tone music. Like Schoenberg, I used familiar rhythmic motives to promote familiarity.

Hypothesis 11: Rationalization

Local actions are justified in progressively global design frameworks. Decisions are justified to promote future action and not necessarily to explain past action.

Environment design is not only a precompositional activity; it continues concurrently with composing. For example, I did not know in advance the properties of *Perpetua's* four patterns (frames), nor did I know that there would be precisely four of them. I only knew that I wanted more than one and wanted them to share properties so there would be continuity during frame changes. Only after I worked by *trial and error* (HYPOTHESIS 14) on the first frame (example 6.6a) did I develop the constraints for frames 2 through 4 (examples 6.6b-d).

Frame Constraints of *Perpetua*

1. All frames are played by strings.
2. All frames share an underlying pulse of eighth notes.
3. Each frame is comprised of three voices; upper voice is mid-range, sixteenth notes; middle voice is sustained notes (dotted quarters) across the full range; lower voice is comprised of eighth note pizzicati across the full range. (See motivic design strategy.)
4. The middle and lower voices of all frames repeat in cycles of 12 and 5 eighth notes (respectively).

These constraints were *rationalized* using a description of the first frame. Similarly, I didn't formulate *Perpetua's* deletion or smoothing strategies as strategies until I tried some things out. Only trials that were successful were rationalized as general strategies.

Rationalizations are not explanations for why an action was taken, but how explanations of the result of previous actions may give structure to future action.

Hypothesis 12: Exception Principle (Minsky, Sloboda)

Defining exceptions is a way of rationalizing an inconsistency.

In *Perpetua*, I turned constraint 5 into an exception because I found patterns I liked in frames 2 through 4 (examples 6.6b-d) and saw no adverse consequences of violating the 7 eighth note constraint. Therefore, I relaxed the constraint.

Exception (A Relaxed Constraint)

5. The upper voice in frame one repeats in cycles of 7 eighth notes. The upper voice in frames 2 through 4 repeat in cycles of 6 eighth notes.

Hypothesis 13: Self-Referencing (Dahlhaus, Babbitt)

Self-referencing controls design management by making a previous design solution a setting for a new design problem. It can also promote user utility, depending on the material self-referenced.

Chin Music is a piece for synthesized *Chin* (a Chinese dulcimer-like instrument) for piano and harp (example 6.7). It is a member of a suite called *The Twins Who Forget Themselves*, a children's drama with a narration written by Chris Cleary.

Chin Music provides examples of *self-referencing*, a general method for using a previous solution as the setting for a new design problem. In self-referencing, the composer takes some *source* material (i.e., previously written material), copies it to a new place, then changes some of its features to make it different.

In example 6.7a, the three staves show a sequence of self-referenced design actions. The first staff (measures 1 and 2) shows the notes [D A D]. This pattern is so general that one could be reminded of a large variety of pieces. However, I was trying to write a *generic* oriental theme (HYPOTHESIS 22) and wrote these notes as a way of outlining a non-triadic harmony. The middle staff used the upper one as a setting for adding contour definition. The lower staff used the middle one as a setting for adding ornamentation.

Self-referencing was also used to produce measures 3-4 from measures 1-2 (in example 6.7b). Notice that the lower staves in measures 1 and 3 have exactly the same rhythms and almost the same notes. The 32nd notes in measures 1 and 3 and the musical scale (expressed by the 16th notes in measure 2) give clues that this section attempts to imitate oriental melodies. Another clue is timbral and not shown: namely, the synthetic version of the *Chin* used to play the melody.

* * *

Obviously, self-referencing cannot work when a piece is just beginning to be written since there is no source material to reference. This is when *designing by example* (HYPOTHESIS 10) can be useful. For example, whatever I might have meant by the idea of an "oriental theme" in *Chin Music* (example 6.7) drew from my *generic* memories (HYPOTHESIS 22) of oriental music.

* * *

In *Next Morning*, the revised Beethoven theme (example 6.12a) was used as the problem setting for the counter-theme found in example 6.12b. Because it is *simple*--i.e., lacks many musical attributes--I was free to add attributes to the counter-theme without conflict problems. I kept the meter and key constant but shortened the phrase parts (from one phrase per measure to two), wrote an accent pattern by emphasizing the weak beats of each measure (beats 2 and 4) with pickup eighths, and wrote an angular contour for the melody.

Hypothesis 14: Trial and Error (Newell and Simon)

Trial and error often works because trials are restricted to choices that are acceptable if not equally satisfactory.

It is easier to self-reference and eliminate or change constraints than to construct constraints from scratch. With sufficient constraints (HYPOTHESIS 15), a designer can explore the remaining options using trial and error. For example, I did not formulate *Perpetua's* methods of variation, the deletion and smoothing strategies (see hypothesis 2), until I heard the consequences of cut-and-paste operations on the repeating patterns. The patterns gave me a simple musical object on which to perform these experiments.

Hypothesis 15: Freedom Through Restrictions (Sloboda)

A designer is more (not less) free because he restricts his design choices to a manageable few.

Designing is inherently a serial process that has to act on an inherently parallel product. This cognitive "bottleneck" is overcome by the designer recursively "freezing" most aspects of the design and exploring what remains "unfrozen" using trial and error (HYPOTHESIS 14). Self-referencing (HYPOTHESIS 13) is one "freezing" method; designing by example (HYPOTHESIS 10) is another.

The background examples to *Perpetua* (see hypothesis 10) provided broad environment design boundaries. These examples helped me to decide what I would or would not think about. The gamelan idea suggested that, once pattern-frames were constructed, I could not add notes, only subtract them. The cut-and-paste tools also played a restricting role. The deletion and smoothing strategies suggested that musical motives would be emergent rather than planned. They dictated an operational notion of "musical development".

Hypothesis 16: Confidence Building (AI)

A designer examines the productivity of the restrictions he imposes on his design process. Design restrictions are less provisional the more previous solutions depend on them.

Restrictions are only useful if they are productive restrictions. Since the designer does not necessarily know beforehand whether a restriction will be productive, he is simultaneously evaluating and using it.

For example, *self-referencing* (HYPOTHESIS 13) might be thought of as a means for constructing a compositional "playpen" in which the composer explores possible solutions using *trial and error* (HYPOTHESIS 14). While operating within the playpen, its restrictions are non-negotiable. Confidence in the playpen is strengthened or weakened while examining its productivity on the emerging artifact.

Hypothesis 17: Judging Fit (Alexander, Sloboda)

In judging fit, the designer decides which of the conflicting constraints to preserve or ignore. Fit is a constraint prioritization—activity.

Alexander says that a designer removes factors that lead to misfit; and Sloboda says that a composer tightens or loosens constraints to achieve fit. Since there are often different ways to achieve fit, this process requires a ranking of factors or constraints so that those ranked lower are removed or relaxed first (chapter 5).

In the Spanish section of *Chin Music* (measures 15-18, example 6.9), the melody takes a surprising turn. Somehow, the ornamentation I was using reminded me of Spanish music. While this genre shift seemed musically inappropriate, I liked the section too much to get rid of it and hoped to find a way to eventually *rationalize* its presence (HYPOTHESIS 11).

In measures 15 and 17 of the Spanish section (example 6.9) the reader will notice that the durations of the notes in the Beethoven theme (the lower staff) have been shortened in order to 'fit' the articulation pattern dictated by the Spanish theme. Normally, the Beethoven theme had the articulation pattern found in measures 16 and 18.

I did not arbitrarily select a variation method from my "tool box". The Spanish and Beethoven themes did not fit together because of articulation differences. The remaining choices were so few that I could examine them using *trial and error* (HYPOTHESIS 14). I decided that the Beethoven theme had to fit the Spanish theme and not the other way around.

Hypothesis 18: Strategic problem design (Newell and Simon)

Sometimes designers design well-defined problems.

In *Perpetua*, frame 4 (example 6.6d) has the most notes of all the frames. The notes in frame 4 can be grouped into two smaller groups of notes harmonically more coherent than the larger group. In thinking about how I would combine frames, I started to use frame 4 as a preparatory frame functionally similar to the dominant 7th chord in traditional harmony; indeed, a move from frame 4 to frame 1 could actually be written as a dominant-tonic (V-I) cadence: [C# F G# B] -> [F# A# C#].

* * *

The first four notes of the harmonic theme in *Next Morning* (example 6.12c) have the same contour as the revised Beethoven theme (example 6.12a). The problem I set for myself was to produce triads, descending stepwise.¹ This plan would *force* harmonic modulations away from D minor (the musical key of example 6.12c). The "goal" was to find a way back to D minor at the end of the subsection. In this way, the resulting pattern would dovetail with all previously written patterns beginning in D minor. By keeping pathways open, I could link any of the previously written patterns at whim.

Hypothesis 19: Redesign Strategy

A designer anticipates problems and develops debugging strategies for dealing with them.

Once the harmonic theme in *Next Morning* (example 6.12c) was written I found the result pleasing but not intense enough to support the scene the music accompanied. Since I had already worked out the chords for the harmonic theme, it would be easy to write arpeggios, *restricted* by the chords (HYPOTHESIS 15), to produce a "rumbling" effect. I gave these arpeggios to the low register of the piano (example 6.12d). I could now use the harmonic theme and then repeat it with

¹ Notice that the descending triads would continue to descend (measures 3 and 5, in example 6.12c) if I had not re-written them an octave up at these points.

the piano arpeggios for a climactic ending of the scene. One might say that the "goal" of redesign was *prolongation* (HYPOTHESIS 30).¹

Hypothesis 20: Working Backwards (Newell and Simon)

By starting with a recognizable solution, the designer can build confidence in what the design problem is about.

At one point in the design of *Next Morning*, I had two counter-themes for the revised Beethoven theme (examples 6.12b and 6.12e) and two patterns for the harmonic theme (examples 6.12d and 6.12f). Some problems remained. There was not enough continuity between the higher-register melodies and the final arpeggios in the low register of the piano (the rumbling sounds). I decided to take the notes on the strong beats of the piano arpeggios and write them as "pounding" half notes (example 6.12g) that would anticipate the arpeggios (example 6.12d). In other words, I wrote last what is heard first (i.e., worked backwards) again with the "goal" of prolonging the time to the climax.



promoting user utility

Hypothesis 21: Evaluating Interpretability

A designer evaluates his emerging product from the point of view of the observer.

In *Perpetua* (example 6.6) I knew that I would need strategies to "sculpt" the music. However, it wasn't until I listened to the unedited cyclic frames that it struck me how monotonous they could become for the listener. Listening AS-IF one is an interpreter is an unconscious way to recognize that there is a problem, beginning a process of groping for possible solutions.

Hypothesis 22: Generic Constructs (Schank)

A designer can promote certain associations by providing generic constructs, themselves mentally constructed from anticipatory and anthropomorphic listening.

Example 6.8 is *designing by example* (HYPOTHESIS 10) using generic constructs, "compiled" from either anticipatory or anthropomorphic listening. The upper voice in measures 1-4 is the oriental melody just described. The lower voice was produced by keeping the perfect 5th (i.e., note A) fixed while writing the lower voice (as Beethoven did in his 5th symphony).

¹ Notice that, by having the "goal" of prolongation, this skill has the objective of promoting user utility.

Hypothesis 23: Serendipity

Serendipity is a rationalization process in which an accident is turned into an opportunity through the construction of a new design context.

In *Chin Music*, the articulation change in the Beethoven theme (lower staff, in example 6.9) made the Spanish theme (upper staff, in example 6.9) less inappropriate, but not entirely satisfactory. The eventual fix was to make reference to the Spanish theme in *Skeleton Man* (example 6.10), a piece for guitar and piano that is one of the suite of pieces that make up *The Twins Who Forget Themselves*. Notice the resemblance of the beginning measures of *Skeleton Man* to the Spanish section (example 6.9).

Example 6.10 illustrates how a crisis can be turned into an opportunity. A listener may think I was clever to have planned this unexpected sequence of events. What he will not know from listening is that I made the connection between *Chin Music* and *Skeleton Man* in order to rationalize (HYPOTHESIS 11) what I perceived as a *interpretive consistency error* (HYPOTHESIS 25).

In the *Skeleton Man* I do not try to hide Spanish musical qualities; rather, I make the music more Spanish-like by producing more *generic* Spanish music (HYPOTHESIS 22) in the accompaniment.

Hypothesis 24: Reconstructing the Interpretive Context

A context is comprised of the particular attributes of a particular span of musical time. Since a composer constructs both, he can reconstruct the interpretive context to achieve unanticipated goals.

I did not change the Spanish theme in *Chin Music* (example 6.9) but produced a new context, example 6.10, in which that theme became meaningful; I extended the interpretive time-span. This design strategy is possible because each musical element can be viewed as operating within a number of spans of musical time. As the composer I am the builder of these spans of time and can correct problems found within one time span by producing solutions within a different, more inclusive, time span.

Consider this pedestrian example. Most people I know have been in the publically embarrassing situation of misjudging their distance from a table or wall, placing their elbow on a virtual rather than real table, or leaning against a virtual rather than real wall. To save face in such a situation, one might reach for one's shoe in the first case or move gracefully in the direction of the virtual wall in the second. If one is lucky, observers will miss the accident which, by itself, defines a narrow time span; instead, observers will notice the more inclusive time span that defines a (seemingly) purposeful action.

Context reconstruction demonstrates that there are crucial differences between the inductive processes of composition and the reductive processes of analysis. The analyst will be able to see and hear the relationship between the *Skeleton Man* music and the Spanish theme. What is opaque to the analyst: is the *rationalization process* (HYPOTHESIS 11) that led to this relationship.

* * *

Below are two outlines of the 40 measures of *Next Morning* (examples 6.12a-g). The first outline shows the order in which the parts of *Next Morning* are heard. The second outline shows the order in which they were written. This also demonstrates the opacity of design process knowledge from the perspective of the analyst.

First Outline

In *Next Morning*; the order in which the parts are heard

measure 1	Revised Beethoven theme Counter-theme 1
measure 10	Harmonic theme and its base line
measure 18	Revised Beethoven theme Counter-theme 1 (an octave lower) Counter-theme 2
measure 26	Harmonic theme with its base line Schoenberg theme "Pounding" half-notes anticipating piano arpeggios
measure 33	Harmonic theme with its base line Piano arpeggios
measure 40	climax

Second Outline

In *Next Morning*; the order in which the parts were written

measure 1	Revised Beethoven theme
measure 1	Counter-theme 1
measure 10	Harmonic theme and its base line
measure 33	Piano arpeggios
measure 18	Counter-theme 2
measure 26	Schoenberg theme
measure 18	Counter-theme 1 placed an octave lower
measure 26	Bass line anticipating arpeggios

Hypothesis 25: Empirical Consistency

As a piece increasingly refers to itself, it becomes its own musical world. If design reasoning is consistent, a listener can use empirical methods to infer the reasoning from the observable patterns.

In *Next Morning*, the first measure of the Beethoven theme (found in example 6.12a) was compressed into the first half of the measure of the revised Beethoven theme. This was done by eliminating the Beethoven theme's first note in the first measure and dividing the duration of its last note in the second measure by half.

Once the first half of the first measure of the revised Beethoven theme was written (example 6.12a), it served as a model for the second half of the measure. Similarly, once the first measure of the revised Beethoven theme was written, it served as a model for the next measure, and so on. This recursive process, characteristic of *self-referencing* (HYPOTHESIS 13), results in patterns that

increasingly refer to each other. As self-reference becomes more abundant, the interpreter has many opportunities to recognize the "laws of invariance" (as Piagetians would say) that are shared among referenced patterns.

Hypothesis 26: Pattern Masking

A pattern becomes more difficult to recognize if some of its features are made inaudible.

Hypothesis 27: Cognitive Masking

A pattern becomes more difficult to recognize if a concurrent pattern competes for the listener's attention.

Hypothesis 28: Establishing Patterns (Meyer)

Repetition is the primary method used to establish pattern.

Meyer suggests that "one of the most effective ways of emphasizing that an event is ended, is to begin it again (Meyer. 1973. p. 52). Repetition is the primary method used to establish patterns, a prerequisite for hiding them in the game of *hide and seek* (HYPOTHESIS 36). Since a musical pattern is complex and comprised of many kinds of features (e.g., notes, rhythms, dynamics, tone color, articulation, etc.) each feature can repeat independently of each other. Meyer uses the word *congruence* to refer to situations when many features repeat together, and *noncongruence* to refer to situations when many features do not repeat together (Meyer. 1973. p. 121). We can say that a musical pattern will be more mentally constructable (Piaget) the more congruent are its pattern elements (Meyer).



promoting user utility



anticipatory listening

Hypothesis 29: Anticipatory Listening (Meyer)

A designer can provide recognizable conventions with predictable interpretations.

The *Boat Made of Light*, for doubled flutes and bells (example 6.11), is one of the pieces in *The Twins Who Forget Themselves*. It illustrates anticipatory effects. The unexpected B-natural in measure 3 causes a harmonic modulation. It is "slippery" (like water) because the modulation is too brief to establish itself in the mind of the listener.

* * *

In *Next Morning* (example 6.12) I decided to write counter-theme 1 (example 6.12b) an octave lower and use it to precede the pounding half-notes. This made it possible for me to shift the music gradually from the beginning high register to the ending low register (to produce the anthropomorphic effect of tumbling downward). I now had enough material to prolong the time preceding the climax so that I could consolidate counter-themes 1 and 2 into one pattern rather than arrange them one after the other.

Hypothesis 30: Prolongation strategy

An expectation can be prolonged or shortened to regulate musical intensity.

The music in *Next Morning* (example 6.12) moved too quickly from the revised Beethoven theme (example 6.12a) to the ending arpeggios (example 6.12d). There was not enough time for the listener to consider the impending disaster. I decided to return to the revised Beethoven theme to write a second counter theme (example 6.12e). This started a sequence of new designing, including the Schoenberg theme (example 6.12f), a simple and throbbing base line (example 6.12g), and form and orchestral changes. These changes were all designed to prolong the time to the climax and, thus, heighten listener expectations.

Hypothesis 31: Conventional Consistency

Empirical consistency is easiest when patterns are modified using familiar conventions.

Anxiety is a piece for string orchestra (example 6.13). It is one of a suite of pieces called *Film Music*. *Anxiety* is comprised of a number of short patterns that only change in the way they are sequenced or layered. Patterns 1-4 (examples 6.13a-d) are usually found temporally near each other. Pattern 2 (example 6.13b) is often repeated a few times to prolong the listener's expectation of change. Because the passage of time marked by each repetition evokes different expectations the "same" pattern is not the "same" pattern from a psychological perspective. Because repetition is a conventional method for *establishing patterns* (HYPOTHESIS 28), it is easy to use it to shape expectations.

Pattern 4 (example 6.13d) is the most esoteric, being a measure of silence. When pattern 4 appears, the listener expects one of the patterns from 5-10 to follow it (examples 6.13e-i). The *unconscious question* the listener asks himself is "what are the options?".

Meyer says that part of listener interest is based on what was possible as well as what actually happened. The informed observer evaluates future options much like a viewer evaluates options during a baseball game. Most foreigners who are unfamiliar with the game of baseball find it extremely dull. If one looks at baseball from their perspective one can see why. Much of the excitement of the game happens between (not during) plays and comes from the viewer understanding the likely future options of play given the current situation. One knows that a runner on third base will have different reasonable options depending on his speed, the number of outs, the inning, whether his team is winning or losing, and who is pitching (e.g., whether he is a right or left hander). For a foreign observer these options are not obvious. For a native, these options are inferred from the conventions of play.

In *Anxiety*, the listener cannot know in advance that pattern 4 (example 6.13d) will lead to one of the patterns 5-10 (examples 6.13e-j). Only if this happens a number of times can the observer infer the rule from the action. What is conventional is the inference construction process, not the particular inference. Patterns of inference are mentally constructed through repetition as are

musical patterns, illustrating the general role of *empirical consistency* (HYPOTHESIS 25) in helping the listener to identify the reasoning that links patterns to each other.

Hypothesis 32: Regulating Ambiguity (Mandler)

A composer can regulate musical ambiguity to produce expressive effects.

City of Storms (example 6.14) is a suite of pieces for chamber orchestra that accompanies a children's story written by Chris Cleary. In the introduction to *City of Storms* (example 6.14a), the top two lines are played by woodwinds and the bottom line is played by the harp. The down beat ambiguity in the introduction (example 6.14a) is produced by delaying in the middle voice the two-note patterns found in the upper voice. Recall from Mandler that *ambiguity* results from the presence of at least two plausible interpretations, or the hint that an alternative interpretation may be required (chapter 2). For example, the upper voice in example 6.14a suggests that the first F# (circled) is a pickup. However, if we imagine that the two upper voices are shifted left two-thirds of a beat, the first F# in the middle voice (also circled) would be the pickup. A listener without access to the written score may not be able to tell which of the two Fs are the pickup.

Voices one and two provide a pure case of ambiguity. However, the lower voice "tips the scale"; its downbeat notes (F# and D) suggest that the F# in voice 1 is a pickup. The lower voice reduces the ambiguity, illustrating how interpretive ambiguity can be regulated during the design process.

* * *

In measure 21 of *City of Storms* (example 6.14b) the melody has changed. For the first time there is something that resembles a conventional melody. The middle voice retains the descending contour of the introduction. Most of the listener's attention is drawn to the lower voice (played by the piano). This voice defines a contour pattern that is repeated in measures 22 and 23. These repetitions prepare the listener for the anticipatory effect of measure 24 (the ascending notes in the lower staff, in example 6.14c). Measure 24 is anticipatory because a new contour is introduced, breaking the pattern of contours established in measures 21-23 (example 6.14b). Measure 24 also introduces a crescendo, a second clue that intensifies the expectation of change.¹

¹ Prolongation, in Schenker's sense, works not because there is more time between the expectation and its satisfaction but because there is more evidence to support the expectation. Time is a side-effect of establishing the evidence.



promoting user utility



anthropomorphic listening

Hypothesis 33: Anthropomorphic listening (Malm)

A pattern can have an analog in reality.

Recall Malm's idea of "word painting" in chapter 2. A musical pattern can serve as an analog to a non-musical scene by mimicing its manner of operation. For example, the melodic texture of the whole passage of *The Boat Made of Light* (example 6.11) is a metaphor for a rowing boat. Notes on the first beat are accented and usually high to represent a rowing stroke, while notes on the second beat are unaccented and usually low to represent a glide. The echoing effect in the upper voice is supported by an undulating pattern in the lower voice that rises like a wave.

* * *

Measure 25 in the introduction to *City of Storms* (example 6.14c) provides a mild climax, the "goal" of the anticipatory effect prepared by the lower voice in measures 21-24 (6.14b). Measures 25-26 produce an anthropomorphic return to the material in the introduction. The cascading piano line (in lower voice) recedes into the background like water falling off of a roof into an undifferentiated puddle.

Hypothesis 34: Patterns as Actors (Maus)

Thinking of patterns as actors helps to animate musical abstractions.

In *Anxiety*, patterns 5 and 6 (examples 6.13e-f) come closest to being melodies as we commonly know them. My intention was to produce two melodies that have about equal complexity (e.g., in rhythmic and contour content) so that when they would appear together, the listener would be inclined to divide his attention between them (HYPOTHESIS 27), much as an observer might divide his attention between two actors in conflict.

I used pattern 5 (example 6.13e) as the problem setting for pattern 6 (example 6.13f), an example of *self-referencing* (HYPOTHESIS 13). In this way, I was sure that the two melodies would "fit". In this specific problem, *fitness* meant that the two melodies would operate within the same scale and meter, and notes appearing at the same time would not be intervallically too close too long (HYPOTHESIS 17).

Fitness was not enough. Because I wanted each of the two melodies to compete for the listener's attention, I needed each to have features that distinguished it from the other. I needed them to have different "personalities" and function as distinct musical "actors". Pattern 5 was written first and had an ascending part followed by a descending part for the first two measures and again for the second 2 measures. Pattern 6 needed to have different features than pattern 5 without violating fitness. My particular solution was a meandering contour in the middle range for the first two measures and then a burst of 3 syncopated rhythms with leaping contours in the last two measures.

The first time patterns 5 and 6 appear together are in measure 68. In a sense, combining the two melodies into a duet was the musical "goal", a kind of climax. The design problem was to work *backwards* from this goal (HYPOTHESIS 20), *establishing* each of the melodies separately (HYPOTHESIS 28) before having them sound together.

Hypothesis 35: Musical staging (Cone)

Familiar background patterns can quickly establish mood.

In *Anxiety*, patterns 7-10 (examples 6.13g-j) can be thought of as examples of how the musical accompaniment serves the dramatic role of *stage direction* (Cone, p. 11). The slowly anxious motion upward of pattern 7, the ticking clock rhythm of pattern 8, the uncommittal quality of pattern 9, and the nervous tremolos of pattern 10 are all familiar types of patterns--*generic constructs*, HYPOTHESIS 22-- for establishing mood.

Musical background, which may include *ostinati* or secondary themes, plays an important role in establishing the interpretive context. The same melody with a different background or a different melody with the same background will be heard differently.

* * *

In the introduction to *City of Storms* (example 6.14a), there are a number of factors that are used to express its dark and rainy mood: the minor key (B minor), percussive attacks of the harp, the tempo (dotted quarter = mm of 90), and the descending contours of the patterns. These all produce musical staging effects.

Hypothesis 36: Hide and Seek (Reti, Piaget)

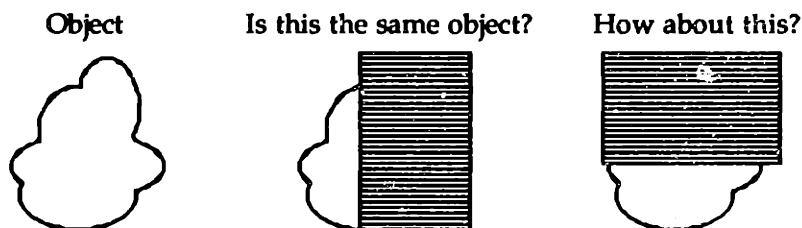
Hide and Seek is a general strategy of regulating patterns of recognition difficulty using different masking strategies.

Recognition difficulty can be achieved either by *masking* elements of the melody with other patterns (HYPOTHESIS 26), or by introducing counter-melodies that are equally interesting and, therefore, *compete* for the listener's attention (HYPOTHESIS 27). Together, these strategies are used in a game of *hide and seek* the composer plays with the listener.

Melancholy (example 6.15) illustrates the use of hide and seek. It a passacaglia for strings and part of a suite of a pieces called *Film Music*. A *passacaglia* is a variation form popular in the Baroque period. It is usually in triple meter, usually slow and usually does not use harmonic modulation. In addition, some patterns (e.g., chords, the base line, a melody) are repeated unchanged throughout the duration of the work. The challenge for a composer using this form is to keep the music interesting in spite of these constraints. In *Melancholy*, what stays constant is the 8-bar melody (example 6.15a). To keep the music interesting I introduced accompanying material that makes the recognition of the melody more or less difficult each time it repeats.

The game of hide and seek is taken from Reti's book *The Thematic Process of Music* where he describes how motivic elements are manipulated to produce different kinds of thematic

associations. It can be explained by two ideas of Piaget's, his notions of object permanence and interest. Pattern recognition first requires that the observer has constructed (and retained) a mental representation of an object before it is hidden, Piaget's *object permanence*. In addition, events are more interesting the more ways we can think about them, Piaget's *interest*. One might say that variation methods are ways of making object recognitions difficult, and interesting when they succeed.



In *Melancholy's* examples 6.15a-b, the game of hide and seek begins by *establishing* the primary melody (HYPOTHESIS 28) in the listener's mind. The piece is clearly in triple meter and marks off the strong beat at the beginning of each measure.

At measure 9 (example 6.15c), a pattern is used to draw attention away from the melody. It *competes* with the primary melody (example 6.15a) because it is relatively fast and distinctively *syncopated* (i.e., starting and ending on weak beats). In addition, because the general rhythm and contour of the counter-pattern (example 6.15c) repeats every four notes, it is quickly *established* in the listener's mind (HYPOTHESIS 28).

The pattern starting on measure 17 (example 6.15d) is a mixture of *masking* and *competitive* strategies (HYPOTHESES 26 and 27). It competes with the primary melody by proceeding in easily recognizable descending eighth notes. One might also argue that the descending contour provokes a new expectation—"what goes down must come up"—and this draws attention away from the primary melody. When the contours of the two melodies cross each other, they produce masking effects. This is especially true in *Melancholy* where all the instruments are strings. For this reason, not only the notes but the harmonic spectra overlap, producing contour ambiguities.

In the pattern starting on measure 25 (example 6.15e), I needed to enlist several instruments. In this pattern I use what I call the *edge heuristic* which says that listeners usually recognize the lowest and highest sounds first, the musical "edges". The two voices in these pattern serve as these edges. In addition, neither voice begins on strong beats in contrast with the "on-the-beat" regularity of the melody. Even though I was comfortable with the edge heuristic, the added syncopations persuaded me that the pattern would *compete* with the melody (HYPOTHESIS 27).

There is a new competition at measure 33 which combines the last two effects (examples 6.15d and 6.15e). The listener has heard both of these patterns separately and would find them less effective if re-introduced alone. Together, they produce a new recognition challenge.

The pattern starting on measure 41 (example 6.15f) and measure 49 (example 6.15g) are close variations of each other. These two 8 bar phrases can be heard as one 16 bar compound pattern that has more time to establish itself as a pattern and is, therefore, more competitive. It is like the main melody whose beats are also subdivided into triplets. However, unlike the main melody, the 16 bar compound pattern often starts on weak beats. Weak and strong beat competitions hide the downbeat and increase recognition difficulty.

The patterns used next are less competitive than those just described. In measure 57 (example 6.15h), I introduce a syncopated rhythm and re-use the competing pattern that began in measure 9 (example 6.15c).

In measure 65 (example 6.15i), I give the base line a simple pattern and introduce an upper voice pattern whose rhythm is synchronized with the melody.

The reason I made the last two patterns less competitive than the previous ones was to regulate the degree of recognition difficulty for the listener over the duration of the whole of *Melancholy*. Recall that in a passacaglia, harmonic modulation cannot be used to construct musical directionality. In its place I decided to make melodic recognitions more difficult to make as the composition proceeded, and less difficult to make at the end. The game of hide and seek served as tension-producing surrogate for harmonic modulation.

Hypothesis 37: Subconscious listening (Reti)

We give familiar patterns that do not change less of our conscious attention. Because we are able to notice them when they do change, we have not forgotten them, but attend to them subconsciously.

Hide-and-seek is embodied in Reti's notion of *subconscious listening*. For him (as well as Meyer), a musical pattern is first recognized on the conscious level through repetition. Once the composer has established the pattern in the listener's mind, he can remove or re-introduce salient features to make it more difficult to recognize. Nothing new so far. What is slightly new is the intended effect of these strategies. By regulating recognition difficulty the composer can attempt to make patterns recede into or emerge from the background of the interpreter's musical thought (Reti, p. 47).

Subconscious effects are achieved by background writing. At first, a background is actually in the foreground. The listener consciously attends to it to identify mod. However, once this purpose has been achieved and the pattern has become firmly established, subconscious listening says that it recedes into the background.

No work illustrates these psychological effects better than Alban Berg's *Wozzeck*.¹ On almost every page of the score one observes a pool of recurring and transforming motives. Specific motives

¹ An invective:

Alban Berg painstakingly avoids every natural manner of expression; the abstruse is his exclusive domain..Nothing must be in tune, or in the sense of people with normal perception, sound well;

representing characters, bonds or moods become more or less audible as the psychological twists and turns of the drama unfold [See Appendix E: On Berg's *Wozzeck*].

Wozzeck is a particularly difficult piece to follow even for experienced listeners. What makes a background easier to recognize than a twelve tone motive is the number of associations on which it can draw. Making these same associations with twelve tone motives is likely to increase recognition difficulty since in twelve tone pieces like Berg's *Wozzeck*, the listener is expected to restrict himself to associations that have been constructed within the body of the work. More listening effort (and learning) is required during the interpretive process. Berg tries to address this problem by conventionalizing twelve tone writing within the body of *Wozzeck*, and by connecting music and drama. While these strategies reduce listening effort, they do not eliminate it.

* * *

In some ways the hypotheses in this chapter were suggestive of the architectural pattern language of Alexander *et al* (chapter 4). The collection of skills serve as a prototype of a theory of design with each skill linked to a design case and its variants. However, the important difference is that Alexander *et al* focus on fully developed design expertise. My approach emphasizes the role of learning in designing, and how artifact design gives rise to the construction of tools, new skill through the use of new tools, and the construction of skill management systems through environment design.

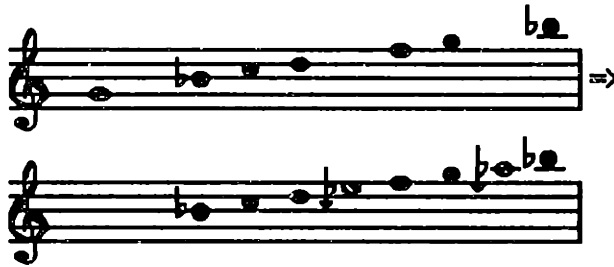
In the next chapter I will use the hypothesized skills as a labelling device for design cases produced by five other composers. Readers will see that many of the skills and all of the perspectives that have been introduced are observable in these composers' processes. Readers will also see that there are new insights that were missed in the self-reflective study.

everything must be rhythmically complicated, harmonically queer and perverse. Whether one sings or plays wrong notes in such an insalubrious style, is utterly immaterial.
Leopold Schmidt, *Neue Freie Presse*, Vienna, December 15, 1925; in Slonimsky

Music Examples

6.1

Old style pentatonic scale:



New style quasi-major/mixolydian scale:

6.2

E-pentatonic:



E-Dorian:



E-Phrygian:



6.3

E-pentatonic:

(symmetry)



m3 M2 M2 m3

6.4

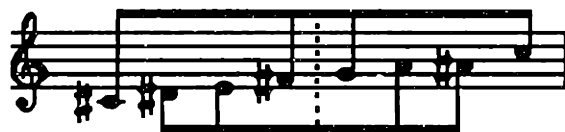
Permutating a symmetrical note cell:

P4 m2 P4 m2 P4 m2



6.5

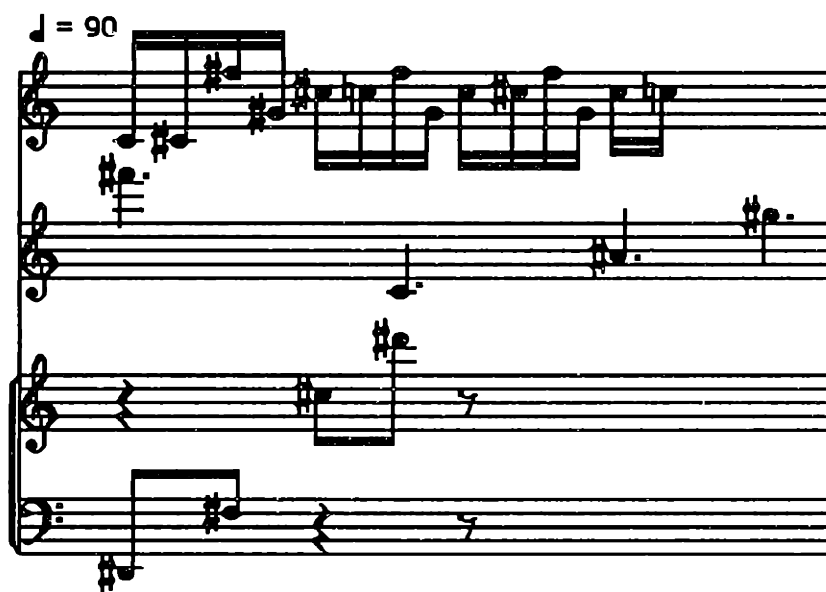
Eight-note scale formed by joining two tone cells:
tone cell 1 *axis of symmetry*



tone cell 2

6.6a

Frame 1



Notes used in frame 1:



Rhythmic cycles found in frame 1: 7 eighths, 12 eighths, 5 eighths

6.6c

Frame 3

♩ = 90

Musical score for Frame 3, showing four staves of music. The tempo is marked as quarter note = 90. The score includes a treble clef, a key signature of one sharp (F#), and a 3/4 time signature. The music consists of a melody in the upper staves and a bass line in the lower staves. The melody is composed of eighth and sixteenth notes, while the bass line features a steady eighth-note accompaniment. The entire frame is enclosed in a dashed rectangular box.

Notes used in frame 3:

Musical notation showing the notes used in frame 3. The notes are: F#4, G4, A4, B4, C5, D5, E5, F#5, G5, A5, B5, C6.

Rhythmic cycles found in frame 3: 6 eighths, 12 eighths, 5 eighths

6.6d

Frame 4

♩ = 90

Notes used in frame 4:

Two groups of notes from frame 4

Rhythmic cycles found in frame 4: 6 eighths, 12 eighths, 5 eighths

6.7a

Beginning of oriental theme in *Chin Music*; the inductive steps in producing the theme:

6.7b

Continuation of *Chin Music* using measures 1-2 (above) as the problem setting:

Measure 3 Measure 4

6.8

Using oriental theme as a problem setting for the Beethoven theme; in *Chin Music*:

Measure 1 Measure 2

Beethoven Theme; characteristic of keeping "accompaning" note constant:

Measure 3 Measure 4

6.9

Oriental theme replaced temporarily by Spanish section; in *Chin Music*:

Measure 15 Measure 16

Detailed description: This musical example shows two measures of music. The top staff is in treble clef and the bottom staff is in bass clef. The time signature is 3/4. In measure 15, the melody in the treble clef features a triplet of eighth notes. The bass line consists of quarter notes and eighth notes. In measure 16, the melody continues with another triplet of eighth notes. Dynamics are marked as 'f' in measure 15 and 'mf' in measure 16. The bottom staff has a dynamic marking of 'mp' (mezzo-piano) in measure 16.

Articulation and dynamics of Beethoven theme modified to fit spanish theme

Measures 17-18 automatically inherit the constraints of measures 15-16:

Measure 17 Measure 18

Detailed description: This musical example shows two more measures of music. The top staff is in treble clef and the bottom staff is in bass clef. The time signature is 3/4. In measure 17, the melody in the treble clef features a triplet of eighth notes. The bass line consists of quarter notes and eighth notes. In measure 18, the melody continues with another triplet of eighth notes. Dynamics are marked as 'f' in measure 17 and 'mf' in measure 18. The bottom staff has a dynamic marking of 'mp' (mezzo-piano) in measure 18.

6.10

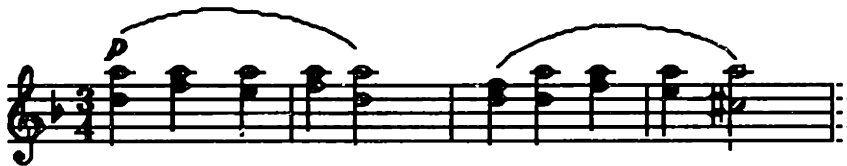
Skeleton Man; related to the Spanish theme:

Measure 1 Measure 2

Detailed description: This musical example shows two measures of music. The top staff is in treble clef and the bottom staff is in bass clef. The time signature is 3/4. In measure 1, the melody in the treble clef features a triplet of eighth notes. The bass line consists of quarter notes and eighth notes. In measure 2, the melody continues with another triplet of eighth notes. The bottom staff has a dynamic marking of 'f' (forte) in measure 1.

6.12a

Beethoven theme in *Chin Music*:



Revised Beethoven theme; in *Next Morning*:
(appears first in m1; again in m18)



6.12b

Counter-theme 1 for Beethoven theme, in *Next Morning*:
(appears first in m1; again in m18 an octave lower)



6.12c

Harmonic theme and base line; in *Next Morning*
(appears first in m10; again starting at m26 and m33)

6.12d

Piano arpeggios, in *Next Morning* (appears in m33):

Musical score for piano arpeggios in *Next Morning*, measures 33-36. The score is written for piano in 4/4 time. The upper staff (treble clef) features a series of arpeggiated chords, with a dynamic marking of *fff* (fortississimo) at the beginning. The lower staff (bass clef) provides a harmonic accompaniment with similar arpeggiated figures. The key signature has one flat (B-flat major or D minor).

6.12e

Counter-theme 2 for Beethoven theme; in *Next Morning* (appears first in m18):

Musical score for counter-theme 2 for Beethoven theme in *Next Morning*, measures 18-21. The score is written for piano in 4/4 time. The upper staff (treble clef) shows a melodic line starting with a dynamic marking of *mf* (mezzo-forte). The lower staff (bass clef) provides a harmonic accompaniment. The score includes dynamic markings of *cresc.* (crescendo) and *dim.* (diminuendo). The key signature has one flat.

6.12f

Schoenberg theme, in *Next Morning* (appears in m26):

Musical score for Schoenberg theme in *Next Morning*, measures 26-29. The score is written for piano in 4/4 time. It consists of three staves (treble clef). The upper staff begins with a dynamic marking of *f* (forte). The music features a complex, rhythmic pattern with many sixteenth notes and rests. The key signature has one flat.

6.12g

Bass line anticipating piano arpeggios, in *Next Morning* (appears in m26):

Musical score for bass line anticipating piano arpeggios in *Next Morning*, measures 26-29. The score is written for piano in 4/4 time. The lower staff (bass clef) shows a bass line with a dynamic marking of *f* (forte) at the beginning. The line includes accents and dynamic markings of *cresc.* (crescendo) and *ff* (fortissimo). The key signature has one flat.

6.13a

Anxiety, Pattern 1 (appears first in m1):

Musical notation for Pattern 1 in 4/4 time, measures 1-2. The treble clef staff contains a half note G4, a quarter note A4, a quarter note B4, and a quarter note C5. The bass clef staff contains a half note G2, a quarter note A2, a quarter note B2, and a quarter note C3. A dashed box encloses the first two measures.

6.13b

Anxiety, Pattern 2 (appears first in m3):

Musical notation for Pattern 2 in 4/4 time, measures 3-4. The treble clef staff contains a half note G4, a quarter note A4, a quarter note B4, and a quarter rest. The bass clef staff contains a half note G2, a quarter note A2, a quarter note B2, and a quarter rest.

6.13c

Anxiety, Pattern 3 (appears first in m6):

Musical notation for Pattern 3 in 4/4 time, measures 6-9. The treble clef staff contains a half note G4, a quarter note A4, a quarter note B4, and a quarter note C5. The bass clef staff contains a half note G2, a quarter note A2, a quarter note B2, and a quarter note C3. A dashed box encloses the first two measures.

6.13d

Anxiety, Pattern 4 (appears first in m12):

Musical notation for Pattern 4 in 4/4 time, measures 12-13. The treble clef staff contains a half note G4, a quarter note A4, a quarter note B4, and a quarter note C5. The bass clef staff contains a half note G2, a quarter note A2, a quarter note B2, and a quarter note C3.

6.13e-f

Pattern 5 is in the upper voice and appears first in m13; pattern 6 is in the lower voice and appears first in m33; in *Anxiety*:

6.13g

Anxiety, Pattern 7 (appears first in m45):

6.13h

Anxiety, Pattern 8 (appears first in m13):

6.13i

Anxiety, Pattern 9 (appears first in m60):

6.13j

Anxiety, Pattern 10 (appears first in m64):

A single staff of music in 4/4 time with a bass clef. It contains four measures of eighth-note chords. Each measure has a trill symbol (tr) under the first eighth note. The notes in each measure are G2, A2, B2, C3, D3, E3, F3, and G3.

6.14a

Background to introduction to *City of Storms*:

Three staves of music in 6/8 time with a key signature of one sharp (F#). The top staff has a treble clef and contains a melodic line with eighth and sixteenth notes. The middle staff has a treble clef and contains a rhythmic accompaniment of eighth notes. The bottom staff has a bass clef and contains a bass line with eighth notes.

6.14b

Measures leading up to a climax; in *City of Storms*:

Three measures of music in 6/8 time with a key signature of one sharp (F#). The measures are labeled 'Measure 21', 'Measure 22', and 'Measure 23' above the staves. The top staff has a treble clef and contains a melodic line with eighth and sixteenth notes. The middle staff has a treble clef and contains a rhythmic accompaniment of eighth notes. The bottom staff has a bass clef and contains a bass line with eighth notes.

6.14c

Measure 24 Measure 25 Measure 26

Three staves of music in 3/4 time, key of D major. The first staff has a melodic line with a slur over measures 24-26. The second staff has a bass line with a slur over measures 24-26. The third staff has a piano accompaniment with a *cresc.* marking over measures 24-25 and *dim.* markings under measures 25 and 26.

6.15a

Melancholy, theme (appears first in m1):

Two staves of music in 3/4 time, key of D major. The first staff has a melodic line with a *mf* marking and several triplet markings. The second staff has a bass line with triplet markings.

6.15b

Melancholy, simple bass line (appears first in m1):

One staff of music in 3/4 time, key of D major, showing a simple bass line with a *mf* marking.

6.15c

Melancholy, competing pattern (appears first in m9):

One staff of music in 3/4 time, key of D major, showing a competing pattern with a *mf* marking.

6.15d

Melancholy, competing pattern (appears first in m17):

One staff of music in 3/4 time, key of D major, showing a competing pattern.

6.15e

Melancholy, competing pattern (appears first in m25):

Musical notation for example 6.15e, showing a competing pattern in measures 25-27. The notation is in 3/4 time and consists of two staves. The upper staff features a melodic line with a circled triplet of eighth notes (F#4, G#4, A4) in the first measure, followed by a descending eighth-note scale (A4, G#4, F#4, E4, D4, C4) in the second measure. The lower staff provides a bass line with a similar descending eighth-note scale (C3, B2, A2, G2, F2, E2) in the first measure, followed by a more complex rhythmic pattern in the second measure.

6.15f

Melancholy, competing pattern (appears first in m41):

Musical notation for example 6.15f, showing a competing pattern in measures 41-43. The notation is in 3/4 time and consists of three staves. The upper staff has a melodic line with a circled triplet of eighth notes (F#4, G#4, A4) in the first measure, followed by a descending eighth-note scale (A4, G#4, F#4, E4, D4, C4) in the second measure. The middle staff has a bass line with a similar descending eighth-note scale (C3, B2, A2, G2, F2, E2) in the first measure, followed by a more complex rhythmic pattern in the second measure. The lower staff has a bass line with a similar descending eighth-note scale (C3, B2, A2, G2, F2, E2) in the first measure, followed by a more complex rhythmic pattern in the second measure. The dynamic marking *p* is present in the first measure of each staff.

6.15g

Melancholy, competing pattern (modification of pattern at 41; at m49):

Musical notation for example 6.15g, showing a modified competing pattern in measures 41-43. The notation is in 3/4 time and consists of three staves. The upper staff has a melodic line with a circled triplet of eighth notes (F#4, G#4, A4) in the first measure, followed by a descending eighth-note scale (A4, G#4, F#4, E4, D4, C4) in the second measure. The middle staff has a bass line with a similar descending eighth-note scale (C3, B2, A2, G2, F2, E2) in the first measure, followed by a more complex rhythmic pattern in the second measure. The lower staff has a bass line with a similar descending eighth-note scale (C3, B2, A2, G2, F2, E2) in the first measure, followed by a more complex rhythmic pattern in the second measure. The dynamic marking *mf* is present in the first measure of each staff.

Chapter 7 Toy Problem Experiments

Introduction

Over the last four summers I have been working at the University of Campinas (Brazil) in Professor Jose Valente's computers and education group¹ with Rodolfo Miguei Baccarelli, a master's student in computer science; and Maria Cecilia Martins, a master's student in education. Baccarelli wanted to know what kind of computational tools would be required in order to make a system in which composers could design musical forms, concepts and patterns.² Martins wanted to understand the reasoning that supports design. I wanted to know whether there was evidence to suggest the necessity of learning within the design process.

In 1991 I suggested that it would be useful to develop some *toy problems*, the name I gave to activities in which composers are given some simple themes and asked to develop them. Martins and another student (Pedro-Paulo) constructed two melodic themes (shown below) and found five composers (four university students and one professor) who were willing to work on the toy problems while being observed, asked questions and video taped.

The two themes used in the toy problems:



¹ Valente's group at the University of Campinas (Sao Paulo, Brazil) is called the Nucleus for Informatics and Education (NIED).

² In Baccarelli's environment, written in C++, a musical object (like a melody) inherits attributes (like scale or meter) from classes of objects specified at higher levels. There are also scripting tools (methods) for modifying patterns locally. A program produces MIDI data and, therefore, reflects the structure of the data. The user-interface provides multiple modes of presentation, either graphic, symbolic or standard music notation. However, MIDI data that is entered in by keyboard must be structured manually. In addition, changes made directly to MIDI data are not reflected upward. To address these problems, Baccarelli intends to build analytic tools that will help a composer to build program structure from the MIDI data.

Each composer was asked to select one of the above themes and "develop" it. He was not told how to develop it nor was he given any time limits, though each composer spent about the same amount of time on a toy problem, from 1 to 2 hours.

The composers were encouraged to talk about their process as they worked, a method known as *loud thinking*. Loud thinking may have its roots in Piaget's experiments with children. Today, it is commonly used by researchers interested in qualitative data on everyday cognition (Lave and Rogoff, 1984).

In the summer of 1992, Martins, Baccarelli, and I met to analyze the video tapes of the composers. We also met with two of the videotaped composers (student-D and professor-M) in a 3-hour session in which we watched and discussed the tapes together. This session was also videotaped and analyzed by the researchers without the composers present. The work reported in this chapter reflects my contribution to these analyses. My collaborators' perspectives can be found in their theses.³

7.1 Preliminary Analysis

In this preliminary analysis, I divide composer solutions into design *episodes* loosely defined as *coherent chunks of action*. (The episodes are about the "size" of the musical examples found in chapter 6.) When an episode appears to illustrate a hypothesis from chapter 6, the hypothesis name is given below the description of that episode. Following a description of each composer's work are "Highlights", a preliminary summary of points that are particularly interesting.

Student-I

Theme of problem:



Student-I modified the theme in the following way.

Modified theme:



³ See Baccarelli's *Musical Microworlds: A Computational Environment for Experimentation* and Martins' *A Cognitive Psychology of Music Composition*.

C2. Student-C then proceeded to analyze the theme and concluded that it implied a pentatonic scale and a meter of 4/4. This analysis helped him to identify attributes of the theme.
[Design analysis]

C3. He wrote out the inversion, retrograde and retrograde-inversion of the theme, standard operations for manipulating a theme. He described this process as "organizing my work material". Notice that this material is not exactly in 4/4 and that student-C did not write the meter; he just "thought it".

Manipulated versions of the theme



My conjecture is that these operations helped him to produce related material.
[Skill design, Conventional consistency]

C4. Student-C decided that the music would have two voices and that the upper voice would answer the lower voice using the manipulated versions of the theme. I see this as an organizational strategy.
[Environment design, Freedom through restrictions]

C5. He decided to maintain the "tonal aspect of the theme", the "implied musical scale". I see this as the production of a compositional constraint.
[Environment design, Freedom through restrictions]

C6. He decided to place the theme and its answers in various temporal relations to each other, overlapping them more and more in the middle of the piece and less and less at the end. I see this as an organizational strategy.
[Environment design]

C7. He said that he planned to use dynamics and articulation later to give the music dramatic shape.

My conjecture is that he planned to use these devices to compensate for the expressive limitations of his organizational constraints.
[Design debugging strategy]

C8. Student-C tested the overlap strategy and found that there were too many rests between introduced material. Because 3/4 would improve the fit by getting rid of 1 rest in the 4/4 meter he revised his compositional system. He also made a few meta-comments. "The ideas come during the process of composing", "I construct the system I use as I compose".
[Environment design, Design environment evaluation]

C9. Student-C then said that he would break the rules of the system when necessary.

My conjecture is that he anticipated the need for relaxed constraints to preserve the "tonal aspect" of the theme. For example, he modified the lower theme at the end of the piece. [Exception principle, redesign strategy]

The image displays four systems of musical notation, each consisting of two staves. The notation is in treble clef with a 3/4 time signature. The first three systems show a piece of music with a specific melodic line in the upper staff and a corresponding accompaniment in the lower staff. The fourth system shows a modified version of the lower theme, where the melodic line in the upper staff is more complex and the lower staff accompaniment is altered to accommodate it. The modification is specifically noted as being for the end of the piece.

modified theme for end of piece

Highlights: Student-C

Environment design. Student-C develops a system and then gives himself the freedom to violate its rules because he knows that without some constraints he cannot proceed, an illustration of *freedom through restrictions*. He also knows that "the system" is not likely to be equipped to handle local anomalies. For example, the overlapping strategy may cause notes that violate the "tonal aspect" that he wants to preserve. If this happens infrequently, he may just want to make an

exception--*relax a constraint* as Sloboda says--and change a few notes in the upper or lower voice. Otherwise, he may need to revise a global constraint which is what he does by changing the meter from 4/4 to 3/4. By deciding whether to make exceptions or change constraints, student-V is attempting to manage the complexity of the design process. He is working on the design environment, not on the artifact.

Analytic-Synthetic pairs. The same musical concept is represented differently depending on whether it is used for analytic or synthetic purposes. One might say that tools come in *analytic-synthetic pairs* : an analytic tool for identifying a potential source of pattern continuation and a synthetic tool for actualizing it.

For example, student-C analyzed the theme to identify its attributes (scale = pentatonic, meter = 4/4 revised to 3/4, etc.). However, when he turned from analysis to synthesis the *attributes* functioned as *constraints*. New notes had to come from the pentatonic scale, new rhythms had to operate within a 3/4 metric framework.

Student-V

Theme of problem:



- V1. Like student-C, student-V saw the theme as pentatonic. What is important is that he felt the need to decide through an analysis of it, and this led to a scale constraint.
[Design analysis, Freedom through restrictions]
- V2. He planned to use the chromatic notes missing from this scale as the notes of an accompanying voice. I see this as an organizational strategy.
[Environment design, Freedom through restrictions]
- V3. He proposed to use a simplified form of serial composition, changing the order and not the notes and durations of the theme each time a pattern of thematic elements was repeated. I see this adaptation (simplification) of the twelve tone method as an organizational strategy for matching the complexity of methods to the complexity of the toy problem as he saw it.
[Environment design, Skill design]
- V4. He wrote the upper voice of the duet first (see duet, below). He then copied it onto a new page and wrote the accompaniment against it. By doing so, he used the rhythms in the upper voice to restrict rhythmic choices in the lower voice.
[Environment design, Self-referencing, Freedom through restrictions]
- V5. Student-V said that the accompaniment would be used to "camouflage" the pentatonic scale whose "tonal aspect" he wanted to minimize.
[Environment design, Design analysis, Pattern masking]

V6. Instead of emphasizing the "harmony" he said he would emphasize the syncopated aspects of the theme in the accompanying voice.

[Design analysis, Self-referencing]

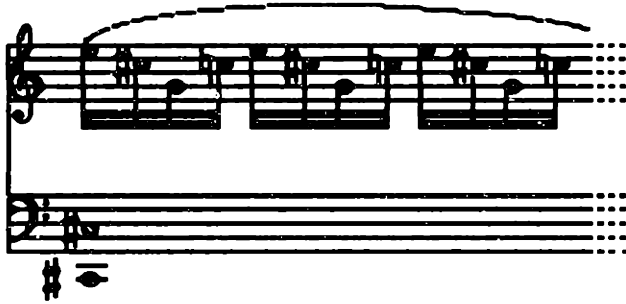
V7. As with student-C, student-V decided to give the music its dramatic shape (what he called "aesthetic treatment") using dynamics and articulation. I see this as a strategy designed to compensate for the anticipated expressive deficiencies of his system.

[Redesign strategy]

In the duet (below), you will notice that he only changed the last measure of the upper voice. Apparently, he had different rules for ending pieces. My conjecture is that, since his rules for producing re-organizations of the theme were not violated by them, he could make the change with little reflection.

[Exception principle]

only revision

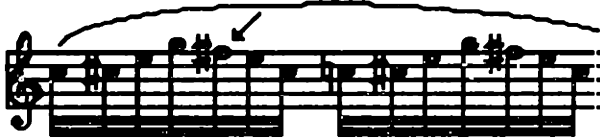


D2. Student-D described this strategy as using the same theme in a different context.

My conjecture is that his comments serve as a justification for the musicality of the strategy since it implies that the listener will experience these contextual shifts.
[Self-referencing, Musica. staging]

D3. He said that he added notes to chords to make them more rich (below). He said that he wanted to restrict these additions to points between the ostinato patterns already in operation. He also wanted to restrict himself to note additions that would not violate the "harmonic approach" he had established. For example, sometimes he extended the diminished harmony inherent in the theme. At other times, he played harmonically ambiguous tone clusters.
[Environment design, Skill design, Freedom through restrictions]

Adding notes, note grouping strategy:



While he didn't say so, he clearly stayed away from the triadic implications found in the theme; i.e., the major third [C E G].
[Negative design]

D4. In the post-interview he said that he used a note grouping strategy he had used in other pieces. The music in D3 and below are examples.
[Designing by example]

Note grouping strategy:



- D5. Student-D's way of developing the music was to produce right-hand arpeggios and left-hand octaves over wider ranges of the piano, increasing the amplitude of the music in the middle and decreasing it towards the end. This appeared to be an organizational strategy he planned from the beginning.
[Environment design]
- D6. Student-D kept the tempo of the music relatively constant. He said that when he began to accelerate the tempo he did not like what he heard and slowly returned to the earlier tempo.
[Confidence building]
- D7. Student-D realized that the chord ending the improvisation was the one used to end a previous piece. He noticed that this was not so unnatural since that chord and the theme organized as a chord were the same except for one altered note (below).
[Skill design, Designing by example]



Highlights: Student-D

Generative schemes. Student-D's use of arpeggios reminds me of Sudnow's comments in his book *The Ways of the Hands*. Sudnow points out that an improviser has the problem of keeping the music going while he is thinking of some next thing to do. This is not accomplished by thinking of notes one at a time, but by developing "handful appreciations" to simplify choices and gain planning time (Sudnow). From a cognitive perspective, a "handful appreciation" is a generative scheme. Student-D did not "compose" notes, he "composed" a generative scheme for producing a number of notes. This is a common organizational strategy in more than improvisational settings.

Complexity management. Student-D not only restricted his note space, he restricted his use of strategies for shaping them. By keeping arpeggiation in one hand and octaves in the other, he gave himself time to explore his additive strategies (D3) and his register-dynamics development strategy (D5). I have been calling such thinking *freedom in restrictions*. This is an example of working in the environment of design in order to manage improvisational complexity.

Environment design. D6, where he temporarily changed the tempo, illustrates *confidence building*. In this case his weakened confidence caused him to retreat to the earlier tempo. This is an example of working on the environment of design.

Design experience. Note adding (D3), note grouping (D4), and the final chord (D7) illustrate the role of previous design experience in current designing.

Professor-M

Theme of problem:

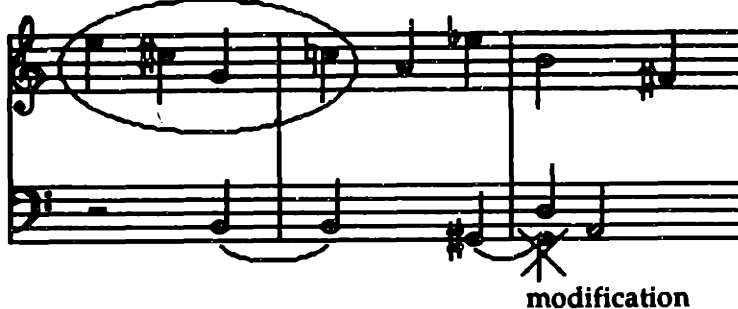


Professor M tried "solving" the above theme twice.

First "Solution"

M1. Professor-M said that his intention was to use the intervals of the theme (circled, below) as a "generator" of the music. His palette of intervals included the intervals between notes, their inverses and octave expansions, as illustrated by the beginning measures of the development.

First 3 measures of first solution:

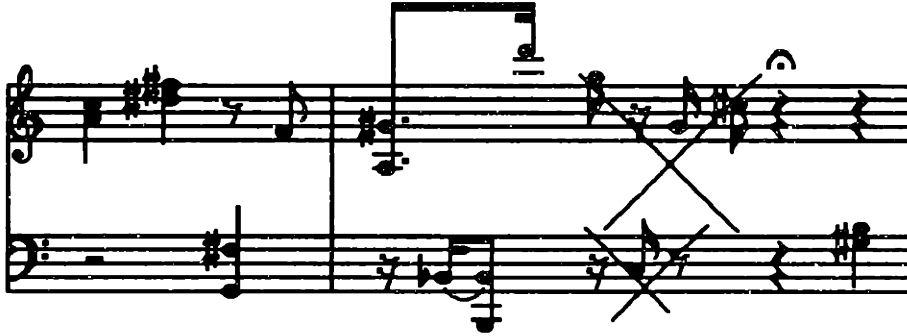


The palette of intervals is not only a musical generator, they are a compositional constraint. Moreover, the fact that he identified these intervals and used them in this way meant that he engaged in an analysis as a means of identifying his synthesis tools.
[Environment design analysis, Skill design, Freedom through restrictions]

M2. He assumed a particular meter. He modified measures 2 and 3 by eliminating the G# in the third measure (i.e., the note with the X over it, above). He argued that this would introduce variety in the phrasing between measures 1 and 2, and measure 3. I think of one of the heuristics given by Brindle' in his book *Musical Composition*: add something new to something old.
[Anticipatory listening]

M3. Measures 4 and 5 are shown below. Professor-M. said that he changed his mind, shifting from a polyphonic to chordal ("harmonic") approach. He said that "composing is an accumulative process" by which I think he meant that he began to produce enough notes to support chords. Alternatively, my conjecture is that he had temporarily exhausted the polyphonic possibilities he allowed himself earlier and this provoked a strategy change.
[Design environment evaluation]

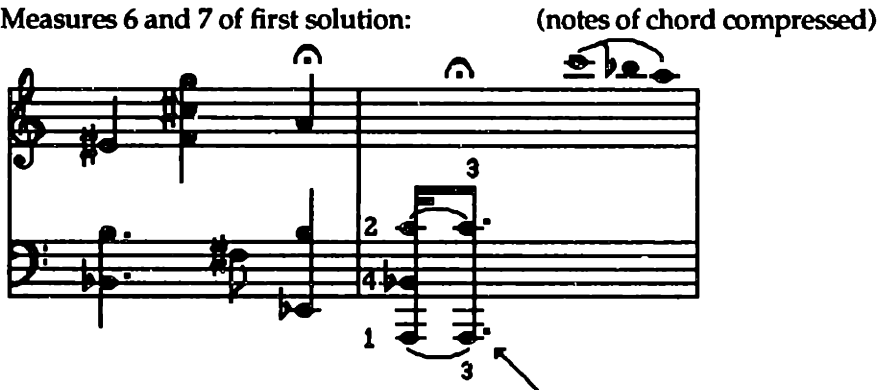
Measures 4 and 5 of first solution:



M4. He said that he started to think of using single intervals as "generators of a process". This seems a reasonable progression from his chordal thinking (e.g., the augmented 4ths in measure 6 and the 9ths in measure 7, below).
[Empirical consistency, Coherent design]

M5. He then looked at what he had done in these 7 measures from a new perspective. He noticed that there were some larger patterns: "the ascending pattern in measures 3 and 4 are followed by another in measure 4 and 5".

Measures 6 and 7 of first solution:



final chord of first solution

Measures 3 through 5 mark a span of time much longer than those he considered while producing the intervallic relationships. This change in perspective made him notice (contour) patterns that were a side-effect of more local actions and provided a potential context of design.

[Rationalization]

M6. After performing the music in his head (while waving his hands like a conductor) he began to have second thoughts about measures 3 through 5. He said that "the music accelerates too quickly; the listener is not given enough time to anticipate the acceleration *during* the acceleration".

[Anticipatory listening, Prolongation strategy]

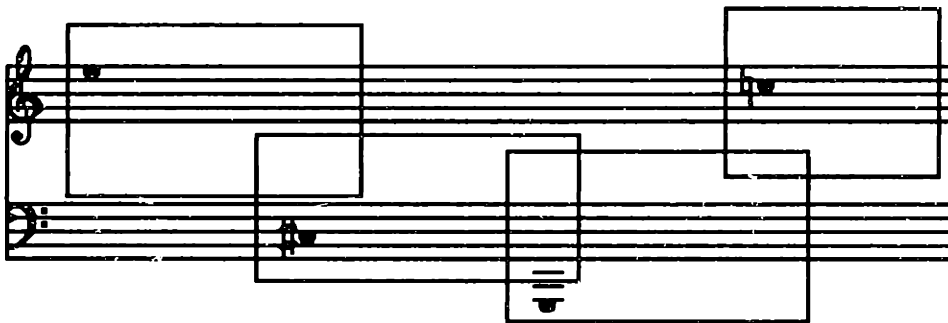
M7. Professor-M wrote the notes in the "final chord" (as he saw it) in the order given by the numbers next to each note (see measures 6 and 7, above). The last note written was the Bb (in the bass) which he described as "camouflage". Notice that it appears during attack time but does not continue into the fermata.

[Pattern masking]

M8. He analyzed the "final chord" of the development by writing the three notes compressed in one octave (measure 7, above). He noted that this chord of only three notes spanned an interval distance of over two octaves. This precipitated comments about registral patterns--i.e., patterns across octaves.
[Design environment evaluation]

Second Solution

M9. Almost immediately, Professor-M began the toy problem again, sparked by his reflections about registral thinking (M8). Below is how he represented this activity using a combination of music and graphic notation.



He said that, in this new approach, the notes of the toy problem would be distributed across several octaves. The boxes show that he intended for several independent but overlapping musical activities.
[Forms as guides]

M10. He said that he planned to use each note as a generator of a process. Recall that he used nearly the same expression when talking about intervals in his first solution (M1). He also called these notes "pivots", making reference to the idea of a pivot in harmonic music.

I think of Malm's discussion of Japanese tonal theory where there are "central pitches" around which "satellite pitches gravitate" (Malm, pp. 38-41). Notice that Professor-M avoids specifying a meter in this version of the "solution".
[Skill design, Empirical consistency, Coherent design]

M11. Within this compositional framework, Professor-M began writing the pattern of Es found below. Notice that the pattern of Es are comprised of 3 smaller patterns. He said that such patterns "have personality", and are very common in the music of the Darmstadt school. I call them "actors" in the illustration.
[Patterns as actors, Generic Constructs, Conventional consistency]

These patterns follow what Professor-M called the principle of *quasi-symmetry*, where component patterns are "similar but not identical to each other". He argued that this creates excitement for the listener "who notices the regularity in the irregularity".

Actor 1

Actor 2

M12. He made the C# a trill (actor 2, above) and described it as a dramatic contrast to E, much like two actors with contrasting personalities may appear on stage. In the same spirit, he added the low G, a third actor with a different "personality" (below).
[Patterns as actors, musical staging]

Notice that these patterns are written using the space on the page as a notational device, rather than rests to represent silences. This is called *spatial notation*.

M13. While pointing to the low G, he made reference to his earlier comments on registral thinking (M8 and M9), and his use of intervals as a generator (M1). He wanted the G to ascend in equal and large intervallic leaps which would combine both ideas into one technique. He used an octave plus a m6 to produce the Eb (in actor 3) and two octaves and a m6 to produce the high C (in actor 4).
[Skill design, Freedom through restrictions, Coherent design]

Actor 4, serendipity

Actor 3

Actor 2

M14. Looking back at the earlier formulation of this toy problem (the notation found in episode M9), Professor-M noticed that the high C he had just written could be used to introduce the fourth note of the theme, also a C. He said that the G (actor 3) could not only generate a process, it could introduce the circle C (actor 4)!
[Serendipity]

M15. Professor-M wrote actor 4 starting with the circled C and ending with Ab. He used a quick group of notes to characterize this voice, saying that he wanted to give it a "personality" different from the other voices.
[Anthropomorphic listening, Patterns as actors]

M16. At the Ab he decided to change the C# trill (actor 2 shown in episode M11) to a Bb trill (actor 2 shown in episode M13). He argued that the quick notes of actor 4 created the opportunity to make the Ab a point of tension. Changing the C# trill to a Bb trill at that moment would produce tension in two ways; it would produce a more dissonant interval (a major-2nd rather than a perfect-fourth), and it would serve as a temporal marker.
[Serendipity, Anticipatory listening]

My conjecture is that this change is reminiscent of Professor-M's camouflage strategy using the Bb momentarily in the "final chord" (described in M7, shown in the notation found in M5). Actor 4 will distract the listener from expecting a change in actor 2, causing a moment of surprise.
[Cognitive masking]

M17. At this point Professor-M decided that he had identified the "personalities" of the four voices (actors). He now said that these *motives*--not the notes or the intervals--could become generators of a continuing development (see actors 1 and 3, below).
[Skill design, Empirical consistency]

The image shows musical notation on a grand staff (treble and bass clefs). Actor 1 is represented by a melodic line in the treble clef with various notes and accents. Actor 3 is represented by a lower melodic line in the bass clef. A section of the notation is circled and labeled "answer in search of a question", showing a descending sequence of notes in the bass clef.

M18. He described the group of descending notes (circled, above) as "an answer in search of a question". He imagined that, if he were to continue, he would produce its "question" through imitative writing.
[Rationalization, Working backwards, Designing by example]

M19. Professor-M leaned back from his writing table and made remarks which I paraphrase here.

"My first "solution" was a methodical investigation of the intervallic possibilities of the theme. My second "solution" was a more gestural approach to the problem. If I was to continue, I would take this material and improvise on it. Only then would I be ready to write a piece."


Highlights: Professor-M

Rationalization. In M5, Professor-M noticed two unplanned ascending patterns. He considered writing a third one. If he had it would have been the result of a new plan, designed to rationalize his previous actions in one operating over a longer span of time. While this example illustrates a number of things—complexity management, the promotion of user utility, and tinkering—I want to focus on rationalization.

With student-C I introduced *analytic-synthetic pairs*, the idea that an analytic tool that serves as a means of identifying a potential source of pattern continuation has a "cousin" in a synthetic tool for actualizing it. Rationalization causes a shift to a different analytic-synthetic pair.

Design style. There are two examples of serendipity (episodes M14 and M16) and two of rationalization (episodes M5 and M18). I think of serendipity as a special case of rationalization. In combination, these examples reflect the tinkerer's design style. A total planner would not allow such opportunistic strategies in his design language.

Promoting user utility. Professor-M incorporated the listener's perspective in his decision making in episodes M4, M6, M10, M12, M13, M16 and M17. Of all the composers, only he explicitly expressed a concern for the listener and used these concerns as a means of creating new design settings, the perspective of promoting user utility.

Design persona.  Professor-M also used two different compositional approaches, each reflecting a different kind of relationship to the materials. In M1 a common set of intervallic relationships were used to generate melodic material. I call this a *procedural model* of composing. In contrast, while the notes in M10 and the motives in M17 also became a "generator of a process", what mattered was the addition of attributes to objects. Professor-M called this approach "gestural". I call it an *actor model* of composing.

These two compositional models are quite recognizable in Professor-M's writing; indeed, they can almost be used to distinguish what he did during solution 1 (procedural) and 2 (actor-based), although his recurring notion of a "generator" is procedural and found in both solutions. Recall that, M19, Professor-M also proposed a third compositional model, improvisation. The fact that he could draw from more than one compositional model gave him the ability to approach his material from different *design persona*. The idea of design persona, elaborated later, is that the composer is a society of simpler composers (as in Minsky's mind as a society of simpler minds). Within any design persona, a composer can use all of the perspectives on designing.

All perspectives. From the very beginning (M1) Professor-M selected music tools, adding new ones as the material "accumulated". He explored the potential benefits of generating notes by

restricting himself to the intervalic content of the theme (M4), to the theme's notes (M10), and to motives generated by his previous methods (M17). He used and re-used ideas about registral thinking (M8 and M9) and "camouflage"(M7 and M16). Episode M13 is a clear example of *skill design* where Professor-M added octaves to the note-generating intervals, combining into one method his ideas about musical register and interval-based note generation. Each experiment working in the current environment of design helped him to determine which tool he would add to his environment of design. Of all the composers, Professor-M was the only one who displayed all the perspectives on designing in his work on the toy problems.

7.2 Post-Problem Interviews

Two of the composers, student-D and Professor-M, agreed to observe and discuss the videotapes of their work with us. This session lasted 3 hours and was itself videotaped. What follows are selected comments from this discussion. The dialogue was translated from Portuguese and edited.

Student-D

Student-D had commented on intuitive and rational thinking during the toy problem session. I thought it would be useful to have him elaborate on these comments.

Author: Do you think your process is rational or intuitive?
Student-D: For me rational thought is the translation of the intuitive into something communicable to others....the interface between people. It's like dream thought...something you may not remember but know about.

Student-D was also clearly concerned with the listener in these post-problem interviews. Indeed, he said that there is a kind of "ethics of aesthetics", "a responsibility of the communicator to communicate".

Author: I think of composing as the construction and use of conceptual tools. What do you think of this?
Student-D: I agree. While some tools are reusable, sometimes you have to invent new tools.
Author: Could you define a composer's style as "the kinds of tools he uses or invents"?
Student-D: Yes, but this is only part of it.
Author: What's missing?
Student-D: I think of intuitive and rational thought as a relation between the "child" and "adult" within a composer.

This became an important issue in a later discussion with him and Professor-M about design environments. In that segment of the interview I took the hard-line regarding *environment design*. Recall that the idea of environment design is that composers not only compose pieces, they construct

the tool box they use to compose pieces. In the hard-line view, the tool box becomes fixed, stable. In the soft-line view, tools are continuously added, deleted, or refined until the end.

Student-D: [In response to the hard-line view] One can never be completely sure that one has the conceptual resources one will need in order to finish a piece.

Author: Would you agree that the design environment is mostly stable?

Student-D: No. Your view is an "equilibrium theory". Perhaps in our time, where methods of composing change so rapidly, we need such a theoretical view. But I think that as soon as the environment of design becomes stable the "child" is cut off from the "adult".

Again about intuition...

Author: Can a composer control his intuitive process?

Student-D: Not control, but direct. Learning to work with one's intuitions is better than if you forget about them. For example, I can trace some of the rhythmic patterning found in my improvisation to the many hours I spent deliberately practicing these patterns. I didn't plan to use them during the improvisation I did for you, they just happened.

Student-D used the phrase "musical fluidity" to characterize the improvisational process.

Author: Is this a fluidity of result or of process?

Student-D: Always with a foot in the past and a foot in the future. Composing is different from improvisation. In improvisation, the music lacks a structure of the whole, or strong links between elements.

Professor-M had watched the videotape of student-D's improvisation. Hearing student-D's comment he remarked:

Prof-M: I found your improvisation very structured.

When you are composing, don't you sometimes feel that you are improvising?

Student-D: Yes.

Prof-M: Good, I'm not alone.

Professor-M

Professor-M resisted the idea of a stable tool box, the hard-line view of environment design.

Prof-M: The musical material dictates the actions I will take, but so does the compositional approach I decide to take. For example, in the first version of the theme I tried to develop a feeling for the material while in the second version I tried to sketch out the overall form of the music....Solution 1 was physical labor...working at the level of the material. Solution 2 was engineering...making a large panel with the objects tested in the first problem.

Author: Why didn't you specify any meter in solution 2?

Prof-M: Meter is at the lower level....not important here. This was a more open context.

- Author: Why do you choose to constrain yourself at all?
Prof-M: The very idea of developing the material requires it. That's what "development" means!
Author: Could you explain again what the difference is between your two solutions of the problem?
Prof-M: In the first solution I was working at the note level while in the second I was working with a series of events....with several notes.
Author: Could you have used the second approach first?
Prof-M: It's difficult to make a hole in a wall without knowing the kind of drill! [I should use], because I don't know if there is concrete or wood inside the wall.
- pause*
- Prof-M: I think that there are valid experiments when one takes a **structure**, puts something inside and leaves it run to hear what happens...this perception will take me to the first step.

From Professor-M's comments it is clear that he finds both approaches necessary. Recall that I described professor-M's intervalic approach as procedural and what he called his "gestural" approach actor-based. The procedural approach was found in both solutions, the actor approach was only found in the second solution. I regret that I did not explore these observations in the post-problem interviews.

Notice that, in professor-M's comments (above), he seems to view solution 2 as structure-building (see **structure**, in bold). This makes sense; solution 1 produces the material, solution 2 explores structures using the material. However, by "structure" he also seems to mean the ability to determine when to employ processes like "elements as a generator of a process".

- Author: After completing solution 2, did you look at solution 1 in a new light?
Prof-M: Yes.
Author: I think that the purpose of your idea of "developing a feeling for the material" is primarily to identify some tools that you might use to develop it. In the first toy problem, you seemed to reach a "dead end" because your tools were limited...you deliberately limited them. In contrast, you deliberately designed your second approach in order to make you think about many kinds of tools. Now you can return to the first toy problem with a much richer tool set and think of developing the old material in new ways.
Prof-M: That seems true.

changing the subject....

- Author: So you don't agree that the tool set becomes stable while you are composing?
Prof-M: No, the process is unconscious.
Author: But during both sessions, you would perform a sequence of "unconscious" actions and then step back to reflect upon the consequences of these actions on the rest of the material. The reflective part of this process does not seem "unconscious".
Prof-M: Yes. What I mean is that I didn't have a clear idea of where the activity was headed.

Author: Would you say that the role of your second ("gestural") approach to the problem was to identify musical goals?
 Prof-M: Not entirely. While the second approach was a way for me to sketch out the music, it is always possible for me to include them in a bigger plan.
 Author: So, goals are always provisional?
 Prof-M: Yes.

I reminded Professor-M that during M11, he said that the ("Darmstadt") pattern he had produced was quite common in contemporary music, then said:

Author: While I know what you mean, how would you describe the pattern....what kind of pattern is it?"

pause

Prof-M: The pattern conveys hesitation...doubt.
 Author: I think that a community of composers--e.g., those writing in the Darmstadt tradition--invent new patterns whose emotive force is negotiated among its members. Your pattern is not emotionally neutral like, say, a pattern of morse code, is it?
 Prof-M: Of course not.

7.3 Learning Skill Management

In spite of those occasional moments when I "lead the witnesses" in the post-problem interviews, I believe the toy problems provides ample evidence to persuade readers of the importance of learning during the design process.

Below is a chart that shows broad similarities and differences among the composers. Notice that the first three composers (students I, C and V) were primarily *planners* by which I mean they designed their composing environments and then executed "a plan" almost blindly. These same composers used one kind of compositional approach throughout the toy problem exercise and expressed little or no concern for the listener.

	Planner	Tinkerer	Compositional Approaches	Listener Concern
1. Student-I	yes	no	1	none
2. Student-C	yes	no	1	none
3. Student-V	yes	no	1	none
4. Student-D	yes	yes	1	some
5. Professor-M	yes	yes	2 (or 3)	considerable

Student-D was also a *tinkerer* by which I mean he was prepared to replan when he encountered problems unanticipated by his initial plan. While he also used one compositional approach, he

did express some concern for the listener. Finally, Professor-M was both planner and tinkerer, used two different compositional approaches (suggested a third improvisational approach), and expressed considerable concern for the listener. The above chart suggests that compositional expertise requires planning and tinkering, the use of several compositional approaches and a concern for the listener. In the remaining subsections I will explore ideas for how this expertise is acquired and managed.

What the above chart does not show is that all of the compositional approaches were different. Not only did each composer have a different notion of how to develop the given musical motive, Professor-M had different notions of musical development that he could apply to the same motive. While this is not a surprising conclusion, it reminds us that composing is experience-based. Composers, and designers in general, use different tools to manage their process and they use the same tools in different ways, depending on their past experiences.

Recall from chapter 6 that I often needed to refer to several skills and to jump between perspectives on designing in order to describe an example completely. In one sense, this is not a problem. One might expect that design process complexity would reveal itself at this level of analytic granularity. In another sense, this complexity poses new design management problems.

Designing appears effortless for the designer because he is able to reduce the field of design options to a few that he can try and test; this is the purpose of skill. However, the notion of skill is recursive; a designer needs to acquire skill in the selection of types of skills. My perspectives on designing provided a proposal for how skills might be organized. Student-D and Professor-M offer evidence in support of these perspectives. Because they took the listener into account, they applied one more perspective on designing than the other three composers.

However, the toy problems reveal evidence for kinds of skill management that I did not take into account or take seriously enough during my self-reflective study. The main conclusion of the following discussion is the assumption on which it is based; namely, there is no question that skill is managed in a variety of ways so that skill can be accessed effortlessly. Paradoxically, designing is complicated for novices who have little knowledge, and relatively effortless for experts who have considerable knowledge. This paradox can only be explained by the presence of different management schemes among novices and experts.

Understanding how skill is accessed or how easier access can be acquired is much more difficult to answer. What follows are skill management proposals; they are conjectures, not answers.

1. My idea of *design personae* provides a process manager for organizing collections of skills that can operate from all the perspectives on designing.

2. There are different *design styles*, planners and tinkerers, and either can operate within each of the perspectives.
3. Some tools come in pairs: an *analytic* tool for identifying a potential source of pattern continuation and a *synthetic* tool for actualizing it.
4. *Rationalization* is a constructive kind of reasoning used to manage process conflicts.

7.3.1 The Idea of a *Design Persona*



Professor-M's environment of design was actually comprised of three smaller ones: an environment for procedural design, actor-based design, and improvisational design. Each kind of designing not only contained its own set of design skills but, as importantly, all of the perspectives on designing that have been identified.

I offer another kind of process manager to address this observation, the idea of a *design persona*. Unlike a thinking cap which reflects a particular perspective on designing, a design persona is a "simpler designer" capable of using many skills and any of these thinking caps. When a designer "tries out" a persona, he automatically gains access to a complex, yet reliable, organization of design experience.

The idea of a design persona can take advantage of Minsky's metaphor of the mind as a society of simpler minds (chapter 1). In the Society of Mind a design persona would be a simple composer organizing particular combinations of skill-agents into perspective-agencies. These simpler composers could be thought of as models of a composer's favorite composers organized by his composing society. When the composer acts like one of them he uses a particular compositional approach. As with the simplest skill, the composer can gain skill in when to use one of the members of the composing society.

7.3.2 Design Style

A designer has a design style that can operate within any of the perspectives on designing. Recall that, among the five composers, student-V was the most rigid and Professor-M the most flexible designer. I called student-V a planner and Professor-M a tinkerer.

Planning has its advantages. By being rigid about the restrictions he enforces, a planner has a clear idea where they work or fail. Planners have a relatively easy time building confidence in the restrictions they impose because they are more conscious of them, though their reluctance to give them up can result in conservative designing.

Tinkering has its advantages. The more ways a designer has to recover from error the more bold he can afford to be. Tinkerers are likely to be more inventive, more opportunistic, though they can

have a difficult time building confidence in the restrictions they impose since they are too willing to give them up.

The differences in design style depend on a designer's receptivity to feedback during the design process. The difference between tinkerer and planner is the cycle-time between environment design and artifact design. Since tinkerers are opportunistic and engage in continuous debugging, they have a fast cycle-time. Since planners are conservative and resist debugging, their cycle-time is slower. Of course, the problem is to understand the organization of mind that gives rise to these cycle-times.

Recall that skill involves know-how (i.e., methods) and know-when (i.e., links to case knowledge). Using Minsky's society of mind metaphor, a skill can be thought of as a mental agency comprised of an how-agent and one or more when-agents. A pure planner will have when-agents that are suppressed after planning, while a pure tinkerer will have when-agents that are active all the time. Both of these skill-agencies are simple and reflect the use of skill by a novice. In contrast, an expert may have a more differentiated skill-agency comprised of many when-agents for managing the activation or the suppression of its how-agent.

Alternatively, differentiation should make skill-agencies reliable enough to support planning. At the same, differentiation should make skill-agencies rigid and necessitate the construction of new management schemes to support tinkering.

7.3.3 Analytic-Synthetic Pairs: Skill Networks

The phrase *analytic-synthetic pairs* refers to the idea that an analytic tool identifies a potential source of pattern continuation and a synthetic tool actualizes it. The shift from analysis to synthesis results in a shift in representation. For example, in order to change notes in a melody, a composer notices that the melody is in the key of C; an analysis produces the identification of the attribute KEY. To make melodic changes, the composer must choose notes within the key of C; synthesis converts the attribute KEY into a constraint NOTES-WITHIN-KEY.

In part 4 on computer-based design environments, readers will see that links between analytic and synthetic tools are often obvious. Sometimes the analytic and synthetic tools are the same tool. For example, a tool for analyzing the potential effect of reversing the notes in a melody is the same tool used to reverse the notes in that melody. Sometimes the tools are not the same but clearly related. For example, a tool for taking melodies apart has (or should have) a corresponding tool for putting it back together.

Becoming a better composer may involve linking skills into networks. Using Minsky's society of mind metaphor, we might say that a skill-agency, comprised of an how-agent and one or many when-agents, develops a when-agent that is linked to the when-agent of a different skill-agency.

7.3.4 Rationalization: Managing Process Conflicts

In episode M5, Professor-M noticed a pattern of ascending patterns that he had not intentionally made. His process of noticing this pattern was an analytic process. The analytic context was measures 3-5. The previous synthetic context was in measure 5 where he worked note-by-note using intervals as a "generator of a process". If he had acted on this analysis, he would have produced a new synthetic context, one including measures 3-5 and the additional measures necessary to add another ascending line to the pattern. The new synthesis would have incorporated the old one i.e. a progressively larger design context. This conceptual shift is what rationalization provides.

In episode M18 Professor-M *noticed* an "answer in search of a question". While writing the "answer" he did not characterize it as such. It was only after he had written it and examined the result from a different perspective did he reconceptualize it as "an answer". This gave him a new "plan": namely, to produce a "question".

Rationalizations are "false explanations". In designing, they have an operational role; they are not about explaining what happened last but planning what to do next. In the above examples, a rationalization was used to shift to different analytic-synthetic pairs, each operating over different time-span contexts.

Minsky's society of mind metaphor can be used to illustrate an image of rationalization as *conflict management*. In the designer's society of littler designers, two designers may come in conflict about what action to take next within the current design context. Rationalization results in a third little designer who dissolves the conflict by proposing a different design context.

At higher levels of abstraction, rationalizations may result in a shift to a different perspective on designing or different design persona. Recall that Professor-M mostly used a procedural compositional approach in his first development of the toy problem and mostly used a gestural approach in his second development. In the procedural approach he would use pitch-intervals found within the given motive to generate new notes. In the gestural approach, he would use various kinds of *ornamentation*⁵ to give "personality" to the notes found within the given

⁵ I use the word "ornamentation" casually to mean "the various subprocedures used for creating *Darmstadt*-like gestures".

motive. However, by episode M17 Professor-M had begun to combine both approaches; he used the procedural approach to select the next gestural note, and the gestural approach to produce new ornamentation for it.

Rationalizations are important for the opposite reason that design contexts are important. Design contexts make the field of design choices simple enough so that each choice can be tried and tested. However, a designer can get locked into a context that offers no means for pattern continuation. The "escape hatch" is rationalization.

The rationalization process is not random. Explorations are done within a restricted discovery space constrained by the current state of the emerging artifact. The designer notices a pattern that depends on something already present in the artifact. The artifact makes the process of rationalization a *controlled* escape from one design context into another.

The artifact may be important for another related reason. Since the artifact under design is co-constructed with the design environment, the artifact can provoke links between tools that have no links within the mental society. Speaking metaphorically, two tools could exist in separate "tool boxes"; the designer may never think of leaving one box open when opening another until unanticipated problems with the artifact make this necessary.

Linking tools is a kind of learning. Moreover, new links between tools can give rise to a new kind of tool like the one used by Professor-M to link the tools associated with note production and note ornamentation.

7.4 Situated Planning

In Suchman's *Plans and Situated Action* she argues that "problem solvers" are not the planners they are made out to be. For her, most problem solving is action taken in a particular situation. She argues that when people defend their actions as planned activities they are *rationalizing* them; they are making actions they did not understand conform to reason (Suchman). Suchman comes close to an insight that she might have made. Rather than discarding rationalization in order to defend more situated forms of action, she might have seen the critical role of rationalization during designing.


We can never be sure that the "explanations" that we give for our actions are the explanations we (subconsciously) used to guide ourselves while taking these actions. In focussing on the possible disparity between these two kinds of "explanations" we miss a more important point. It doesn't much matter whether there is such a disparity if an "explanation" leads to a new plan of action. In designing, this is why we make them.

These comments seem to dissolve a debate found among planning and situated action theorists. "Plans" are not as brittle nor is situated action as situated as either kind of theorist might have us believe. Designing requires *situated planning*. The artifact constrains plans, though the application of a plan changes the artifact and necessitates replanning.

The idea of situated planning compliments the thinking expressed in chapter 4 around problem solving and designing. There I said that conventional problems are well-defined and their solutions easy to recognize, while design problems are ill-defined and their solutions provisional, often debatable. One of the goals of designing is to reduce the field of choices so that the few remaining choices can be tried and tested. It is a small step to say that the "goal" of situated planning is to produce a conventional problem.

* * *



One,  learning by designing requires the construction of know-how (tools, methods, techniques, etc.), know-when (positive and negative links to case experience), skill (know-how plus know-when) and a variety of skill management schemes. Two, it is experience-based. Designers use different tools and management schemes and use the same tools and management schemes differently. Three, designing involves situated planning since plans change circumstances and new circumstances necessitate replanning.

The main question in part 4 of this thesis is: How can we develop computer-based environments to support learning by designing?

Part 4
Design Support Tools

Chapter 8

Constructionist Interactivity

8. Introduction

In the remaining chapters I will discuss conceptual interfaces that are computer-based, *design microworlds*, and an aesthetic for improving them, *constructionist interactivity*.

A design microworld can be thought of as a kit comprised of design tools (either material, conceptual, or computational). While the phrase "design microworld" may be foreign, the idea is not; any time a designer customizes his knowledge to support the design of a particular artifact, he is making a design microworld. Before computers, this customization process happened primarily in the mind of the designer. With computers, tools can be designed, used, examined and re-designed in a concrete way; indeed, the conceptual interface becomes an artifact that can be evaluated as any other.

Constructionist interactivity is about evaluating a design microworld's interactive quality. I have already argued that designing is simultaneously a process of making things and learning how to make things, of making tools to gain access to new experiences and making artifacts to gain experience in the use of tools. This is why design environments that are interactive in constructionist ways must give support to how people learn through the use and development of design tools.

8.1 Design Microworlds Without Computers

Readers can think of a design microworld as application software. Many of my examples will be of this type. However, a design microworld does not have to be limited to environments that are computer-based. Consider the following example.

Nynex, the parent company of New York telephone, put together a team of people who were given the mission of re-designing the company's way of handling orders. Each member of the design team was sent out to a different facility within the company. Among other things, they discovered that it was taking 126 worksteps and 40 people to fill a single order. This was causing many errors, duplication of effort and delays. The information the service representatives needed to take orders was often insufficient for the engineers to fill orders. Work was routed from the representatives to service supervisors and from them to technicians. Particularly difficult orders would be handed off to yet other technicians. Because people with different functions were insulated from each other, there was no way for Nynex employees to share experiences or learn from each other's mistakes. Nynex had become a learning dysfunctional organization.

The design team began to explore a model of work in which orders would be processed by a team comprised of representatives of each of the functional units. The design team also began to examine different models of team interaction (e.g., How does an African band function? How does a startup company function?). They even imagined a virtual employee, Melvin. Melvin would be able to handle everything himself. What Melvin could not do, his virtual assistants would be able to do. These creative ways of approaching the re-design of Nynex caused the design team to recommend measures that they thought would radically reduce Nynex's costs of doing business while improving its performance (Corcoran, pp. 118-120).

The Nynex design team's approach illustrates elements of good design, including microworld design. Melvin, their virtual employee, illustrates Papert's notion of an object-to-think-with. The flow of work in a corporation is too abstract to contemplate and debug without a virtual object in which to embody it. By using Melvin to conceptualize work-flow, the designers could experience it in a personal way ("get their heads around the problem").

The practice of building and debugging models is another good design idea. This practice was supported by the design team's organization into functional unit representatives which mapped naturally to Nynex's larger organization. It was also supported by Melvin and his virtual assistants. Melvin became the point of intersection of the perspectives of each of Nynex's functional unit representatives. Through model building, the design team began to think of Nynex as a system. Through an examination of team models (African bands, startup companies) the design team could explore and debug different notions of system until one that best fit Nynex emerged.

Finally, the design team was *designing* in the senses I have discussed. The company knew there was a problem of inefficiency but they did not know how to formulate it; the problem was open-textured. The design team suspected there was a solution, perhaps several equally satisfactory ones; the solution was debatable. They did not have an algorithmic solution available to them; rather, they had to construct the environment of design in order to explore candidate solutions and use them to reflexively redefine the problem; the solution was emergent rather than planned.

8.2 The Toolmaker's vs Conduit Paradigms of Communication

The Nynex approach reflects what Reddy calls the *toolmaker's paradigm* of communication. In this paradigm "communication will almost always go astray unless real energy is expended". Communication requires mental work; there are not channels of communication through which knowledge flows but tools for constructing and refining knowledge as it is being used.

In contrast, tool designers often assume what Reddy calls the *conduit paradigm* of communication. They assume that tool users can easily take advantage of someone's else case knowledge. In the conduit paradigm, communication is automatic. Thoughts and feelings are "inserted" into words, and language serves as a "conduit" through which these words are passed to

another interlocutor who recovers the meaning of these words by "extracting" the thoughts and feelings they contain (Reddy).

The conduit and toolmaker paradigms of communication assume opposing models of learning. The conduit paradigm denies the importance of personal experience on the process of understanding. The toolmaker's paradigm depends on it; it assumes that attention needs to be placed on the development of environments and tools through which a designer can construct his own experience, case by case. The toolmaker's paradigm is also the designers.

Recall that Gross's Constraint Explorer was a computer-based environment for designing architectural spaces (chapter 4). For Gross, expert designers have sets of constraints that they can re-use in particular kinds of design situations. However, rather than give these sets of constraints to novices, Gross developed an environment in which designers can explore the productivity of different sets of constraints and construct invariance ("default constraints") for themselves. Gross's Constraint Explorer also reflects the toolmaker's paradigm.

Contrast this with many CAD environments currently available or under development. Silverman and Mezher argues that expert designers make mistakes for two general reasons; they either use the *wrong knowledge* or they use the *wrong reasoning*. Some currently available CAD environments provide assistance to designers by evaluating human proposed solutions to see whether the designer has ignored important facts or violated first principles or constraints. Silverman and Mezher are attempting to extend these systems by adding *knowledge collaborators*, software tools for knowledge acquisition (as in the "learn word" button on spelling checkers), case based tools to help designers avoid errors, reusable data, and expert critics to check designs from a variety of heuristic viewpoints (Silverman and Mezher).

The knowledge collaborator assumes the conduit metaphor of communication; it offers information compiled from the experiences of other users. A subscriber to the toolmaker's paradigm would argue that a knowledge collaborator "who" helps a user avoid errors could hinder a user's ability to learn how to avoid errors.

Making reusable data available is also a task of the knowledge collaborator. No one would argue against the idea of reusable data. Data that is often reusable is standardized product design data, material and costing parameters, machine tool tolerance and wear parameters, and aspects of a previous design specification that do not have to change in the new design. Companies typically incur large costs in the production of data. Duplicating data duplicates the costs of generating it (Oliva). Reusable data illustrates what Piaget means by certain kinds of mental schemes. What makes a mental scheme "reusable" is that the learner has come to recognize pieces of knowledge that are invariant among a variety of situations; indeed, reusability is what makes a mental scheme powerful!

However, automated reusability reflects the conduit metaphor; it reminds the user of data he never remembered in the first place. Reusability in Piaget's sense requires support for the user to develop his own notions of what kinds of data are reusable.

Many intelligent tutoring systems assume the conduit paradigm of communication. They assume that the more intelligent the system, the more intelligent the user of that system. An exception is an air traffic control simulator developed by David Cavallo.

An air traffic controller has to manage an air space that can be populated with many converging airplanes, additional departing planes and still others flying through the air space onto other destinations. Traffic patterns are designed to maximize safety. The goal of a controller is to move airplanes entering his air space into safe patterns or variations of them. However, there are many strategies for achieving this goal, and many variables and constraints that can influence the choice of strategy.

Experienced controllers say that there is no best strategy for a given situation, just better strategies. Since traffic patterns are never exactly the same, controllers have to construct solutions, they cannot use ready-made ones. Moreover, traffic patterns are dynamic, and "solutions" are always provisional. Expert controllers do not see airplanes they see patterns of airplanes. Experience tells them what strategies to use in order to maneuver one airplane pattern into another. These are among the reasons why experienced controllers encourage novices to develop their own style and then use strategies within that style.

Cavallo's simulator could not be a conventional tutoring system where problems and strategies for solving them are well defined. Instead, Cavallo needed to develop a microworld in which a novice controller could acquire the cluster of strategies necessary to dynamically "design" flight patterns.

Cavallo's strategy was to reformulate the active tutor found in conventional systems as a collection of passive computational agents, each with a specialized function. There are three categories of computational agents in his system: domain agents, agents that suggest things to think about, and meta-agents that critique and control the activities of other agents. Some agents manage pieces of information (e.g., flight regulations, schedules, types of planes, positional information), and other agents recognize ineffective decisions (e.g., re-vectorings of airplanes that could have been done more simply, or decisions that resulted in the need for more drastic action later). In all cases, agent information is available to user on demand only; the agents are passive. It is the user, not the system that has to make these inquiries since knowing when to know something is part of what it means to have skill.

Cavallo's simulator keeps a trace of a run through a particular scenario. It also has a collection of flight scenarios, each designed to emphasize certain kinds of general control ("design") problems. Even though a scenario is never predictable for very long due to novice-scenario interactions, an

examination of a run might suggest what other scenario to try next. The novice can also create or alter flight scenarios, giving him the chance to expose himself to experiences he feels he needs.

Much of the neatness of conventional tutoring systems is a result of developers putting the intelligence into the system. In such systems, it is always easy to assess progress because progress runs along a predictable line. Cavallo did not have this luxury. His users had to be intelligent, not the system. What Cavallo provides the novice controller is the means to run experiments, build up a case history and a way to examine histories. Perhaps, because of the nature of air traffic controller skill, Cavallo was forced to develop a simulator that applied AI methods in a constructionist way (Cavallo).

One can guess that it is difficult for a novice air traffic controller to get the necessary experience without endangering human life. This is why a simulator was desirable. A reason why simulation was thought to be effective is that air traffic controllers experience the world mediated through a technology anyway; a simulation designer can provide "natural mappings" between the virtual and real worlds.

One difference between the real world and Cavallo's simulator is that a novice can stop an air traffic scenario and re-run it from any point using different control strategies. Cavallo's system allows visual comparisons of up to three different traffic patterns beginning in the same way. The simulator also makes it possible for users to construct virtual worlds in order to support pattern-debugging.

Of course, this kind of design support makes the simulated world unlike the real world. It is "unnatural" because an air traffic controller does not have this kind of control over the real world. However, questions about the naturalness or unnaturalness of a simulator depends on what the simulator is for. Only part of the problem is for the virtual world to capture what is important about the real world. Another consideration is for the design environment to support how people learn.

My final example of an environment that assumes the toolmaker's paradigm is Machover's hyperinstruments, a tool designed to enhance musical expression. *Hyperinstruments* is an orchestra building environment that preserves the performer's control over the human-machine interaction. Hyperinstruments uses software and *MIDI data*--a kind of ASCII for music--to create a rich relationship between performer actions and musical result. In the simple case, one gesture produces one note. However, in more complex cases, a gesture may evoke an instruction for the computer to play a melody stored in its memory. Alternatively, a gesture (e.g., a particular note, tremolo, or pizzicato) may evoke an "automated arpeggiator" or some other algorithm that manipulates the notes or timbres of notes that have been played. The character of the computer-generated material can be altered by the performer playing particular notes loud or soft. The tempo or timbre of the computer-generated music might also be altered depending on other performance gestures (as in

pitch bend or afterpressure). MIDI data, the product of these gestures, might be used as inputs to algorithms. Because gestures can be mediated by software, rather than the performer changing the material directly, he might change the behavior of the algorithms which change the material.

Machover is careful to avoid giving performers either too much or too little to do within the interpretive process. Hyperinstruments must remain an extension of the body much as traditional instruments are. Hyperinstruments must also serve as a vehicle for musical intention. A performer must be able to imagine the music that will result from his gestures. He must be able to send data using natural gestures and receive musically salient feedback so that he can master the new performance craft made possible by the tool (Machover).

Hyperinstruments facilitates these expressive goals for both composer and performer because it is an environment in which different kinds of orchestras can be conceptualized, tried out, and modified. It offers new ways to manage musical complexity by providing natural mappings between its gestural language and the musical result. Thus, hyperinstruments amplifies human expression in a constructionist way.

* * *

The toolmaker's paradigm is constructionist; it assumes that knowledge is mentally constructed through use. Gross's Constraint Explorer, Cavallo's air traffic controller simulator and Machover's Hyperinstruments are all examples of design microworlds that foster the construction of knowledge through the construction of objects, either real or virtual (e.g., buildings, flight patterns, orchestras).

The new idea of design microworlds is that computing makes them concrete and, thus, as easy to design and evaluate as other kinds of artifacts. But then, we need a collection of ideas to support the process of microworld design and evaluation. This is the gap constructionist interactivity attempts to fill.

The following two chapters report on the development of two Logo-based design microworlds, one in music and the other in textile design. These design microworlds are used as a means of identifying some of the ideas that comprise the aesthetic of constructionist interactivity.

Chapter 9

The Music Designer

Introduction

Papert-the-epistemologist has said: One cannot think about thinking without thinking about thinking about something. Applied to designing we can say that one cannot think about designing without thinking about designing something. That "something" in this chapter is a design microworld for music composition.

My initial work on *The Music Designer* was inspired by an early paper by Seymour Papert entitled *Teaching Children to be Mathematicians vs Teaching About Mathematics* (Papert, 1971). In that paper Papert describes Logo's Turtle Geometry and how it supports mathematical thinking rather than mathematics teaching. Mathematics teaching involves familiarizing novices with the tools of the mathematicians trade like the times table or the laws of Euclid. However, mathematicians do not only use tools, they make them; they do not only operate within mathematical systems they construct these systems and learn to appreciate the advantages and disadvantages of them. Some of the most exciting mathematical thinking happens at this epistemic level. Logo supports mathematical thinking by providing novices a modelling language that can be personalized through turtle geometry. Rather than teaching mathematics, mathematical thinking is made more learnable.¹

It was obvious that Papert's complaint about traditional mathematics education applied to traditional music education. I began to look for ways of extending Logo so that it would provide a medium for coming in contact with musical thinking just as turtle geometry had done for mathematical thinking. While I did not entirely succeed, the process of developing the microworld made me aware of some of the criteria I was using to design and evaluate it, criteria that I began to organize as an aesthetic of microworld design.

¹ I believe this difference between learning and teaching is what separates my work from the work of Jeanne Bamberger, the most prolific researcher in Logo music. For Bamberger, Logo is used to support the teaching of Western musical thought much like computers might be used to support the teaching of Euclidean geometry. Music does not have this privileged status in my work. I am interested in musical thinking as an instance of learning by designing.

9.1 The Music Designer²


9.1.1 Representation

Logo's list processing facility seemed to provide a natural representation for music. With lists one could represent a string of notes and durations, and construct procedures for manipulating them. For example, the following list represents one C major scale using Logo lists.

(Logo List)

```
[[C1 30] [D1 30] [E1 30] [F1 30] [G1 30] [A1 30] [B1 30] [C2 30]]
```



Notice that the above list contains tiny lists (i.e., *sublists*), one for each note-duration pair. The durations (the number 30 in each sublist) are in Logo WAIT units (where 60 WAIT units equals 1 second and where 10 WAIT units = ). A list does not have to be a scale nor do all the durations have to be the same. A list can be a melody of any length and any durational pattern. I wrote a procedure for playing lists of notes (e.g., PLAYNOTES).

Plays list of notes

```
PLAYNOTES [[C1 30] [D1 30] [E1 30] [F1 30] [G1 30] [A1 30] [B1 30] [C2 30]]
```

9.1.2 Naming

In Logo, one can describe a list in a musically salient way by naming it (e.g., CMAJOR1). In the following examples, notice that the Logo command MAKE is used to give a name to a list. When a colon precedes the name of something (e.g., :CMAJOR1), the computer knows to look for the associated list. The Logo command SHOW shows a list on the computer screen.

Gives name CMAJOR1 to list of note-duration pairs

```
MAKE "CMAJOR1 [[C1 30] [D1 30] [E1 30] [F1 30] [G1 30] [A1 30] [B1 30] [C2 30]]
```

Shows what name CMAJOR1 stands for

```
SHOW :CMAJOR1 =>
[[C1 30] [D1 30] [E1 30] [F1 30] [G1 30] [A1 30] [B1 30] [C2 30]]
```

Plays list with name CMAJOR1

```
PLAYNOTES :CMAJOR1
```

9.1.3 Motivic Development: A Powerful Idea Analytic and Synthetic Tools

The procedure REVERSE was designed to reverse lists. REVERSE can be thought of as a compositional tool. It is one of many that I designed to support motivic development, a *powerful*

² For a full demonstration of this approach see the E&L Memo 14 entitled *Making Music* (Gargarian).

idea in Papert's use of the phrase. Most of these procedures could be used as either analytic or synthetic tools. For example, one might want to know what a melody sounds like backwards and use REVERSE to explore this question; or one might want to construct a procedure that makes new melodies by reversing old ones. In either case, the tool facilitates debugging because it makes explicit the kind of action taken.

Shows reverse of list with name CMAJOR1

```
SHOW REVERSE :CMAJOR1 =>
[[C2 30] [B1 30] [A1 30] [G1 30] [F1 30] [E1 30] [D1 30] [C1 30]]
```



Plays list of notes after it has been reversed

```
PLAYNOTES REVERSE [[C1 30] [D1 30] [E1 30] [F1 30] [G1 30] [A1 30] [B1 30] [C2 30]]
```

Plays reverse of list with name CMAJOR1

```
PLAYNOTES REVERSE :CMAJOR1
```

The following tools break apart lists of notes and durations. EXTRACTDURATIONS takes out the durations from a list of note-duration pairs; and EXTRACTNOTES takes out the notes from a list of note-duration pairs. With these tools, a user can reverse just the notes or durations of a melody.

Shows just durations in list with name CMAJOR1

```
SHOW EXTRACTDURATIONS :CMAJOR1 =>
[30 30 30 30 30 30 30 30]
```

Shows just notes in list with name CMAJOR1

```
SHOW EXTRACTNOTES :CMAJOR1 =>
[C1 D1 E1 F1 G1 A1 B1 C2]
```

Shows reverse of notes in list with name CMAJOR1

```
SHOW REVERSE EXTRACTNOTES :CMAJOR1 =>
[C2 B1 A1 G1 F1 E1 D1 C1]
```

The following tools put lists of notes and durations into a list of note-duration pairs. MAPDURATIONS will map a list of durations to a *list-of-pairs* (e.g., CMAJOR1); and MAPNOTES will map a list of notes to a *list-of-pairs*. In both cases, the procedures have been written so that they accept input lists comprised of either note-duration pairs or just patterns of durations or notes.

Possible forms

MAPDURATIONS *durations notes*
 MAPDURATIONS *list-of-pairs list-of-pairs*

Maps durations onto list with name CMAJOR1

SHOW MAPDURATIONS [10 10 10 10 10 10 10] :CMAJOR1 =>
 [[C1 10] [D1 10] [E1 10] [F1 10] [G1 10] [A1 10] [B1 10] [C2 10]]



Possible forms

MAPNOTES *notes durations*
 MAPNOTES *list-of-pairs list-of-pairs*

Maps notes onto list with name CMAJOR1

SHOW MAPNOTES [C1 D1 C1 D1 E1 F1 G1 C1] :CMAJOR1 =>
 [C1 30] [D1 30] [C1 30] [D1 30] [E1 30] [F1 30] [G1 30] [C1 30]]



To produce melodic variations, it is useful to be able to extract durations and notes from one list and use them with another list. Alternatively, one can manipulate just the notes or durations of a list and re-apply them to the same list. For example, let's represent the beginning of the melody *row row row your boat* and give it the name ROW1.

Give the following list the name ROW1

MAKE "ROW1 [[C1 30] [C1 30] [C1 20] [D1 10] [E1 30]]

Shows list with name ROW1

SHOW :ROW1 =>
 [[C1 30] [C1 30] [C1 20] [D1 10] [E1 30]]



With the tools we already have we can reverse the melody, reverse just the notes of the melody, or reverse just the durations of the melody.

Reverse melody

SHOW REVERSE :ROW1 =>
 [[E1 30] [D1 10] [C1 20] [C1 30] [C1 30]]

Reverse just notes

SHOW MAPNOTES REVERSE :ROW1 :ROW1 =>
 [[E1 30] [D1 30] [C1 20] [C1 10] [C1 30]]

Reverse just durations

SHOW MAPDURATIONS REVERSE :ROW1 :ROW1
 [[C1 30] [C1 10] [C1 20] [D1 30] [E1 30]]

Once we see what our tools give use, we can organize their use in higher-level composing procedures, an example of how tools can support both analytic and synthetic activity.

9.1.4 Harmonic Development: A Powerful Idea

I constructed a different representation to explore harmonic development. Instead of a melody being defined as a list of note-duration pairs, the new representation defines a melody as the application of a melodic *contour* to a scale. Changing the contour, the scale or both produces a different melody. Being able to change scales independent of other factors (e.g., contour or rhythm) is useful at the harmonic level.

Below is the C major scale. Above each note is a number that stands for each note's contour position.



Below is another scale, a C minor scale. It has the same number of contour positions even though the notes are different.

Gives name CMINOR1 to list

```
MAKE "CMINOR1 [[C1 30] [D1 30] [Eb1 30] [F1 30] [G1 30] [Ab1 30] [Bb1 30] [C2 30]]
```

Shows list with name CMINOR1

```
SHOW :CMINOR1 =>
```

```
[[C1 30] [D1 30] [Eb1 30] [F1 30] [G1 30] [Ab1 30] [Bb1 30] [C2 30]]
```



The Logo procedure used to produce melodies from contours and scales is called CONTOUR. It has two inputs, a contour pattern and a scale. CONTOUR is a tool that helps the composer to formulate a melody as a contour and a scale.

Notice that when the contour pattern [1 3 5 3 1] is applied to the C major and C minor scales the results are different.

```
SHOW CONTOUR [1 3 5 3 1] :CMAJOR1 =>
[[C1 30] [E1 30] [G1 30] [E1 30] [C1 30]]
```



```
SHOW CONTOUR [1 3 5 3 1] :CMINOR1 =>
[[C1 30] [Eb1 30] [G1 30] [Eb1 30] [C1 30]]
```



A contour pattern like [1 3 5 3 1] specifies the shape of a melody without specifying its note content. Note content is not specified until the contour is applied to a scale. It is possible to specify the contour of an entire melody like *row row row your boat* and apply it to a number of different scales to produce *harmonic* variation. However, in order to represent *row row row your boat* in this new way, we need a contour pattern and duration pattern for each of the parts of the song.

row, row, row your boat,

MAKE "ROWCONTOUR1 [1 1 1 2 3]
MAKE "ROWRHYTHM1 [30 30 20 10 30]



gently down the stream.

MAKE "ROWCONTOUR2 [3 2 3 4 5]
MAKE "ROWRHYTHM2 [20 10 20 10 60]



merrily, merrily, merrily, merrily

MAKE "ROWCONTOUR3 [8 8 8 5 5 3 3 3 1 1 1]
MAKE "ROWRHYTHM3 [10 10 10 10 10 10 10 10 10 10 10]



life is but a dream.

MAKE "ROWCONTOUR4 [5 4 3 2 1]
MAKE "ROWRHYTHM4 [20 10 20 10 60]



Next, we need to construct a Logo procedure written to take advantage of CONTOUR's flexibility. ROWMELODY is such a procedure. Notice that each of the lines of the procedure are almost the same except for the names of the different contours and durations.

```
TO ROWMELODY :SCALE
  PLAYNOTES MAPNOTES (CONTOUR :ROWCONTOUR1 :SCALE) :ROWRHYTHM1
  PLAYNOTES MAPNOTES (CONTOUR :ROWCONTOUR2 :SCALE) :ROWRHYTHM2
  PLAYNOTES MAPNOTES (CONTOUR :ROWCONTOUR3 :SCALE) :ROWRHYTHM3
  PLAYNOTES MAPNOTES (CONTOUR :ROWCONTOUR4 :SCALE) :ROWRHYTHM4
END
```

What each line of ROWMELODY does is produce a note pattern by applying a contour to a scale (e.g., CONTOUR :ROWCONTOUR1 :SCALE) and then use MAPNOTES to combine the previous result with a duration pattern (e.g., :ROWRHYTHM1) to produce a melodic part.

Finally, the procedure ROWVARIATIONS takes a list of scales and gives them one by one to ROWMELODY (inside ROWVARIATIONS) until all the scales have been used, then it stops.

```
TO ROWVARIATIONS :SCALE-LIST
IF EMPTY :SCALE-LIST [STOP]
ROWMELODY FIRST :SCALE
ROWVARIATIONS BUTFIRST :SCALE-LIST
END
```

Typing,

```
ROWVARIATIONS [:CMAJOR1 :CMINOR1 :CMAJOR1] =>
```

will produce versions of *row*, *row*, *row your boat* in a major, minor and then major key. ROWVARIATIONS gives a hint of the possible projects one might pursue using patterns of scales (rather than notes) as construction elements.

9.2 The Strengths of The Music Designer

The The Music Designer has strengths and weaknesses. I begin with its strengths, referring to ideas presented in earlier chapters on design theory and practice.

9.2.1 Powerful Ideas

Papert's *powerful ideas* are ideas that are either useful in a variety of contexts or ideas that are generative of other ideas. Tools are available in the Music Designer to support the use of powerful ideas like motivic and harmonic development.

9.2.2 Debugging Tools for Feature Differentiation

We have seen that designing is a reflective practice, that designing is, in part, re-designing. The Music Designer provides debugging tools that allow data extraction (analysis) and data construction (synthesis).

It is difficult for experienced musicians to imagine that novices often view melodies as undifferentiated, un-decomposable patterns. They do not hear melodies as constructs made up of recognizable elements like notes and durations. What novices need, and what The Music Designer supports, is a way to examine these characteristics of melodies by running melodic experiments.

For example, in a workshop held at the University of Campinas in 1990, Brazilian researchers ran a 2-week workshop using The Music Designer with several public school teachers. These researchers found that teachers became more discriminating listeners, differentiating notes from durations, contours from melodies. The feature differentiating tools were persuasive because they made kinds of features explicit and manipulations of them compositionally productive (Baccarelli and Martins).

9.2.3 Perspective Taking

Recall from chapter 5 that Jose became a more creative songwriter because he was able to entertain a variety of metric representations in his text-fitting problems. Perspective taking is supported by The Music Designer through its two forms of representation, melodic and harmonic. A designer wants to look at the level of abstraction relevant for his current design problem. In music, levels of abstraction are spans of musical time. Scales in a song are at a different level of abstraction than notes in a melody.

9.2.4 Preserving Representations in Future Extensions

In LogoWriter notes can only have frequency (i.e., pitch) and duration. It is easy to imagine a future Logo that includes amplitude values and musical instruments (i.e., timbre). The amplitude values could be added to the microworld. For example, the list:

```
[[C1 30] [D1 30] [E1 30]]
```

would look like:

```
[[C1 30 p] [D1 30 mp] [E1 30 f]]
```

where *p*, *mp* and *f* stand for amplitude values written in conventional music notation. (Naming allows designers to assign amplitude names to numeric values.) With amplitudes incorporated in the representation, tools like EXTRACTAMPS and MAPAMPS (for "extract amplitudes" and "map amplitudes", respectively) could be constructed.

Names list PHRASE

```
MAKE "PHRASE [[C1 30 p] [D1 30 mp] [E1 30 f]]
SHOW EXTRACTAMPS :PHRASE =>
[p mp f]
```

Maps amplitudes onto list with name PHRASE

```
SHOW MAPAMPS [f f f] :PHRASE =>
[[C1 30 f] [D1 30 f] [E1 30 f]]
```

Reverses only amplitudes in list with name PHRASE

```
SHOW MAPAMPS REVERSE :PHRASE :PHRASE =>
[[C1 30 f] [D1 30 mp] [E1 30 p]]
```

Musical instruments (i.e., timbre) could be similarly represented. However, Logo currently has the command SETSH (for "set shape") which is used to change the shape of a graphic object. The shape stays around until another SETSH command is used. It seems reasonable to think metaphorically of a musical instrument as an auditory shape to which a user assigns notes.

Select instrument

```
SETINST name
```


SETINST (for "set instrument") might do for sounds what SETSH does for graphics. *Name* is a number or name associated with a particular instrument. When a Logo interface to MIDI becomes available³, sound articulation will also be available.

Here I only wish to point out a direction of development. Many Logo projects would be greatly improved with concurrent Logo turtles each "carrying" a different graphic shape and driven by its own processor (Resnick, 1992). For example, Randy Sargent has demonstrated how video game design can be made more natural with concurrence.⁴ The same applies to musical "objects", either those that might support animation projects with sound effects, or pieces of music with more than one voice. One can make an analogy between Logo turtles and graphic shapes, and Logo *voices* and instruments. A Logo *voice* could be assigned an instrument and the controls for coordinating turtles could be similar in form to those coordinating voices. Of course, it is easier to make the analogy than to implement it.

These extensions to The Music Designer—voices, instruments, notes, durations, amplitudes and concurrence—would be consistent with the representations currently used in the microworld.

9.3 Responding to the Weaknesses of The Music Designer

I now turn to an evaluation of the weaknesses of The Music Designer and my attempts to remedy them. These evaluations and re-designs give me an opportunity to elaborate additional criteria of constructionist interactivity.

9.3.1 No Object-to-think-with

The Music Designer suffered from the lack of an *object-to-think-with* defined by Papert as an object "in which there is an intersection of cultural presence, embedded knowledge, and the possibility for personal identification" (Papert, 1980, p. 11). A classic example of an object-to-think-with is the Logo turtle. The Logo turtle is a (computational) object the child can use to develop anthropomorphic relationships with knowledge, what Papert calls *syntonic* relationships. These relationships are *ego-syntonic* because the learner can identify with the turtle; *body-syntonic* because "playing turtle" makes body movements illuminating of turtle movements; and *culturally-syntonic* because navigating the turtle connects with one's everyday contact with navigation (Papert, pp. 63-68).

Logo lists and the commands for manipulating them are not objects-to-think-with as is the Logo turtle. It is true that identification is possible because list processing commands borrow meanings from natural language.

³ Paula Bonta is working on a Logo-MIDI interface.

⁴ Through conversation.

Examples of Using Logo Lists	Comments
SHOW FIRST [ONE TWO THREE FOUR] => ONE	;show first of list
SHOW LAST [ONE TWO THREE FOUR] => FOUR	;show last of list
SHOW BUTFIRST [ONE TWO THREE FOUR] => [TWO THREE FOUR]	;show all but first of list
SHOW BUTLAST [ONE TWO THREE FOUR] => [ONE TWO THREE]	;show all but last of list

It is also true that those familiar with music can use The Music Designer to "make friends" with lists. However, these identifications take some time and are somewhat abstract. This becomes apparent if one imagines a programming bug with turtle graphics and a programming bug with lists. How does one "play lists" like one "plays turtle"? It is possible, but not obvious.

What could I use as a musical object-to-think-with? Two concrete things happened that precipitated an answer. First, a version of Logo that incorporated sound digitizing became available. This technical development was thanks to Alan Shaw. Alan had been working with black children in the U.S. while I had been involved in Logo projects in Brazil. Our experiences caused us to draw similar conclusions; namely, that Logo programming could serve as a bridge between the arts and sciences if Logo was more media rich.

Sound digitizing made sound "objects" concrete. With digitized sound, a user could record any sound, name it, and then use it within Logo procedures. In order for Logo users to use these sounds as they use other sounds in The Music Designer, I wrote the procedure **PLAYSOUNDS** which does with digitized sounds what **PLAYNOTES** does with Logo notes. For example, typing the following results in two sounds named **THUMP** with durations 20 (in Logo **WAIT** units).

```
PLAYSOUNDS [[THUMP 20] [THUMP 20]] =>
```

PLAYSOUNDS has many supporting procedures that I will not discuss here (see Appendix F: Using Digitized Sound in The Music Designer) What they do is measure the duration of the digitized sound in Logo **WAIT** units, cut off the excess sound if it is longer than what the user wants, or add rests if the sound is too short. Because tools like **EXTRACTNOTES**, **EXTRACTDURATIONS**, **MAPNOTES**, **MAPDURATIONS** and **CONTOUR** do not actually play sounds, they can also be used with digitized sounds.

Second, I began going to the Paige Academy, an Afrocentric school in Roxbury Massachusetts, a school established in order to give black children opportunities to construct their learning in a collaborative and culturally-sensitive way. One cannot avoid noticing the energy of the children at Paige and the high place given to music and dance by the school's founders, Joe and Angela Cook.

I saw an opportunity to integrate Logo into Paige's school culture by developing an animated conga drummer and Shaw's sound digitizing feature to serve as the interface between the children and The Music Designer.

**9.3.2 Objects-to-think-with:
A Conga Drummer and Flamenco Dancer to Create Natural Mappings between Music and Movement**



The animated conga drummer (above) became the object-to-think-with and the area of inquiry became drumming. I wrote procedures for moving the hands of the drummer while playing prerecorded conga drums sounds.

drum gestures

LTHAND	strike drum with left hand
RTHAND	strike drum with right hand
BOTHHANDS	strike drum with both hands

drum sounds

RIM	the sound of the drum at its rim
HIGH	the sound of the drum between its rim and center
LOW	the sound of the drum at its center

Each hand gesture could be accompanied by one or several sounds, using my list representation and the procedure `PLAYSOUNDS` (both "hidden" from the user).

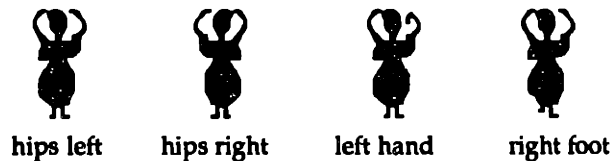
one gesture, one sound

LTHAND [HIGH 20]

one gesture, many sounds

BOTHHANDS [[LOW 20] [LOW 20] [LOW 20]]

The conga drumming microworld solved the problem of giving users an object-to-think-with and made list representation concrete by connecting list elements to physical gesture, and music to movement. Users could now "play conga drummer" and through this process define and debug drum patterns.



The idea of making an animated flamenco dancer came at the time I was working at Paige Academy and while my wife Jacqueline was taking flamenco classes. It is another object-to-think-with similar to the conga drummer. With the flamenco dancer, percussion and dance are intertwined. The dancers hands, feet and hips are animated. The hands move when the dancer plays a castanet, and the feet move when the dancer stomps the ground. These two gestures also use PLAYSOUNDS, the procedure for playing digitized sounds.

dancer gestures

LTCAST	play castanet with left hand
RTCAST	play castanet with right hand
LTFOOT	stomp left foot
RTFOOT	stomp right foot
HIPSLT	move hips left
HIPSRT	move hips right

dancer sounds

CAST	castanet sound
STOMP	foot sound

one gesture, one sound

LTCAST [CAST 20]

Hip movements serve a different purpose. They move left or right to mark melodic phrases produced using PLAYNOTES, the procedure for playing Logo tones. This additional melodic possibility distinguishes it from the conga drummer.

one gesture, many sounds

RTFOOT [[STOMP 60] [STOMP 60] [STOMP 60]]

one gesture, many notes

HIPSRT [[G1 15] [C2 30] [G1 15] [C2 30] [G1 15] [C2 30]]

9.3.3 Need for an Operational Folklore

Recall Granott's research on anthropomorphic versus mechanistic descriptions of cybernetic robots (chapter 2). Her research generates what I call an *operational folklore*, a cultural interface between the natural culture and a technology (in this case, Lego-Logo). The conga drummer and flamenco dancer are examples of objects around which such an operational folklore could form.

Some music historians believe that music began intimately connected to speech. They argue that the intonations and timings that give speech its expressive quality are the "musical" components of speech and that over time musical thought developed an autonomous organization. There is much evidence for this. The "talking" drum in Africa is an instrumental example. Another is the prevalence of *troubadours* (i.e., poet-musicians) in the early histories of most cultures across the world. Even the notations used to represent expressiveness in western music began with punctuation marks taken from the written text (Keller).

Other music historians believe that music began intimately connected to physical movement. Work songs from around the world demonstrate how music was used to coordinate physical movement and thus make collective work more efficient (Blacking, 1990, pp. 56-59). Classical musical forms also inherit their structure from movement; in particular, from court dance. It is not a coincidence that the parts of a symphony are called *movements*, each originally modelled on dance. As with music and speech, music has been able to develop conceptual autonomy from movement.

Finally, music has often been connected to drama, both secular and liturgical. Here one finds connections between music and speech, and music and movement. If it took hundreds of years for the most capable composers to evolve an autonomous musical craft, why should we expect a novice to construct musical knowledge without similar foundations? The conga drummer, flamenco dancer and the talking head (soon to be discussed) were attempts to offer routes into music via performance, movement and speech.

9.3.4 Transcending the *Learning Paradox*

An operational folklore is necessary because of the *learning paradox* (chapter 2). Recall that for Piagetians, new learning is possible because one uses a familiar mental scheme to make observational discriminations. However, if something is totally unfamiliar one cannot use a familiar mental scheme to identify unfamiliar data; and without data, one cannot construct a new mental scheme. The learning paradox reminds us that learning something completely new is impossible, or if learning is happening, what one is learning is not completely new. The conga drummer and the flamenco dancer provide links between music and movement in order to transcend the learning paradox.

An analysis performed in 1991 provides a similar insight. At that time I studied a tape (recorded by the ethnomusicologist Stephen Erdely) of 38 songs sung by a population of 20 seven-year-old children, 14 female and 6 male. The songs on the tape are western songs, comprised of a mixture of popular childrens' songs and church songs (e.g., *Jesus Loves Me*).

The principle purpose of the analysis was to study these childrens' ability to replicate a song and to account for replication errors when they occurred. For this reason, the analysis was most illuminating when a song was performed *incorrectly* (i.e., from the perspective of a native adult listener).

The details of this study are reported in Appendix G: An Analysis of Children's Replication of Songs. Some of my observations are based on inadequate data. For example, there were gender and ethnic differences that would be interesting to pursue in future studies focussing on the sociology of music. It would also be interesting to explore a notion of song *innovation* that I define in the study as replication errors that do not violate the musical conventions of the interpreter. I think of an

analogy with biology; *mutated* copies of a song that are *adaptive* (pleasurable) *survive* (are repeated). A few innovations of this type were made by the children.⁵

Here, I want to focus on patterns of error found in the study that were too frequent to be accidental. The analysis showed that a correct replication of a melody required a correct replication of its contour but the reverse was not true. It seems that an intuitive knowledge of musical scale was missing in cases where contours but not melodies were correctly replicated. This conclusion supports the utility of the contour representation used in the Logo microworld (i.e., the idea that a contour applied to a scale produces melody notes).⁶

There was strong evidence of the importance of text structure in establishing metric stability. There seems no other way to account for the fact that children maintained good metric structure within a phrase and poor metric structure at phrase endings (more than half of the time). In other words, they "lost" (or distorted) the meter at points of rest between musical phrases. It is also interesting that musical key and tempo served as relatively independent organizational devices even though these ideas play a critical expressive role in advanced interpretive practice.

Experienced musicians are tempted to organize musical concepts hierarchically from "simplest" to "most complex". For example, the following hierarchies reflect the assumption that understanding meter requires an understanding of beat; and understanding melody requires an understanding of musical key, contour and scale.

simplest
beat
meter
most complex

simplest
keynote
contour
scale
most complex

⁵ This notion of innovation allows interesting epistemological shifts like the one I observed while in Senegal, West Africa. The *Kora* is a 21-stringed plucked instrument. The one I heard played was tuned to the mixolydian scale. When it was used to play the French melody *frères Jacques* the melody was assimilated to the mixolydian scale. From a Frenchman's perspective, *frères Jacques* was played incorrectly. From a Senegalese perspective, everything important about the melody was copied because the mixolydian scale was preserved.

⁶ Dowling and Harward observe that children recognize contour by the age of 2 and simple phrases a little later. Given a constant scale, young listeners can recognize that two melodies are different by recognizing differences in their contours (Dowling and Harwood, 1986, pp. 90-152). Also see Adams' article *Melodic Contour Typology* (Adams) and Friedmann's article *A Methodology for the Discussion of Contour* (Friedmann).

According to my analysis, these hierarchies do not reflect childrens' understandings in over half of the cases. Preserving tempo is equivalent to "keeping the beat", something many of the children in my analysis were unable to do. Instead, they were able to capture much of what is important about musical meter through their understanding of text meter. Similarly, musical key was much less important than either contour or scale. Therefore, the notions of "simple" and "complex" depended much more on the analogies children could make to their own experience than on the knowledge prerequisites one finds in music textbooks.

The key idea here is that personal experience can provide a multiplicity of pathways to increasing expertise. In the case of the song replication study with children, personal experience included familiarity with natural language. In the case of the successful users of The Music Designer, personal experience could include familiarity with Logo.

9.3.5 **Objects-to-think-with** **A Talking Head to Create Natural Mappings between Language and Music**

While at Paige Academy I observed the language arts teacher working with children. In order for children to make connections between the spoken and written word and between words, the language teacher would use rhyming words like CAT, BAT, HAT or FALL, BALL, TALL.

Using Logo with sound digitizing, it was possible for users to record word sounds and use programs to put these sounds together. I wrote one program that would try out a word ending like AT or ALL with all the consonants of the alphabet: for example, it would produce an auditory sequence like BAT, CAT, DAT, FAT, GAT, HAT, JAT... or BALL, CALL, DALL, FALL, GALL, HALL, JALL... while printing the word in a large font on the screen. The children enjoyed the nonsense words as well as those familiar to them.

Another program I wrote produced random sentences from collections of pronouns, verbs and nouns, printed them on the screen and spoke them.

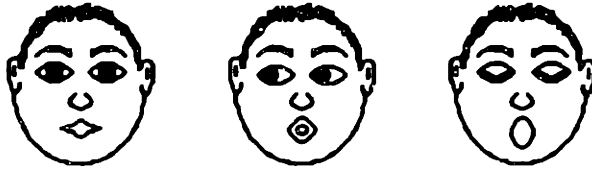
word collections

pronouns = [I YOU THEY]
verbs = [LIKE HATE SMELL]
nouns = [CAKE RATS FLOWERS]

randomly generated sentences

I LIKE CAKE
YOU HATE RATS
THEY SMELL FLOWERS
I SMELL RATS
THEY HATE FLOWERS
etc.

Once again, the children liked the nonsensical sentences and were intrigued by the computer, though many of them still kept their distance.



At this point it occurred to me to produce an object-to-think-with, an animated face I call *the talking head* (shown above). The only animated parts were the eyes and the mouth. Still, this allowed a number of animations of the face.

face animations

OPENEYES	open eyes
CLOSEEYES	close eyes
EYESLT	eyes left
EYESRT	eyes right
EYESCTR	eyes center
WINK	wink one of the eyes
BLINK	blink
OPENMOUTH	open mouth
CLOSEMOUTH	close mouth

The procedure SPEAK was written to speak one or more prerecorded sounds while animating the mouth.

"hello" with mouth animations

SPEAK [HEH LOW]

"hi" with mouth animations

SPEAK "HI

I then asked each of the children to record their names and write procedures for making the talking head speak their names. This accomplished a number of things at once. It provided an occasion for the children to learn how to use the sound digitizing facility (with the help of their more experienced friends), and it gave some of the children their first contact with Logo procedures. The children were also excited to see the talking head speak with the sounds of their own voices. (Imagine what it would be like if their own faces were digitized and animated!)

In addition, the SPEAK procedure was similar in form to the procedures used to communicate with the conga drummer or the flamenco dancer. The names of the procedures--e.g., SPEAK, LTHAND, RTFOOT, etc.--made reference to the body part being animated; and the sounds--percussion effects or syllables--were simple and organized as lists. Here was yet another way for the children to come in contact with Logo lists, and a way to relate syllables with sounds much like the children seemed to do in the song replication study.

I had hoped to integrate the talking head, the conga drummer and The Music Designer in a theatre production at Paige. To these ends, I wrote example procedures like THREEBEARS (below) in which the talking head was used as a narrator. While this work has not yet been completed, my intention was to use all of the historical links between music and other activities--movement, speech, and drama--as a strategy for transcending the learning paradox.

	<i>results</i>
TO THREEBEARS	
SPEAK [SOME ONE]	Some one...
EYESLT	(eyes left)
SPEAK [IS SLEEP ING]	is sleeping...
EYESRT	(eyes right)
SPEAK [IN MY]	in my...
EYESCTR	(eyes center)
SPEAK [BED]	bed.
END	

9.3.6 Technocentric Thinking

Initially, it did not occur to me to make any of these links. Papertians would say that I was being too *technocentric*. In his article *Computer Criticism vs Technocentric Thinking* (Papert, 1990), Papert provides a critique of approaches to the use of computers in education that focus too much on the computer and not enough on the learner. In these approaches, using computers becomes an end rather than a means to an end. Similarly, curriculum is suppose to facilitate learning in a domain for which the curriculum was designed. Instead, what often happens is that the curriculum becomes the central focus. Teaching curriculum is as technocentric as teaching computers.

Once we become aware of technocentric thinking we see it everywhere, including in music pedagogy. Teaching music is technocentric when we think of music as an isolated domain of knowledge. Domains of knowledge are partitioned to serve practical ends. Specialists are created because of the abundance of knowledge, not because experience is, itself, specialized. My shift from topics in music to more general questions about expression and design reflects my increasingly anti-technocentric posture. Expression and design are not "domains" but ways of organizing thought and action that traverse domains.

9.3.7 Learnability and Holding Power

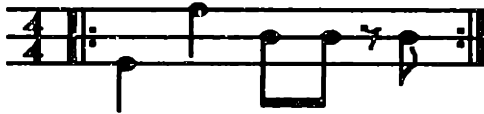
While the children at Paige were intrigued with the conga drumming microworld they were not entirely persuaded by it because they were accustomed to playing real drums along with other real drummers. I addressed this complaint in part by showing them that they could use a computer-generated drumming pattern as an accompaniment to live drumming. For example, the following drumming pattern could be played as an accompaniment (repeated 60 times) using Logo's repeat command.

```

TO PATTERN
RTHAND [LOW 30]
LTHAND [RIM 30]
RTHAND [[HIGH 15] [HIGH 15]]
REST 15
LTHAND [HIGH 15]
END

```

REPEAT 60 [PATTERN]



However, children had another complaint related to those some people have with Turtle Geometry. Why should one write a program to play a pattern (or draw a square) when it can be played (drawn) by hand? For many children this question is answered by just using Logo. However, this complaint raises subtle questions about how a design environment supports the learner's continued engagement, what Papert refers to as *holding power*.

The reason why one should write programs is that people can use simple procedures as components of more complex procedures whose results are too difficult to produce or debug manually. However, this answer is only persuasive if the user becomes engaged in an activity long enough to produce the more complex pattern. The rewards of programming are only apparent after one has learned to program, and learning to program without a meaningful programming context provides few rewards!

This is a kind of paradox, a paradox of engagement, strikingly similar to the problem of interpretability in music. Contemporary music is rewarding only after its rewards have been felt; but this requires knowledge acquired during a listening process which might not be rewarding in itself! Recall that the two criteria of learnability (chapter 5): (1) learning must be incremental and (2) the pathways to knowledge must be rewarding in themselves. It is the second criterion that I was unable to entirely meet.

9.3.8 Natural Mappings between the Conceptual and Natural Worlds

The problem of natural mappings (chapter 5) intersects with problems of representation in computer-based environments. Consider the following Senegalese polyrhythm as it is currently represented in Logo programs that direct the conga drummer. This pattern is performed by the drummer playing the top line with the left hand and the bottom line with the right hand.

Left hand in 6/8 (RIM sound)



Right hand in 3/4 (LOW and HIGH sounds)

In Logo, this pattern is represented in the procedure SENEGAL (below). Notice that there is a new sound, LOWRIM. It is a mix of the sounds LOW and RIM.

```

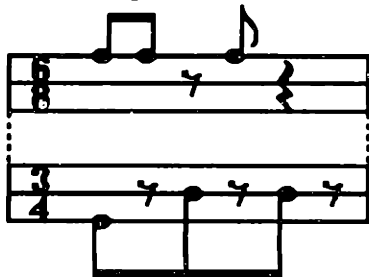
TO SENEGAL
  BOTHHANDS [LOWRIM 15]
  LTHAND [RIM 15]
  RTHAND [HIGH 15]
  LTHAND [RIM 15]
  RTHAND [HIGH 15]
  REST 15
END

```

The procedure SENEGAL is an accurate representation of the *sound* of the pattern but an inaccurate representation of how it is performed and conceptualized. By definition, a polyrhythm has at least two concurrent meters (in this case 6/8 and 3/4). It would be useful for the representation to reflect this fact by separating metric parts in right and left hand gestures of the conga drummer, the way Senegalese drummers perform it.

Below is the same polyrhythm represented in this conceptually accurate way. LEFTPATTERN is the pattern for the left hand and RIGHTPATTERN is the pattern for the right hand.

Left hand pattern



Right hand pattern

```

TO LEFTPATTERN
  LTHAND [[RIM 15] [RIM 15]]
  REST 15
  LTHAND [RIM 15]
  REST 30
END

```

```

TO RIGHTPATTERN
  RTHAND [[LOW 30] [HIGH 30] [HIGH 30]]
END

```

With these metric parts differentiated, a drummer can hear them separately and together. With LAUNCH, an hypothetical command for controlling concurrent processes, one could start more than one procedure at the same time (below).

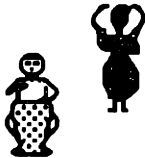
```

start LEFTPATTERN and RIGHTPATTERN together
  LAUNCH [LEFTPATTERN RIGHTPATTERN]
do above 20 times
  REPEAT 20 [LAUNCH [LEFTPATTERN RIGHTPATTERN]]

```

LAUNCH would start LEFTPATTERN and RIGHTPATTERN together, and Logo's REPEAT command would cause them to be played as an *ostinato* (i.e., repeating) pattern. With concurrent representations, physical coordination tasks (like drummer gestures) could be linked to conceptual coordination tasks (like polyrhythms), thus making debugging more natural.

I do not wish to suggest that computer representations must be familiar in order for them to be "natural". Computers could support unfamiliar conceptualizations that are learnable and productive. For example, imagine that, with concurrence, the conga drummer and flamenco dancer (below) could be directed much like the hands of the conga drummer were directed to perform the polyrhythm.



The difference is that the "program-director" would be coordinating two "actor-performers". A user could write a simple improvisation in which dancer and drummer imitate each other. DRUMMIMIC takes a flamenco pattern and uses LOOKUPDRUM to translate it into a drumming pattern. Conversely, DANCEMIMIC takes a drumming pattern and uses LOOKUPDANCE to translate it into a flamenco pattern.

mimics dancer

```

TO DRUMMIMIC :PATTERN
IF EMPTY? :PATTERN [STOP]
IF NOT LIST? (FIRST :PATTERN) [LOOKUPDRUM :PATTERN STOP]
LOOKUPDRUM FIRST :PATTERN
DRUMMIMIC BUTFIRST :PATTERN
END

```

```

TO LOOKUPDRUM :ELEMENT
IF FIRST :ELEMENT = "CAST [RTHAND LIST "HIGH LAST :ELEMENT]
IF FIRST :ELEMENT = "STOMP [LTHAND LIST "LOW LAST :ELEMENT]
END

```

mimics drummer

```

TO DANCEMIMIC :PATTERN
IF EMPTY? PATTERN [STOP]
IF NOT LIST? (FIRST :PATTERN) [LOOKUPDRUM :PATTERN STOP]
LOOKUPDANCE FIRST :PATTERN
DANCEMIMIC BUTFIRST :PATTERN
END

```

```
TO LOOKUPDANCE :ELEMENT
IF FIRST :ELEMENT = "HIGH [RTCAST LIST "CAST LAST :ELEMENT]
IF FIRST :ELEMENT = "RIM [LTCAST LIST "CAST LAST :ELEMENT]
IF FIRST :ELEMENT = "LOW [RTFOOT LIST "STOMP LAST :ELEMENT]
END
```

Now, imagine a virtual music ensemble—a mental music-society in the spirit of Minsky's Society of Mind—comprised of many "actor-performers", not just one drummer and dancer. The communications that regulate the musical behavior of the ensemble might provide an effective, though unfamiliar, metaphor for expressing the operational content of musical imitation or polyphony. This is an example of how computation can give concreteness to abstract ideas in music. Only curriculum-centered (rather than learner-centered) thinking prevents us from considering such options.

Chapter 10

The Textile Designer

Introduction

This chapter continues with the identification of criteria for constructionist interactivity, this time focussing on a textile pattern design microworld, what I call the *textile designer*. This microworld, much simpler than the music microworld, provides a context for discussing microworld design by novice programmers.

In the past, Logo researchers have discussed the power of "teaching the computer" as a way of learning. Microworld design by novice programmers has the potential of extending this idea in new and interesting ways. A learner can teach himself by designing his own environment of learning. He can also share this design environment with others. By sharing a design environment a learner is not sharing experience directly; rather, he is sharing a particular collection of synthetic and analytic tools and commands for making new ones. In combination they reflect what I called a *design persona* in chapter 7.¹

Since design tools are mind-stretching, sharing design tools promotes cooperative mind-stretching. Microworld design and evaluation offers a context for cooperative learning and, thus, the potential benefits of making knowledge found within community available to each of its members.

10.1 Selecting a Domain

In the music microworld, the domain was a given, not chosen. I was a composer and wanted to find ways to use Logo to support composing by novices. In contrast, the textile designer was selected because I saw a human need and a way of giving domain knowledge operational content using Logo.

When I first began observing at Paige Academy, the art teacher described Logo graphics as "unmotivating". For her, the finished picture was not worth the work necessary to produce it. She was not interested in the kinds of patterns that were natural to proceduralize in Logo. In order to understand what she was interested in, I went to the Massachusetts College of Arts where she was taking a computer animation course. The software she was using (which I will leave un-named) made it possible for her to use drawing tools to make color pictures of human figures the size of the computer screen. With a sequence of 3 or 4 figures she was able to produce crude screen-size animations of a person walking across the screen.

¹ Recall that a design persona is a "little designer" in the designer's mental society of designers. A design persona allows all of the perspectives on designing outlined in chapter 5 and illustrated in chapter 6.

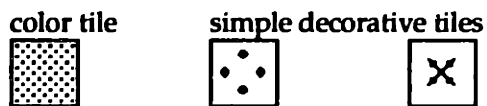
The animation tools that came with the software gave her the ability to cut and paste portions of drawings, and (with distortion) stretch, scale or rotate images. The art teacher used these tools to take an existing drawing, modify it, then place the modified drawing in the next position in the animation sequence. "Programming" amounted to placing each of the animation frames in a visual sequence on the screen. She could also loop a sequence so that it would run over and over again. More complex sequences were produced by editing video tapes of animated sequences. One might say that debugging happened at the video editing stage.

Logo is not designed to allow animated shapes computer screen size without erasing and then drawing each animation frame. This takes too much time for real-time animation effects. It also does not provide tools for animating drawings. On the other hand, the power of Logo is that production and debugging are closely connected. In Logo, one does not "debug pictures", one debugs the programs that "draw" the pictures.

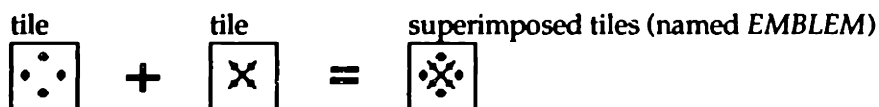
I had already committed myself to using Logo as the design environment. The challenge was to select a design domain that took advantage of it. I discovered that Paige's art teacher, the same one who was resistant to Logo, was a banner artist² and was planning to work on the design of banners and quilts with children at Paige. It seemed to me that Logo could facilitate these design interests. Logo shapes could be used as textile pattern elements which, in turn, could be organized into progressively more complex patterns using Logo procedures and superprocedures.

10.2 Constructing the Design "Language"

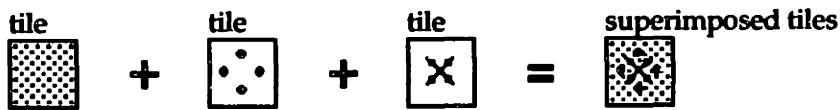
I began to work on the textile designer [for details see Appendix H: The Textile Designer]. In this world, Logo shapes are used as design elements. I call them *tiles*. One can "draw" a decoration (20 dots by 20 dots) using tiles and stamp it on the computer screen, or one can stamp a color with these dimensions (below).



In addition, one can superimpose color or decorative tiles to produce more complex tiles.



² Many of her beautiful banners hang in the Roxbury Crossing subway station.



This approach to using Logo shapes requires the following design commands (i.e., Logo procedures).

simple tile

TILE [shape color]

superimposed tiles

TILE [[shape color] [shape color] [shape color] [etc.]]

10.3 Naming

One can name a tile made up of a simple tile or superimposed tiles and use it as if it were a simple tile. Notice that shape and color numbers can be used, or names like *cross* or *blue* can be given to shape or color numbers (respectively).

naming tile

MAKE "EMBLEM [[19 4] [9 5]]

MAKE "EMBLEM [[dots blue] [cross red]]

using it

TILE :EMBLEM

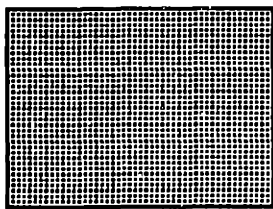
10.4 Designing as Redesigning (Debugging)

I call a combination of tiles a *patch*. A patch can be made up of color or decorative tiles. A patch 3 tiles high and 4 tiles wide is produced using the following PATCH command (see below).

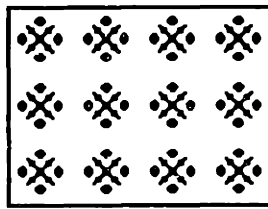
Color tile named *patch*



Decorative tile named *EMBLEM*



PATCH 3 4 [patch color]



PATCH 3 4 :EMBLEM

There are several patch commands.

patch commands

PATCH height width tile

BORDER height width tile

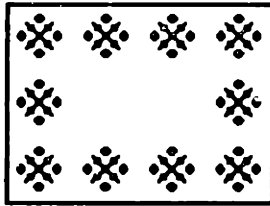
CORNERS height width tile

RANDOMPATCH height width list-of-tiles

CHECKERPATCH height width tile1 tile2

BORDER and CORNERS are illustrated below with a 3 x 4 border patch and a 3 x 4 corner patch.

BORDER 3 4 :EMBLEM



CORNERS 3 4 :EMBLEM



RANDOMPATCH is the same as PATCH except that its third input is not one tile but a list of tiles which are used by the program to randomly populate the patch.

form

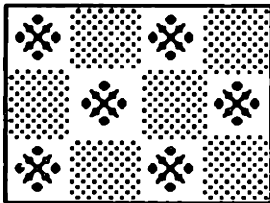
RANDOMPATCH *height width list-of-tiles*

using it

RANDOMPATCH 3 4 [star oriental emblem]

CHECKERPATCH makes a checkerboard pattern using two different tiles.

CHECKERPATCH 3 4 :EMBLEM :COLOR



All of the patch commands leave the turtle at the upper-left corner of a patch. This makes it possible for the user to overlay patches, either to add `HOW` pattern complexity or to cover over patterns that are unappealing. For example, the CORNERS command can be used to place a pattern in the corners of a patch or to cover over corners with the background color of the patch.

10.5 Objects-to-think-with

A design microworld needs an *object-to-think-with*, Papert's idea of a turtle-like entity with which a user can relate (like the conga drummer, flamenco dancer and talking head were in the music microworld). In the textile design microworld objects-to-think-with are tiles and patches.

10.6 Drawing vs Programming

The textile designer uses the shape editor to draw tiles, microworld commands to superimpose them and make patches, and Logo procedures to make progressively complex textile designs.

In a thoughtful paper by Mike Eisenberg entitled *Programmable Applications: Interpreter Meets Interface*, he describes a research perspective that examines the creative tension between user-interface and language design. For him, a user-interface should allow users "to perform those tasks best suited to the human skills of hand-eye coordination" and "the programming language should provide a good match between language primitives and domain concepts" (Eisenberg, p. 3).

The potential exists for a new class of applications software, more expressive, more extensible, and more respectful of the user's imagination than that which preceded it. Instead of dividing the world into computer gurus and computerphobes, these applications would welcome the spread of a programming culture. And because these applications would make maximum expressive power their fundamental goal, they would truly be user-friendly, rather than—as is often the case—user-condescending (Eisenberg, p. 2).

As Eisenberg sees it, direct manipulation user-interfaces offer certain advantages. He uses standard paint programs as an example. Because painting on the computer resembles painting on paper, these programs provide ease of initial access. While Logo's shape editor provides a rather limited drawing environment, because it is used to draw simple tiles, it illustrates Eisenberg's point. Writing programs to draw simple tiles would be unnatural.

For Eisenberg, programs that only allow direct manipulation are limited because they take little advantage of standard programming ideas like conditionals and recursion, the ability to create data objects like arrays and lists, or the ability to name procedures or build abstractions (Eisenberg, pp. 6-8). While general purpose programming environments provide these features, they are seldom designed with users other than professional programmers in mind (Eisenberg, pp. 10-11). Domain experts should not be required to become professional programmers; rather, programming should amplify the "programming" that experts already do in their heads.

The textile designer provides many of these features. It provides commands for superimposing tiles, abstractions for making different kinds of patches, and user extensibility, the facility to construct new kinds of abstractions.

10.7 Design as Environment Design

There are five navigation commands for moving a tile in tile-size steps (below). Four of them (shown below) were used to produce the design commands PATCH, BORDER, CORNERS and CHECKERPATCH, and RANDOMPATCH.

navigation commands

MOVEUP *number-of-tiles*
MOVEDN *number-of-tiles*
MOVERT *number-of-tiles*
MOVELT *number-of-tiles*

Because of user extensibility, a user can construct new patch commands using TILE and the navigation commands. In fact, CHECKERPATCH and RANDOMPATCH were added in later versions of the microworld once it became clear that more design tools were necessary. This is a clear example of design as environment design.

10.8 Feedback that Improves User Utility

A fifth navigation command, MANUALMOVE, makes it possible to move the turtle manually using the arrow keys. Pressing the space bar stops MANUALMOVE which then outputs the current position of the turtle in X-Y coordinate values. The X-Y value can be used to position the cursor at this location at a later time.

using it
 MANUALMOVE
 arrow keys
 PRESS space bar => [X Y]

The idea of providing the user the turtle's position (the X-Y value) is simple enough; yet, it illustrates how the designer can give an environment more user utility by offering additional forms of immediate feedback.

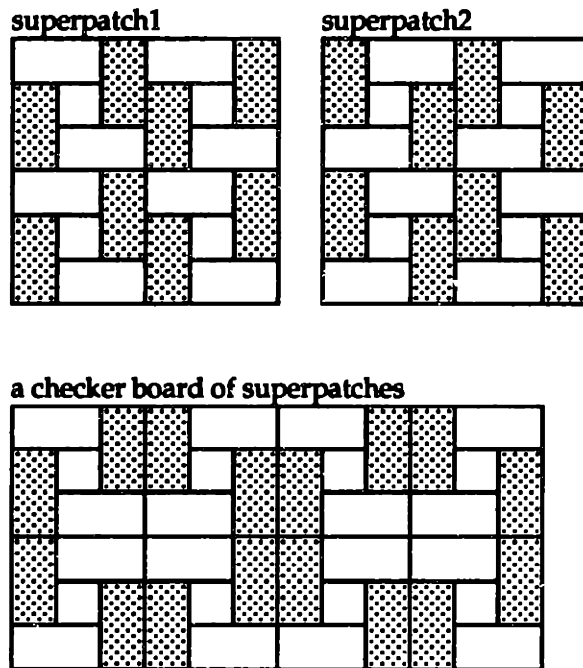
10.9 Design Persona Formation

The combination of commands in the textile designer reflect a particular *design persona*, designing through the successive addition of design layers, or *designing-by-layers*.³ Within this design persona, a designer can take advantage of different perspectives on designing; he can work on the artifact to produce layered patterns, or work on the microworld to extend its power. Regarding the latter, the commands RANDOMPATCH and CHECKERPATCH were added after it appeared that users wanted pattern exploration tools.

After seeing the textile designer, one person wanted to design ceramic tiles for her swimming pool. Her particular application required *supertiles* (i.e., composite tiles of two sizes), and commands for making *superpatches* (below).



³ I use "design persona" instead of a "design perspective" for two reasons. One, "perspectives" are already taken by the "perspectives on designing". Having a different term for a different administrative level keeps discussions unambiguous. Two, a design persona can accommodate a variety of perspectives on designing as I have defined them.



Logo shapes could not be used for these tiles and patches because she wanted the outline of her tiles to represent the color of the "grout". This made most of the commands in the *designing-by-layers* persona irrelevant. It was necessary to construct a different design persona to satisfy her request, supertile and superpatch procedures. While Logo made the construction of a new design persona possible, the textile microworld did not.

10.10 The Developer's Dilemma

At first, the woman's request for supertiles was somewhat surprising to me. What I wanted (but did not) say to her was: You shouldn't want to make such designs! I do not believe that this problem is unique to the textile designer. It is quite consistent with the notion of learning by designing that a tool is mind-stretching. New tools make new kinds of designing thinkable and necessitate still newer tools. I call this unavoidable problem the *developer's dilemma*. The developer's dilemma reminds us that a design environment needs to support user-programming.

10.11 Design Conventions, Biased and Neutral

It is useful to establish conventions within the design environment to make actions easy for the user to remember. For example, the patch commands always leave the cursor in the upper left-hand corner of the designed textile. Leaving the cursor in the upper-left hand corner is useful because it facilitates designing and debugging by layers. However, because it facilitates designing by layers it is not a neutral convention but biased by a design perspective.

In contrast, some conventions make the arbitrary predictable. I think of Donald Norman's example of the clockwise motion of clocks (chapter 5). There is nothing that requires clockwise motion; it simply makes reading the time easier to those who are accustomed to it. The inputs to PATCH, *height* and *width*, follow a convention and illustrates this idea.

10.12 Producing an Operational Folklore

Recall from chapter 2 Granott's work on developing a discourse around the use of Lego-Logo robots. At that time I used the phrase *operational folklore* to refer to the collection of practices that support tool use. Simple examples of operational folklore are also found in the STARTUP procedure for the textile designer.

When a user loads the textile designer, STARTUP causes the following text to be printed on the screen.

Type TUTORIAL for a brief introduction or TEXTILEHELP for the commands.

TUTORIAL is a procedure that shows the user what the cursor looks like and the list of textile design commands. TEXTILEHELP is for experienced users who have forgotten the names of some of the commands. TUTORIAL also prints the following text on the screen.

Type EXAMPLES for examples of textile patterns.

EXAMPLES is a procedure that displays on the screen two textile designs and their names DESIGN1 and DESIGN2.

10.12.1 Instruction On Demand vs On Schedule

In earlier versions of the textile designer, the introductory tutorial, list of commands and examples were all presented together. In keeping this information under program control, instructions for the user were based on a schedule determined by the programmer, me. This became annoying for experienced users. By dividing this information into separate procedures (TUTORIAL, TEXTILEHELP, EXAMPLES) I made it possible for new and experienced users to take different paths into the environment, a novice-track and an expert-track. Now, information was under the control of the user, solicited *on demand* rather than *on schedule*.

Whether instruction is obtained on demand or on schedule illustrates a piece of what Papert means when he contrasts the educational paradigms of instructionism and constructionism. In *instructionist education*, a learner is asked to learn what the instructor thinks he should learn. The problem with this approach to education is that the instructor cannot know what the learner is ready to learn. The instructor does not have perfect knowledge of the intellectual and emotional state of the

learner and is likely to be blind to the barriers that make what the instructor wants learned inaccessible to the learner.

Recall the toolmaker's paradigm from chapter 8. Even a simple conversation is full of miscommunications that are rectified through continuous debugging. To facilitate debugging, *constructionist educators* try to give the learner the freedom to demand knowledge when he is most receptive to it.

10.12.2 Learning by Example

In an earlier version of the textile designer, there were no examples of how the commands work within the microworld. Since most people find it easier to learn from concrete examples rather than abstract principles, I improved the microworld by providing examples.

Notice that introducing design examples was a good idea, but making them available on demand rather than on schedule was an even better idea.

10.12.3 Minimizing Instruction to Serve Constructionist Goals

Radical constructionists are quite sensitive about the notion of instruction. They would argue that my improvements in the textile designer were revisionist. By offering users more control over the kinds of instruction they could receive or by offering them design examples, I made a painful process less painful, not more constructionist.

Even though I accept this criticism, I operate with a pragmatic heuristic: If the interactions within a microworld require instruction, then the microworld needs to be improved. I may need to represent the domain knowledge differently; maybe the object-to-think-with does not offer the concreteness I had hoped it would. The point is that the presence of instruction serves as a source of feedback for the microworld designer rather than cause for alarm. This pragmatic approach recognizes the unavoidable tension between short-term and long-term goals. While I am doing something less than perfect today, I can develop strategies for doing something better tomorrow.

10.13 Microworld Design by Learning Communities

Many years ago, Papert described Logo as having "no floor and no ceiling". What he meant by "no floor" is that the Logo turtle was sufficiently natural to use and identify with that a user would require only a minimum of instruction before using it. What he meant by "no ceiling" is that Logo was sufficiently rich in possibilities that a user's previous experiences in Logo would provide a framework for acquiring new experiences in Logo.

A microworld like the textile designer is much more application-specific than the environment in which it was designed (i.e., Logo). This creates two problems. One, narrowing the kinds of tasks one can do in a design microworld increases the need for task-related knowledge, violating the

principle of "no floor". This problem was reflected in the discussions about instruction versus construction. Two, task-specific microworlds reduce knowledge transfer to other tasks, violating the principle of "no ceiling". This problem was reflected in the discussion about learning by designing and the developer's dilemma.

These problems can go away only if users design their own microworlds, or their own design personae within them. But this makes some notion of "programming" desirable, all the more reason why an aesthetic is needed to support the process of environment design by novices as well as experts.

10.12.1 Supporting Social Constructionism

It has long been understood that a good way to learn is to teach. However, if everyone is teaching, who is learning? If the answer is "everyone who is teaching" we are caught in a viciously antisocial circle. One way to break this vicious circle is by using microworld evaluation as a tool to support cooperative action.

Papert invented the notion of microworlds to answer critics of Logo's discovery learning. The main argument of critics was this.

Discovery learning is fine; it may even be the best way to learn. However, it takes too much time. If it took the whole of human history to bring us to our present knowledge, how can we expect children to "discover" this knowledge on their own?

Microworlds provide the means to control what is discoverable without giving up discovery learning. Moreover, powerful ideas--those that are useful in many kinds of situations--are what design microworlds make discoverable. For example, melodic development is a powerful idea in the music designer, and the layered approach to design is a powerful idea in the textile designer.

Social constructionism mobilizes the knowledge of the community to support learning among each of its members. The community is itself a microworld (or micro-culture). Using computer-based microworlds to facilitate the discovery of what the culture-based microworld knows, is a Papertian answer to critics of discovery learning.

The basic idea of *social constructionism* is that a community (eg. school, classroom, friendship network, corporation, etc.) is more intelligent than any of its members, including its leaders. The problem is how to mobilize community knowledge so that its members benefit from it.

Perhaps, an answer can be found in microworld design and evaluation, a process that necessitates cooperative learning. For example, my desire to satisfy the request for supertiles caused me to construct a design persona I did not anticipate. Through this process my ideas about "tiles" and "patches" were enriched.

* * *

One of the factors that limit discovery learning is inadequate design support tools. One of the reasons for examining the design process in parts 1-3 was to understand how computer-based design environments could retain the quality of design environments that predate computers.

A second factor that limits discovery learning is inadequate support for cooperative action. Constructionist interactivity provides this support by identifying a number of ideas for engaging in microworld design and evaluation, and by providing a social framework in which the expertise of a community of designers is placed at the service of each of its members.

What follows is a condensed summary of the ideas and practices that have been presented.

Design Domain. A good match between human need and programming environment is when domain knowledge can be formulated so that it has operational content.

Design Content. Look for the powerful ideas within a domain and build the system around them.

Identification. Objects-to-think-with serve as a sources of feedback during the debugging process.

Transcend the learning paradox. Provide multiple pathways to the same knowledge. Look at the history of ideas within the domain for clues.

Respect learning styles. Provide different ways to represent the same data or solve the same design problem. Provide both synthetic and analytic tools to support different kinds of debugging.

Developer's Dilemma. Learning by designing requires facilities for the development of new tools.

Establish conventions. Eliminate unnecessary decision-making when choices are arbitrary.

Learnability. Provide incremental learning steps that are rewarding in themselves.

Constructionism. View the need for instruction as feedback for system redesign.

On-demand instruction. If instruction is unavoidable, increase user control by supporting access to instruction on demand rather than on schedule.

Operational folklore. In order to promote the formation of a design culture, construct a collection of practices around the use of a design tool.

Summary Insights and Future Directions

Insights

My research has been dominated by the combined perspectives of the developmental psychologist and tool designer. The developmental psychologist is interested in the role of learning during the design process. The developmentally sensitive tool designer is interested in designing tools that support learning how to design.

I have used music composition as the research domain. As with other kinds of designing, music is a good domain in which to study the relationship between design and interpretation, reasoning in dynamic problem contexts, and the role of concept design in artifact design.

Through an examination of the compositional process, I have shown that the designer progressively customizes his design environment around the artifact under design. Designing is experience-based; designers use different customization methods, and designers use the same customization methods in different ways. I have also shown that the designer engages in a process of situated planning as a means of reducing design problems to conventional ones.

Finally, through the development of two computer-based design environments I have outlined an aesthetic for developing computer-based design environments that preserve the qualities of interaction found in design environments predating computers.

* * *

During my research, I have experienced several personal insights, some little and some big. The following extended summary is organized around them.

One, I began to see that it is not enough for a composer to know what to do, he needs to know when to do it. True skill requires both know-how and know-when. Know-when is past design cases that illuminate the current design case. Because several past design cases can illuminate a current design case, the organization of skill must be quite complex.

Two, I began to make an analogy between software development environments and the intellectual environment in which the composer composes, the design environment. This analogy and discussions concerning design in the cognitive science literature made me think that composing was an instance of a larger class of problems, design problems, in which the problem context is dynamic.

As described within the problem solving literature, conventional problems are well defined and their solutions are easy to recognize. While it began to appear that design problems are different from conventional problems, problem formation requires strategy exploration in both conventional

and design problems. Both require the use of different representation schemes as a means of examining and constructing the problem context, and both require the use of analogy to locate past cases that might be relevant in the current problem case.

Unlike conventional problems, design problems are ill defined and their solutions are provisional, even debatable. Design problems require strategies for dealing with this additional ambiguity. I began to think of *designing* as discovery learning with the goal of producing an artifact, and used the phrase *learning by designing* to underscore the idea that designing is also always learning how to design.

Three, it is common knowledge that composers develop compositional "systems" or "languages". The analogy to software development made me think more concretely about the structure of these "systems" or "languages", how they are developed and used. I felt that the design environment had to support the development and use of skill just as it does in software development environments. I also began to formulate a definition of the *design environment as the conceptual interface between the internal world of the designer and the external world of the emerging artifact*. This definition seemed to apply in both the concrete world of computer-based design and in the abstract world of mental designing predating computers. I was now able to think of compositional "systems" or "languages" as design tools customized to support the construction of a particular artifact.

The management of design knowledge among expert designers facilitates both skill selection and use. Regardless of the level of abstraction at which skill is being employed, a designer uses a particular skill at a particular time in order to reduce the field of design choices to a few that can be tried and tested. This became a kind of skill management heuristic for evaluating my conclusions, a *constraint on intuition*: Conscious designing undermines intuitive designing. If a designer's thinking interferes with the design process, then he must lack a particular skill management scheme. Moreover, the acquisition of expertise must be a process of skill management scheme construction.

One form of skill management I discovered through self-reflection and confirmed by examining the process of other composers is perspectives on designing. *Perspectives on designing* are broad classifications of skills, each reflective of a different design concern. I identified six of them.

1. **Managing design complexity.** The designer ranks the restrictions he imposes on his process based on their past or anticipated productivity. This process increases the reliability of the design environment for the designer.
2. **Promoting user utility.** A designer re-appropriates conventions, or invents new ones that can be learned by the interpreter. This process increases the reliability of the artifact for its anticipated user.

While operating within the perspective of promoting user utility, the designer uses the interpretive perspectives presented in part 1.

3. User utility is promoted by making anticipatory listening easier to do. In general, the designer takes into account how users make expectations.
4. User utility is promoted by making anthropomorphic listening easier to do. In general, the designer takes into account how users relate to, identify with, artifacts.

Finally, the designer alternates between the perspectives of environment design and artifact design.

5. **Environment design.** Sometimes the designer is constructing and reorganizing skills in order to accommodate new design demands.
6. **Artifact design.** Sometimes the designer is selecting skills in order to construct the artifact.

Four, the idea that an artistic artifact can have user utility as any other came after an examination of why people play, enjoy jokes, watch sports events, look at art or listen to music. I believed that the observer is not a passive "player" but a constructor of his own experience. Using the interpretive perspectives available to him, the observer progressively constructs a virtual world in which he takes mental risks he may not be prepared to take in the real world. From this cognitive view, the interpretive process is a kind of "cognitive aerobics" in which the interpreter exercises kinds of reasoning he may need in the future. In short, the cognitive function of interpretation is to get better at making interpretations, and a particular artifact (piece of music, virtual reality) provokes the construction of particular kinds of interpretations.

Five, I began to use the perspectives on designing to compare the skills illustrated by the pattern language of Alexander *et al*, and the skills I identified. It was clear that each of their skills incorporated several of my perspectives on designing while only a few of mine did. This was an indication that many of my skills did not represent fully developed expertise; for example, a skill used to manage design complexity is not necessarily used to promote user utility. I conjectured that one objective of skill refinement is to identify and integrate the concerns represented by my perspectives on designing.

The toy problems gave evidence to support this conjecture. It showed that the student composers were much less concerned with promoting user utility than the professor. Except for student-D, the other student composers were preoccupied with design process issues and seemed to express little concern for the interpreter.

Six, in the analysis of Professor-M's different approaches to the same toy problem--i.e. what I called his procedural-model, actor-model, and improviser-model-- it was clear that he had another form of skill management, what I began to call *design personae*. A design persona is not a perspective on designing; indeed, it can incorporate all of the perspectives on designing. It is a complex, yet reliable, organization of skills. Using Minsky's agency model of the mind as a society of littler minds, I imagined a composer as a society of design personae each representing the

expertise of a favorite composer. When a design persona is in charge, the composing society behaves as if "it" was that design persona, performing actions and analyzing results as the composer represented by it might.

The formulation of the designer as a society of simpler designers has problems when the simpler designers come in conflict. For example, an action that is approved by one simple designer may be sharply criticized by another. Within the agency model, this conflict is resolved in the direction of the stronger, more influential, simple composer.

Seven, what if the simple composers are equally influential? This is where the notion of rationalization began to carry more weight in my thinking. Rationalization can be thought of as yet another form of skill management, in this case a way of managing shifts to different skill management schemes. Speaking in anthropomorphic terms, rationalization produces a third "composer" who dissolves a conflict between two others by reformulating the problem context.

Rationalizations are important for the opposite reason that design contexts are important. Design contexts make the field of design choices simple enough so that each choice can be tried and tested. However, a designer can get locked into a context that offers no means for pattern continuation. The "escape hatch" is rationalization.

The rationalization process is not random. Explorations are done within a restricted discovery space constrained by the current state of the emerging artifact. The designer notices a pattern that depends on something already present in the artifact. The artifact makes the process of rationalization a *controlled* escape from one design context into another.

Viewing rationalization as a constructive reasoning process dissolves a debate between planning and situation action theorists; indeed, the role of rationalization within this debate is an illustration of itself. "Plans" are not as brittle nor are situated actions as situated as theorists might believe. Instead, designing requires *situated planning*. The artifact constrains plans, though the application of a plan changes the artifact and necessitates replanning.

The idea of situated planning compliments my thinking about problem solving and designing. One of the goals of designing is to make design problems less ill-defined and their solutions more easy to recognize (or less debatable). It is a small step to say that the "goal" of situated planning is to produce a conventional problem.

These observations suggest an inherent limitation in analytic methods that avoid an examination of the design process. Composing cannot be entirely inferred from the artifact because there is not a one-to-one relationship between the interpretive and compositional contexts. I believe this point generalizes to other kinds of designing.

Eight, it remained helpful to think of the design environment as an abstract version of a software development environment, as the conceptual interface. Indeed, I had begun to develop computer-based design environments, *design microworlds*:: one for music composition and nother for

textile pattern design. I found myself making a series of revisions to both the music and textile design microworlds, and began to approach design microworld revisions in the self-reflective way I had approached the compositional process. An aesthetic dialogue began to form around both of these activities which eventually led to *constructionist interactivity*, a collection of ideas and practices for preserving the quality of interactions found in design environments predating computers.

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Operational folklore. In order to promote the formation of a design culture, construct a collection of practices around the use of a design tool.

Constructionist interactivity is not a prescription that insures good microworld design, but an aesthetic for giving a constructionist texture to the notion of "interactivity". In general, constructionist interactivity supports learning by designing, and this requires support for (1) the construction of tools (2) the construction of experience in using tools (3) and the use of kinds of reasoning necessary for dealing with dynamic problem contexts.

Nine, over the course of my research I developed the following collection of investigative strategies. They may be applicable as a general experimental approach in research on design support tools.

Experimental Approach

1. Examine skill from a developmental perspective; look at the acquisition as well as use of skill within a design domain.
2. Use self-reflection as a means of gaining sensitivity about design practice in the design domain; if necessary, simplify your practice until aspects of it become clear.
3. Construct design activities ("toy problems") in the design domain in order to examine the design practices of others.
4. Use loud thinking to examine in-process designing in the design domain. Use video tapes and interviews to collect other data. Use this data as a source for self-reflection by the observed designer and as a method for confirming or refuting hypotheses about what the designer is doing.
5. Construct computer-based tools or use already available ones in the design domain and examine them using the above steps.

Future Directions

Learning by Designing. It would be useful to test whether the ideas and themes presented in this thesis are applicable in other application areas: as examples, *skill* as know-how plus know-when, differences in *design style* as differences in when tools are employed, differences and similarities between *problem solving* and *designing* as I have described them, the six *perspectives on designing*, skill refinement as the construction of different *skill management schemes*, and the constructive role of situated planning during the design process.

Research on design support tools. By building new kinds of design support tools and examining how they (or currently available tools) are used, it should be possible to gather new kinds of data about the design process and, reflexively, new thinking on how to improve tools designed to support it. Moreover, new design tools will support the broader objectives of my work (see the Afterward: Creating a Commonwealth of Skills).

Programming as concept customization. There is the unavoidable challenge, the developer's dilemma, of providing novices the support they need in order to customize their own concepts. A design microworld always allows the construction of "little design microworlds" within it, design personae. Observations of novices constructing and sharing design microworlds may provide ideas on how to build concept customizing languages. Alternatively, experts might develop different kinds of design personae for novices to use as conceptual pathways to the larger programming environment in which they reside.

Concept organization as user-interface design. My different formulations of skill management may provide insights on how to develop more developmentally sensitive user-interfaces; for example, design environments may provide tools for users to develop different kinds of windows and menus reflective of different design personae.

Making Design Experience Reusable. Since people learn from experience, we might design indexing tools that allow designers to construct their own library of cases, including the ability to represent, store and retrieve cases in different ways and for different reasons. For example, a musical case might be indexed by:

1. feature-patterns (e.g. pattern matchers for key, meter, contour, motivic content),
2. the tools used to produce it (e.g. transposition, inversion),
3. example cases (e.g. using cut-paste operations as pointers to a case's ancestor),
4. functional role (e.g. melodic, accompaniment, transition),
5. names given by the user (e.g. using word search as a retrieval method).
6. design personae (e.g. organizations of skills and cases at a high level)

A sub-theme is the examination of how AI techniques could be used most effectively. Notice that a design system might be able to automatically keep a record of design actions using indexing schemes 1-3, while the user might have to manually index cases using schemes 4-6, at least initially. One can even imagine a semi-automated system in which designing is primarily a process of identifying past cases and making small revisions to them. However, it is not obvious where the "intelligence" should go and in what ways automation might enhance or undermine the design process.

Presumably, it would be useful to have a variety of example design cases in the target domain so that different indexing schemes can be tested. In this regard, the experimental approach used in this thesis may have general applicability.

Afterward Creating a Commonwealth of Skills

Design is basic to all human activity.
Papanek's *Design for the Real World*

While in Brazil at the University of Campinas (1992) I made an important discovery. One day I caught two members of the administrative staff in front of the Macintosh using my textile designer. Unlike the researchers who were interested in the textile designer in an academic way, these administrators made textiles for a hobby. For them, having a textile designer was a useful technology. With my encouragement they continued to design, often interrupting me (and others) in order to get assistance. After a couple of weeks they had the courage to express frustration in the fact that it was not possible to get a life-size color copy of their patterns so that they could use them to make real textiles.

The enthusiasm of these administrators gave me conviction that environments to support designing could provide links between the crafts and information technologies. This is similar to D'Ambrosio's way of thinking about *ethnoscience*. Ubiratan D'Ambrosio is a Brazilian mathematician who, for many years, has been concerned about the widening gap between the haves and have-nots in Brazil. He has been interested in examining the coherence of craft practices in order to show how these practices reflect the kind of thinking valuable in science. The textile designer is a simple example of a tool that could support D'Ambrosio's ethnoscience; it is a potential point of entry into the information age for those who already find meaning in textile design.

Seeing Science with a capital "S" as ethnoscience with a small "e" suggests how the computer can play a pivotal role in the formation of new kinds of cultures that are welcoming for all of the world's inhabitants. Collisions between culture and information have been a source of resistance to science and technology in the past. The computer can make future collisions between culture and information synergetic rather than catastrophic.

* * *

Designing can serve as a core element of a new curriculum that unites the sciences and the arts. Consider the "poetry" in "scientific" activities like artificial life design. *Artificial life* can be described as the activity of making synthetic life forms as a means to understanding natural life forms.¹ The following two artificial bugs illustrate.²

¹ Also see Kevin Kelly's article "Designing Perpetual Novelty: Selected Notes from the Second Artificial Life Conference" (In *Doing Science*. Edited by John Brockman. Prentice Hall. New York. 1988).



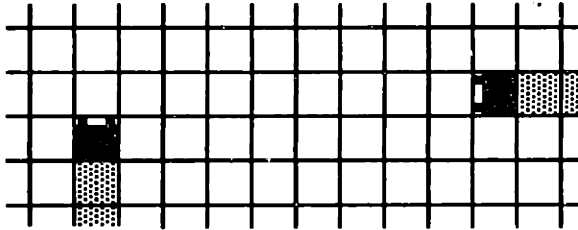
Bug facing up



Color patch

In this artificial world, a bug can move, recognize *scents* or leave behind *scents* (represented as patches of color, above). Bugs on the screen move up, down, left or right depending on what they smell.

Imagine an invisible checker board whose squares are the size of the bugs. The shaded squares are the scents each bug leaves behind while it moves in bug-size steps.



While the bugs look alike, they do not "think" or "act" alike because their behaviors are not the same (below). Notice that bug 2 has a larger repertoire of behaviors than bug 1.

Bug 1

1. If it senses black, it leaves a red scent and goes one square to the left.
2. If it senses red, it leaves a black scent and goes one square to the right.
3. Otherwise, it moves forward one square

Bug 2

1. If it senses black, it leaves a red scent and move one square to the right.
2. If it senses red, it leaves a yellow scent and moves one square to the right.
3. If it senses yellow, it leaves a green scent and moves one square to the left.
4. If it senses green, it leaves a black scent and moves one square to the left.
5. Otherwise, it moves forward one square.

Bug 2 is more "sensitive" than bug 1 "who" does not "know" what to do when encountering the yellow-scent or the green-scent. It even appears that bug 2 "helps" an immobile bug 1 when bug 2 replaces an unrecognizable scent with a scent bug 1 does recognize (black and red). I think of bug 1 as the child of bug 2 [for program details, see Appendix I: Artificial Life Design].

Part of the fun for the human observer is to identify the rules each bug follows. An observer can also experience differences between anthropomorphic and mechanistic descriptions. Sometimes creatures (natural or synthetic) appear more intelligent than they really are because the behaviors we observe tempt us to produce anthropomorphic descriptions. While we cannot be easily taught when anthropomorphic thinking might be useful, we can use artificial life design to reflect on the strengths and weaknesses of such descriptions.

² This project was inspired by an article by A. K. Dewdney entitled "Two-dimensional Turing machines and tur-mites make tracks on a plane". In *Scientific American*, September 1989.

Some observers will ignore the "scientific" implications of artificial life design. Instead, they will enjoy the colors produced by the bugs, or "humanize" the interactions between the bugs as I did.

Artificial life lives in a terrain where science and art overlap. As science it can be thought of as hypothesis exploring activity in which one comes in contact with the powerful idea of *mechanism*. As art, artificial life design can be thought of as computer animation, painting or as a vehicle for self understanding as fairy tales are: persona exploring, rather than hypothesis exploring. Artificial life design can be described in either way, depending on whether it speaks to the "little humanist" or "little scientist" within us. In general, designing welcomes these various modes of human inquiry.

* * *

There is no need for everyone to become a scientist, nor is there a need for everyone to become an artist. However, there is an urgent need for everyone to develop design skill. Those who have been following the current revolution in industrial production methods--the "Toyota way", also described as *lean production* by Womack, Jones, and Roos--will have noticed the the importance of educating the new work force. According to the authors of *The Machine that Changed the World*, the three major paradigms of production are craft, mass and lean production. In *craft* production, producers use highly skilled workers and simple but flexible tools to make exactly what the consumer asks for--one item at a time. In *mass* production, producers use narrowly skilled professionals to design products made by unskilled or semiskilled workers who run expensive, single-purpose machines that churn out standardized ("good enough") products in very high volume. Finally, in *lean* production, producers combine variety and quality, the advantages of craft production, with high volume and low cost, the advantages of mass production (Womack, Jones, Roos. 1990).

Unlike the transition from craft to mass production where worker skills were abundant, the transition from mass to lean production requires reskilling a deskilled labor force. Moreover, the kinds of skills required in lean production are learning skills; a worker not only needs to learn to perform complex operations, he must become a perpetual learner. Industrialists who wish to "go lean" are being forced to see learning as the new competitive advantage. Industrial settings of the future will need to become learning as well as producing environments.

At a NATO sponsored conference in November of 1992, Martial Vivet reported on "project-based teaching" which he is using to educate blue-collar workers in France. The microworld he created was a table-size model of a running factory. Workers were asked to build micro-robots (similar to Lego-Logo robots) that could be used in this microworld. Through this process it was hoped that workers would begin to understand principles in robotics and the role of robots within an integrated system of manufacturing.

There was a sense of urgency in Vivet's work. His pedagogy had to work because the economic lives of workers were at stake. Vivet found that it motivated workers when he selected robot projects that appeared useful to them and that resembled robots they had seen on the factory floor. He organized workers into small teams, each working on the same kind of robot project. The best projects were those with no apparent solution, even to the instructor. This placed the instructor in the role of a researcher and established trust between him and the workers. In addition, projects that could be solved in many ways created opportunities for teams of robot designers to discuss robot similarities and differences.

Vivet asked work teams to debate the efficiency of their different robots and to identify factors of efficiency. For example, some teams were able to produce a robot more quickly than others, though robots produced by quick teams were sometimes not as efficient to use as the robots produced by a slower teams. Some teams were very slow in designing a robot, but the superior design of their robot—e.g. the use of subassemblies—made it possible for a robot to be quickly reconfigured to perform a different function. Some robots were easier to integrate into the factory than others. These debates, often heated, were testimony to Vivet's success; they demonstrated that the workers had not only begun to consider different kinds of robot constructions, they began to think about the integration of robots into a total production system (Vivet, 1992).

One might characterize Vivet's pedagogy in the following way. His first task was anthropological: Build on the daily experiences of the workers. A second task was contractual: Build trust among the workers and clarity about the pedagogical goals of the activity. A third task was managerial: Organize the teams, design types of projects, and manage the discourse around the project activity. A fourth task was advisory: Provide assistance when requested.

Contrast Vivet's approach with the rigid approach of conventional schooling. Vivet's anthropology replaced curriculum; his social contracts with the workers and his knowledge about robots replaced brute authority; and his management methods replaced assessment. Unlike Vivet's lean approach, I call conventional schooling *mass* education to emphasize that conventional schooling reflects a mind-set inherited from several decades of mass industrialization.

In mass education, teachers are like assembly-line workers, ordered to teach a standard curriculum they have no control over. Mass education produces students unable to meet the minimum educational standards while fostering habits of mind appropriate for mass production workers: obedience, an ability to tolerate alienation, and blind adherence to routine (Gargarian and Cleary, 1992b). In short, mass education has deskilled society.

When mass education is used to support mass work it is doubly deadly; an out-of-date pedagogy is used to instruct workers in an out-of-date form of production. It is no wonder that corporate training is usually given a low priority. Corporate training does not accomplish much in the way of

"added value"--everyone knows training as it is commonly practiced does not really work (Gargarian and Cleary, 1992a).

Of course, lean production should not dictate a new system of pedagogy as mass production did; indeed, it seems vulgar to think of learners as items that are manufactured. However, even the most cynical among us, willing to completely embrace my analogy between school and work, will recognize the need for a revolution in education in which design is likely to play a central role.

* * *

What is a "revolution in education"? I think of Piaget's notions of assimilation and accommodation. A learner can *assimilate* new ideas that are only slightly different from his own, whereas a learner has to change his perspective to *accommodate* ideas that are very different from his own. Revolution requires support for accommodative thought.

"Revolution" also makes me think of an important difference between Piaget-the-practioner and Papert-the-practioner. For Piagetians, "if you want to get ahead, get a theory". This phrase from Annette Karmiloff suggests that one way to make mental progress is to construct a model of the world and then test it against the world. If it works one gains additional confidence in one's model; if it does not, one has new data from which to construct a new model. In Piaget's hands, the scientific method is a learning method.

For Papertians, "if you want to get a theory, get ahead". This phrase from Edith Ackermann suggests that tools (e.g. telescopes, microscopes, and powerful ideas) give learners access to data previously unavailable to them. With this new data learners can construct new theories with which to get ahead. In Papert's hands, tools support new kinds of inquiry and expression.³

* * *

Individuals are not only constrained by their own thoughts but by institutional constraints. When thinking about "revolution" I also think of Mary Douglas's analysis of the cognitive function of institutions in her book *How Institutions Think*. We need institutions for at least two reasons. First, we need them because we cannot think about the world without partitioning it into manageable parts. Second, we need them in order to sustain particular kinds of cooperative action. Both reasons lead directly to classification no matter how primitive. "The more fully the institutions encode expectations, the more they put uncertainty under control" (Douglas, p. 48). "An institution needs some stabilizing principle to stop its premature demise. That stabilizing principle is the naturalization of social classifications" (Douglas, p. 48).

The process of building institutions requires two sorts of cognitive acts. Systematic forgetting--"what are the impossible thoughts?", and systematic remembering--"what are the accredited

³ One might say that Piaget-the-practioner is an assimilator while Papert-the-practioner is an accommodator. One might also say that Papert-the-theorist assimilates Piaget-the-practioner into his learning paradigm.

ways of thinking?" (Douglas, p. 71). "For better or worse, individuals really do share their thoughts and they do to some extent harmonize their preferences, and they have no other way to make the big decisions except within the scope of the institutions they build" (Douglas, p. 128).

Because institutions are resistant to the kinds of inquiry and expression for which they were not designed, their strengths can also be their weaknesses. They can become disabling when the objectives they embody do not meet the objectives required by changed circumstances. I argue that it is not natural--indeed, it is epistemologically irrational--for most of our current institutions to assimilate constructionist tools and practices. We need a new kind of institution, one in which design is the core curriculum. I call it *Discovery Village*.

In a paper written by Cleary and myself, we describe Discovery Village as "a hybrid of learning laboratory and theme park whose themes are technology, media, and the arts". We imagine Discovery Village as a public access institution for use in developing countries to support the formation of a media-rich culture. We argue that most attempts at "technology transfer" have failed--indeed, usually have been experienced as "technology invasion"--because the implicit knowledge surrounding a technology's use is also not "transferred" (Gargarian and Cleary, 1992b).

I was recently at a party where I mentioned autonomous robots to a couple of dancers. They were intrigued by the idea and asked for more detail. I must have gotten carried away because I could see a certain anxiousness in the dancers' eyes. It then occurred to me that these dancers had devoted many years of their lives to movement and, in their own way, understood these issues much better than I did. I remembered *contact improvisation*, a kind of dancing in which dancers interact physically through a process of give and take and, through these interactions, produce a spontaneously choreographed dance. I then mentioned to the dancers that when programming autonomous robots it is necessary to make the rules of interaction more explicit than they are among the dancers during a contact improvisation. There are also far fewer rules and kinds of movement. I then asked whether the kinds of interaction among dancers change since each contact improvisation produces a different dance, a different emergent effect. This question led to a rich discussion in which the dancers felt perfectly comfortable talking about "mechanism", "parallelism" and "emergence" but in a culturally meaningful way. My error had been in giving the impression that "robotics" is an idea that comes from outer space. In fact, "robotics" was a part of the daily experience of these dancers. If I had been Vivet the anthropologist, I would have avoided the technology transfer mind-set I had used at the start.

Discovery Village could be thought of in different ways depending on how it is used. After reading about the problems in reskilling labor I imagined Discovery Village as an environment installed within factories. After talking with a media company about the "textbook of the future" I began to think of Discovery Village as a learning environment for publishers to explore design-based education. In seeing the favelas in Brazil, I imagined Discovery Village as a community

square maintained by teenagers. After the riots in Los Angeles (1992) I imagined Discovery Village as a new kind of hangout that combined both physical and cognitive aerobics.

For Discovery Village to be an experiment in institutional redesign, it needs experimental subjects operating within an experimental social context. This is why it is a "living laboratory" and not just a research laboratory. Discovery Village experiments could facilitate the development of a variety of installations populated with a variety of microworlds, each with designing as the core activity. Discovery Village could serve as a re-socialization mechanism through which the artificial barriers that separate science from art, school from play, or work from life are gradually dismantled. In place of these barriers one would find a commonwealth of skills. This is constructive revolution.

Appendices

Appendix A diSessa's Dynaturtle

What follows is a brief description of the Logo procedures for making a Dynaturtle. The procedure `SETUP` assigns 0 to the X and Y components of the turtle's initial momentum and a force value of 1.

```
TO SETUP
CG CT PD
MAKE "VX 0
MAKE "VY 0
MAKE "FORCE 1
END
```

`NAVIGATOR` uses the arrow keys to change the turtle's direction (LT or RT) and to give a kick in the direction the turtle is facing (not the direction in which it is heading). The space bar is used to print on the screen the X and Y components of its current velocity. Notice that the turtle leaves a trace of its movement which is erased (using `CLEAN`) when a kick is introduced.

```
TO NAVIGATOR
IFELSE KEY? [MAKE "CHAR READCHAR] [MAKE "CHAR 0]
IF (ASCII :CHAR) = "29 [RT 15 STOP]
IF (ASCII :CHAR) = "28 [LT 15 STOP]
IF (ASCII :CHAR) = "30 [CLEAN KICK STOP]
IF (ASCII :CHAR) = "32 [PRINT SE [The X and Y of resultant: list :vx :vy]
END
```

`KICK` updates the effect of a kick on the X and Y vectors.

```
TO KICK
MAKE "VX :VX + (:FORCE * SIN HEADING)
MAKE "VY :VY + (:FORCE * COS HEADING)
END
```

`DYNATURTLE` is the recursive superprocedure that incorporates the use of the other procedures. The turtle moves are produced by adding the X and Y components of the turtle's momentum to its current position.

```
TO DYNATURTLE
NAVIGATOR
SETPOS LIST (XCOR + :VX) (YCOR + :VY)
DYNATURTLE
END
```


Appendix B Some Theoretical Assumptions and Background

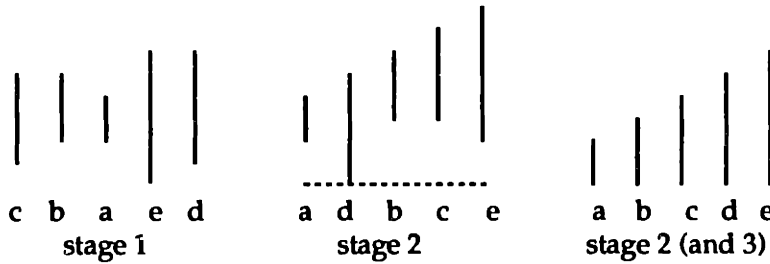
The *constructivist* claim. The interpretive process uses musical knowledge for the mental reconstruction of musical events. Native listeners usually have this knowledge, outsiders may have to learn it.

Musical patterns do not seek each other; rather, people project these properties onto musical patterns. The music notations are just a collection of scratch marks on paper, the sounds just a collection of vibrations in the air. The meanings we find are expressive because they are projected by the composer and listener onto the product. When I talk about what the music does, behind the scenes are the intentions of the composer and interpreter. These intentions animate the scratch marks and vibrations.

The constructivist claim is a general conclusion we can draw from the life work of the Swiss cognitive psychologist Jean Piaget. His extensive investigations of human mental development show that subsequent knowledge is constructed out of previous knowledge (metaphorically, like a house is built out of walls which are built out of bricks). Piaget has found that a child's development can be partitioned into developmental stages marked by the presence (or absence) of certain kinds of concepts, laws of invariance, or what he calls *conservation* laws. For example, the child needs two important ideas in order to develop the concept of number: (1) the notion of one-to-one correspondence (i.e. ordinality) and (2) the notion of class inclusion (i.e. cardinality). The child not only has to know that numbers have an order (like 1, 2, 3, 4, etc.) but that the number 2 includes the number 1, 3 includes the number 2, and so on. Neither notion alone is sufficient. The conservation of integers presumes that these ideas are *coordinated* (or organized) into a new intellectual system.

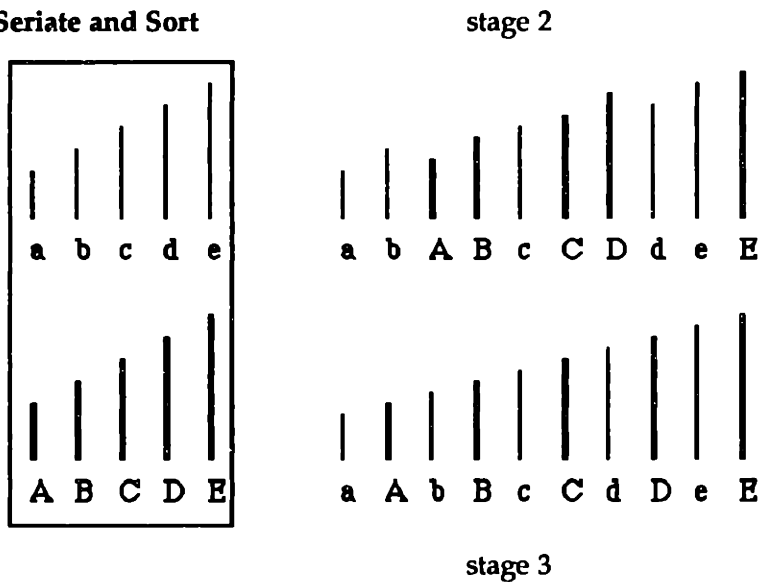
Piaget's seriation task illustrates. In this task the child is asked to arrange a number of sticks from shortest to tallest. Stage 1 children (ages 4-5) tend to arrange the sticks at random. Stage 2 children (ages 5-6) will arrange the sticks in the appropriate order, ignoring the bottom of the sticks. They understand a little better what to do but are unable to attend to all of the dimensions of the problem simultaneously. They have no guiding principle; for example, that a reference point (the dotted line in the illustration, below) can be used to relate the lengths of the sticks to each other.

Seriation Task



Some children get good results after extensive trial and error. However, others get in trouble when the task becomes slightly more complicated. For example, the following seriation task begins where the previous one left off. After a child has successfully arranged the sticks in the first task (sticks a-e), the experimenter asks the child to integrate a second collection of sticks (sticks A-E) into the first collection.

Seriate and Sort



Stage 2 children often have trouble performing this task because they don't seem to be able to think about a stick as being both taller than one stick and shorter than another. For this reason, they often make local errors. Only stage 3 children are able to coordinate this relational knowledge in a reliable way (Ginsburg and Opper, pp. 136-141).

The epistemic claim. My comments apply only to the tension-repose model of listening, what one might call the *resolution* aesthetic. There are other listening aesthetics.

What I call the *opposition* aesthetic is another listening aesthetic based on my experience analyzing Senegalese drumming music from West Africa. Many of my readers are familiar with the notion of a *polyrhythm* (or "multiple rhythms") which we find characteristic of African drumming music. Why are polyrhythms interesting?

In the simple case of 2-against-3, a rhythm must be supported by the division of some *proto-meter* (i.e. meter of meters) divided into two parts (*duple* meter), and three parts (*triple* meter).


The proto-meter (or kernel representation) must be subdivided into 6 parts so that it can adequately represent either the duple or triple meter.

Duple Representation (6 beats)



Triple Representation (6 beats)

With a division of the proto-meter into 6 parts, the duple meter can be represented by striking beats 1 and 4, and the triple meter can be represented by striking beats 1, 3 and 5. The strong beats are special because, when struck, they communicate to the listener the appropriate metric interpretation.

However, in African drumming music the metric interpretation is seldom entirely clear. Rhythmic patterning involves continuously crossing between several metric frameworks. It is the qualitative changes in the ambiguity, the metric mix, which is considered aesthetically pleasing. Removing the ambiguity eliminates what is musically expressive. For example, the following shows a more complex subpatterning where weak  beats as well as special beats (and silences) are used in both duple and triple representations.

Triple Representations



Duple Representation

In addition, 6-beat patterns can be combined to produce 12-beat patterns that allow 3-against-4 as well as 2-against-3 over longer spans of time.

Duple Representation (12 beats)



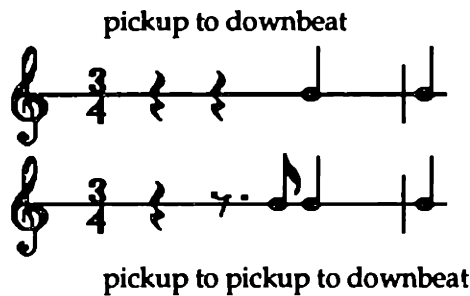
Triple Representation (12 beats)

Duple Representation (12 beats)

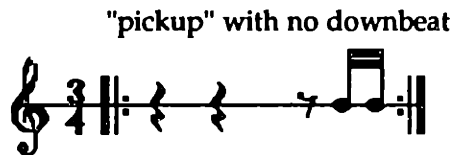


Triple Representation (12 beats)

In western music one expects that a note on a weak beat will lead to a note on a strong one (see "pickup to downbeat", below). This tension producing strategy can be used recursively; for example, a pickup can, itself, have a pickup (see "pickup to pickup to downbeat", below).



However, in African music it is common to have rhythms where the downbeat remains silent. In the following ostinato pattern the two sixteenths notes are for a downbeat that never comes. But then, is it functionally correct to speak of these sixteenths as a "pickup"?



True, rhythmic ambiguity is a source of tension in both western and African musics. However, the function of ambiguity is different in each case. It seems to stretch the explanatory power of tension-repose to say that the polyrhythms or the "pickups" create tension until the final repose (when the music is over). A different aesthetic is in operation, one in which *opposition* serves as an end, not a means (Gargarian. 1987 pp. 84-85).

The *mechanistic* claim. I assume, like Minsky, that emotions are "kinds of thinking" used by the mind to set priorities and settle mental conflicts. This "cool" way of defining emotions seems counter-intuitive when we do not distinguish between a description of the mechanisms of emotion and the experience of emotion.

The psychologist George Mandler views emotion as the combination of arousal (fight-flight systems) and cognition (differentiating and evaluating systems). He points out that, in exploring arousal, experimenters have tried to evoke emotional states by manipulating arousal levels using hormone injections. The results of these experiments have led to what Mandler calls AS-IF emotions. AS-IF emotions are quasi-emotional states that only partially induce an emotional experience. People who receive hormone injections feel aroused but don't know how to interpret their arousal. Mandler concludes that "both physiological arousal and cognitive evaluation are necessary, but neither is a sufficient condition for the production of emotional states (Mandler, p. 25). Because states of arousal are, themselves, products of cognitive processes, cognition is a product of both arousal and cognition.

Minsky's society of mind theory is a conflict model of emotion that attempts to integrate arousal and cognition. For example, we may be simultaneously tired, hungry and want to complete some work. These are different desires with corresponding satisfaction-goals that we can entertain simultaneously. There must be some mediating mechanisms which allow us to evaluate the importance of our desires with respect to each other, mechanisms for setting priorities, and others to help us to suppress desires of less relative importance. Minsky views emotion "varieties of thinking", as the collection of mechanisms which manage the competitions (Minsky, pp. 163-164).

Parson's Stage Theory of Art

Michael Parson's developmental theory of aesthetic experience is a stage theory in the Piagetian tradition.¹ I offer it as an example of the use of developmental theory to understand the experience of art.

Like Piaget, Parson assumes that later stages of development depend on previous stages. Unlike Piaget's stages which occur at relatively predictable ages, Parson's stages reflect kinds of awareness that are knowledge-dependent, not age-dependent.

Outline of Parson's Stage Theory of Aesthetic Experience

Stage 1: Favoritism

The viewer uses the painting to make free associations. Feelings are pictured, colors are pretty, and values are taken for granted (Parson, pp. 33-35).

Exp.

"At stage one, the [painting by Paul] Klee is mostly pretty colors; we may say it is about the colors."

Stage 2: Realism

The painting must represent the important parts of the subject. The subject of the painting becomes almost too important. A viewer might not like the painting because the painter painted dogs and the viewer doesn't like dogs (Parson, pp. 39-40).

Exp.

"At stage two, [the Klee] is obviously about a man, or a man's face."

Stage 3: Expressionism

¹ Piaget spent several decades observing children in order to understand their cognitive development. A component of his cognitive theory is the famous but now controversial stage theory. While a literal reading of his stage theory has been disputed by some psychologists, most psychologists (except for the most stubborn behaviorists who do not believe in "mind" anyway) agree with its basic tenet; namely, that knowledge coheres into stage-like entities at the micro-level if not at the macro-level (as Piaget would suggest).

Realism gives way to feeling and a willingness to search for meaning. The viewer can separate his interest in dogs with how well the painter used dog-images as a vehicle for telling some story through visual imagery. In general, the viewer has a greater tolerance for complexity (Parson, pp. 57-78).

Exp.

"At stage three, [the Klee] is about something like the balance of femininity and masculinity."

Stage 4: Formalism

The viewer has developed a sensitivity to form, medium and style. The medium, itself, can be viewed as subject matter. The viewer is checking his interpretation with the interpretation of others. He is aware of an art world that consists of many other paintings and is able to make historically sensitive judgments (Parson, pp. 80-114).

Exp.

"At stage four, [the Klee] is a universal symbol of humankind, and expresses a quirky humor and a sophisticated spontaneity."

Stage 5: Autonomy

The viewer has the ability to make judgments about the value of the tradition represented by the painting. Interpretation is the reconstruction of meaning, judgment is the evaluation of the worth of the meaning (Parson, pp. 123-151).

Exp.

"At stage five, [the Klee] raises questions about how we see things, and can be said to be about the nature of perception."



According to Parson, fairly early in the process of observation (stage 2), an observer begins to look for a model (i.e. a story) which he uses to interpret what he observes. This model comes from the observer's personal experience and is projected onto what he sees. It is anthropomorphic.

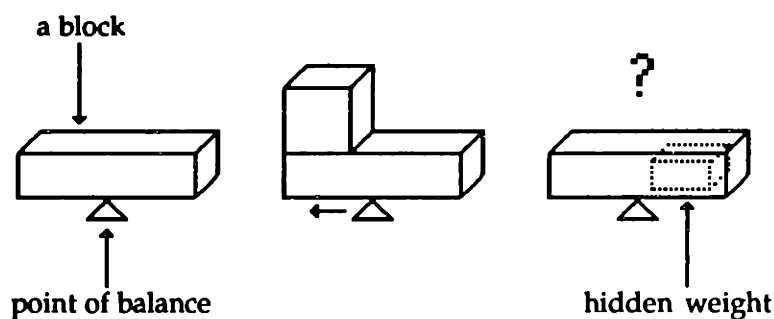
Each subsequent stage is about modelling more kinds of things including those that are not entirely observable. For example, by stage 4, the observer begins to consider the methods the artist used to construct the model; and by stage 5, the observer begin to consider whether the artist's model has merit. By this final stage, the observer has become a vicarious explorer of aesthetic experience. He is not only an observer of the artist's paintings, he is as close to being the painter as he can be (Parson)!

The vicarious involvement in the painting process includes both anthropomorphic and anticipatory elements. By the observer projecting himself into the role of the painter he is exhibiting anthropomorphic behavior ("What would I do if I were the painter?"). However, the observer's reason for doing so is, in part, to understand the painter's inferential process.

Appendix C

The Temptation of Homogeneity

The temptation for homogeneity is illustrated by an experiment reported in a classic paper in Piagetian psychology entitled "If you want to get ahead, get a theory" (Karmiloff-Smith and Inhelder). In this experiment, the experimenters asked children to balance some blocks. The first block resembled the one shown on the left (below). A few other blocks were like the one shown in the middle where blocks, also of uniform weight, were arranged asymmetrically. In contrast, blocks like the one shown on the right had hidden weights or other unusual characteristics (the dotted lines in the most right block, below).



Initially all the children adjusted the position of the blocks without hidden weights using the geometric center and visual cues to compensate for the differences in how the blocks were stacked. Since this approach proved successful, the children continued to use it for each subsequent weighing. I will call this geometric approach to weighing *procedural theory 1*.

Notable in the various action sequences of these children was the interplay between the endeavour to use information acquired from previous actions and the gradual introduction of a coherent, analogous approach to all items (Karmiloff-Smith and Inhelder, p. 300).

However, the children found that theory 1 failed on blocks with hidden weights. The authors point out that, at first, counterexamples to theory 1 did not dissuade the children from using it. The children needed a new procedural theory for utilizing a feature of the blocks unsuccessfully balanced; namely, that of weight. In fact, many of the children learned how to handle these more difficult blocks by closing their eyes so they would not be influenced by visual cues (Karmiloff-Smith and Inhelder, p. 301). Once the weight theory was recognized, what I will call *procedural theory 2*, the children would try it out when theory 1 fails (Karmiloff-Smith and Inhelder, p. 302).

Notice that both theories 1 and 2 are general procedures, a natural consequence of the children identifying actions that are invariant across block-balancing trials. Also notice that theory 1 (the geometry theory) was not abolished once theory 2 (the weight theory) had been mentally constructed. Only when theory 1 failed did children try theory 2.

The tendency to explain phenomena by a unified theory, the most general or simplest one possible, appears to be a natural aspect of the creative process, both for the child and the scientist (Karmiloff-Smith and Inhelder, p. 306).

What the above experiment shows is that it is natural for children to generalize by applying a previously successful procedure to new situations that seem similar to old ones. Procedural theory 2 was constructed by the children testing theory 1 and then locating invariance across tactile cues that were not salient in theory 1. With both procedural theories in mind the children were now able to handle all the situations they would encounter in the block-balancing world.

The title of Karmiloff-Smith's and Inhelder's paper "If you want to get ahead, get a theory" is apt. A learner will try out a successful theory first, then find what is invariant in the situations not covered by that theory and make that the new theory. Rather than throw out a successful theory or data when things go wrong, the child makes a second theory that covers the territory not covered by the first. The differentiation process is facilitated by the subject over-generalizing from previous experience and debugging based on new experience.

This approach to the theory construction process illustrates what Minsky calls the *Paperi Principle*. In Minsky's society of mind theory, the greater a mental society's investment in a rule (in this case, the geometry theory of balancing) the more likely it is for the mind to store exceptions to the rule rather than throw out the rule. The accumulation of exceptions, drawn from block-balancing trials, may give rise to a new rule (in this case, the weight theory of balancing). Formulated as an agency model, a new mental agent, BALANCE, is enlisted to administrate the use of GEOMETRY and WEIGHT, agents representing the two procedural approaches to block-balancing.

Without changing any of Karmiloff-Smith's and Inhelder's findings it is possible to argue that the preferred procedural theory was not necessarily simpler than the second; rather, it was the one that explained the trials the children encountered first. This revision in the experimenters' conclusions makes it possible to see how the fine-grained structure of each individual's experience can be different without altering performance. While either WEIGHT or BALANCE may have been the preferred procedural theory in some mental society, BALANCE, in which both WEIGHT and BALANCE are organized, must become invariant for all observers.²

Each music theory can be thought of as a way the interpreter deals with particular aspects of the musical world, much as GEOMETRY and WEIGHT are theories for dealing with particular

² The AI scientist Ken Haase calls the preferred theory the *prototype*. Using his computational model of this process, he argues that preferences can shift from an earlier constructed prototype to one constructed later, especially if it has proven itself to be more productive (Haase).

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aspects of the block-balancing world. There is more than one music theory because each provides a different "thinking cap" for apprehending the observed musical complexity. In this regard, Cook's comments about performers seems to apply to interpreters as well.

"...it is not enough [for a performer] simply to know a piece as a stereotyped action sequence, or as a series of individually known sections, or as a tune supported by harmony, or in terms of how it looks on the page. What is required is a tissue of intertwined, mutually reinforcing imagery; the security such a complex representation gives [the performer] is comparable to the strength of a length of rope made up of a large number of individually short and insubstantial fibres" (Cook, pp. 111-112).

The Papert Principle provides a means for making a musical analogy. More effective balancing is like more effective listening. In both cases, effectiveness is a result of the observer developing strategies for differentiating between types of situations and constructing more than one strategy for dealing with the same situation.

Appendix D

Problem Solving and Discovery

Problem Solving

Newell, Simon and Shaw describe creative thinking as a special kind of problem solving activity involving unconventional thinking and the production of novel solutions. Their notion of creative problems differs from conventional problems in one respect. As in my notion of design problems, creative problems are ill-defined; indeed, an important part of the task of creative thinking is to formulate the problem (Newell, Simon and Shaw. p. 145). Each conventional problem has a search space of possible solutions. Because a creative problem may be one of many different types of problems each with its own search space, creative problems have a much larger search space. Unconventional thinking is required to make the problem less ill-defined until conventional problem solving methods can be used. One might say that the goal of a creative problem is to produce a conventional problem (Simon, Newell and Shaw. pp. 144-174).³

The work of Brown and Chandrasekaran is an extension of the problem solving tradition. They, too, see the problem of creative problem solving as one of managing very large search spaces. While Newell, Simon and Shaw attempt to develop unconventional methods for identifying a repertoire of heuristics at the task level, Brown and Chandrasekaran bundle different repertoires of heuristics at the *generic* task level. Associated with each generic task are the problems, representations, concepts and inference strategies necessary to address them. Generic tasks provide classifications of heuristics that are relevant for types of tasks. Changing from one generic task to another is a computational way of representing a change in perspective. Structuring the search space in this way makes it possible for a problem solver to navigate rapidly across large problem spaces without getting caught up in details before the details are necessary.

Brown and Chandrasekaran provide three classifications for design problems. Class 1 design problems have similarities to my notion of design problems in that they are open-ended and ill-specified. In class 1 problems strategies may not be available and solutions are more or less plausible rather than clearly recognizable. These authors have little more to say about class 1 problems except by contrasting them with class 2 and 3 design problems.

Class 2 design problems (e.g. automobile design) and class 3 design problems (e.g. customization) resemble conventional problems except that there are too many interacting requirements for an

³ An example of unconventional thinking is to locate properties of the solution common to all possible formulations of the problem. This might lead to the elimination of possible solutions which, in turn, might lead to a better formulation of the problem. As another example, solve easy problems which are in the province of possible problems and solutions and use them to identify a productive repertoire of heuristics.

algorithmic approach to work (Brown and Chandrasekaran, pp. 32-35). One might even say that if a problem yields to algorithmic approaches, it is probably not a design problem. This comment needs qualification. In many cases, the "solution" brought about by designing is a problem that is well-defined, and such problems *do* yield to algorithmic approaches. Moreover, as a designer becomes more experienced, aspects of his process can become "automated". This is one reason why expert designers are often unaware of their own expertise!

Discovery

In Herbert Simon's autobiography *Models of My Life*. Simon describes the *discovery process* as gaps between problem solving steps that are filled by metaphor. The process of metaphor construction is not, as yet, amenable. For example, when trying to examine word frequency distributions and city size distributions as sampling problems, he "visualizes a cascade, with successive pools of water each maintained at a constant level by flow in from the pool above and flow out to the next pool below" (Simon, 1991, p. 374). Through this metaphor Simon argues that he was able to identify probabilistic relationships these two patterns shared.

For word distributions, it can mean that the chance of a word's being chosen as the next word in a text is proportional, because of association, to how often it has been used already, and also proportional, because of long-term associations stored in memory, to how often it is used in the language. In the case of city sizes, it can mean that birth and death rates are approximately independent of city size, while cities will be visible and attractive to migrants in proportion to their current sizes" (Simon, 1991, 374).

In another problem Simon tries to find a way to defend "partial equilibrium analysis", a method used by economists to partition the world into smaller, more analyzable parts. An economist might defend a partial analysis by saying that, because interactions between one part and the others is negligible, they can be ignored. However, Simon wanted to find a more rigorous defense of this method. Once again, he used a metaphor to guide him to his final formalism.

I visualized a building divided into rooms, each room divided, in turn, into cubicles. We start out with an extreme disequilibrium of temperature, each cubic foot of each cubicle being at a different temperature from its neighbor (Simon, 1991, p. 377).

He then uses this metaphor to exercise the economist's problem.

In studying the equilibration of each cubicle, we can ignore the other cubicles. In studying the equilibration of rooms, we can represent each cubicle by its average temperature, and ignore the other rooms. In studying the equilibration of the building, we can represent each room by its average temperature. As a result, the mathematics of the problem can be drastically simplified (Simon, 1991, p. 377).

In these problems, Simon is looking for a setting in which to explore the properties of a problem and, eventually, a representation which will make it possible to solve it. This discovery process is

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characteristic of designing and reflects Simon-the-practioner, not Simon-the theorist. The latter Simon insulates problem solving from the learning processes that make solutions possible.

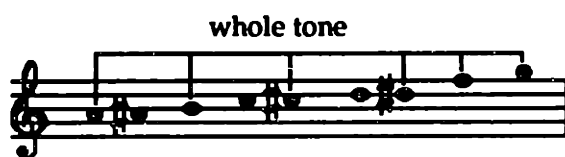
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One set can be expressed by a variety of note patterns since a set defines a pattern of pitch-intervals not pitches. For the purpose of comparison, I will write all the remaining sets as patterns of notes starting with the note A.

Berg purposely used the whole tone set 6-35 which is only different from the other "almost whole tone" hexachords found in *Wozzeck* in the placement of the semitone (Schmalfeldt, p. 48).

Whole and Almost Whole Tone Sets found in Berg's *Wozzeck*

6-35	[A B C# D# F G]	whole tone
6-34	[A B C# D F G]	almost whole tone except for the D
6-21	[A B C C# D# F]	almost whole tone except for the added C
6-22	[A A# B C# D# F]	almost whole tone except for the added A#



Berg's method of semitone placement to produce different sets is like Bartok's method of adding or subtracting notes to produce different scales (described in Chapter 6) and, one might add, similar to Debussy's use of the whole tone scale as a palette from which he constructed diminished and augmented harmonies. All these methods were designed to address the perceived breakdown of Western common practice writing.

As I have suggested, Berg used whole tone scales to produce a quasi-tonal musical result. Set 4-19 (*Wozzeck's* set) contains the maximum number of major thirds and minor sixths found in any *tetrachord* (i.e. four-note set) used in *Wozzeck* (Schmalfeldt, p. 89). Moreover, Berg often produced new sets by adding notes to 4-19 (below). One can conjecture that Berg hoped to use the quasi-tonal sets as a bridge from the familiar to the unfamiliar.

In addition, Berg associated sets with particular characters and situations in the drama, thus, integrating musical development with dramatic development. For example, set 4-19 (*Wozzeck's* set) is found inside sets 5-30 and 8-24. Set 4-19 is the *tetrachord* that is held invariant across several other sets and is symbolic of *Wozzeck's* personality. Similarly, set 4-18 is Marie's set (*Wozzeck's* wife) and is found in sets 5-Z18 (the drum major's set) and 7-Z38 (above).

Progressively adding elements to produce new sets

<u>Set</u>	<u>Notes</u>	<u>Character</u>
4-19	[A A# C# F]	Wozzeck's set
5-30	[A A# C# D# F]	
8-24	[A A# B C# D D# F G]	

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4-18	[A A# C# E]	Marie's set
5-Z18	[A A# C# D E]	Drum major's set
7-Z38	[A A# B C# D E F]	

The image shows two musical staves. The top staff has three labels above it: '4-19 ->', '5-30 ->', and '8-24'. The bottom staff has three labels above it: '4-18 ->', '5-Z18 ->', and '7-Z38'. Both staves show a sequence of notes on a five-line staff, with some notes grouped by boxes to illustrate set relationships.

Set 5-Z18 (the drum major's set) is associated with the seduction between the drum major and Wozzeck's wife, Marie. Schmalfeldt conjectures that Berg built 5-Z18 around Marie's set 4-18. Interestingly enough, Wozzeck's set 4-19 is not included in this set. However, set 6-Z19 includes both Wozzeck's set 4-19 and Marie's set 4-19 and represents the fatal bond between them (Schmalfeldt, pp. 155-56).

Comparing Sets

<u>Set</u>	<u>Notes</u>	<u>Character/s</u>
4-18	[A A# C# E]	Marie
4-19	[A A# C# F]	Wozzeck
5-Z18	[A A# C# D E]	Drum Major (includes Marie)
6-Z19	[A A# C C# E F]	Wozzeck and Marie (does not include Drum Major)

Wozzeck demonstrates Berg's strategies for using set relations and transformations to promote subconscious musical associations that are dramatically salient. Organizing sets into networks of sets is an example of environment design; it helps the composer to make short-term decisions that serve long-term goals—for the composer, by helping him to manage compositional complexity, and for the listener, by promoting interpretive consistency. And as I have suggested, by associating set development with character development, Berg integrates the structure of the drama into the structure of the music.

Appendix F

Using Digitized Sound in the Music Designer

The procedures **PLAYSOUND** and **PLAYSOUNDS** have the same form as the procedures **PLAYNOTE** and **PLAYNOTES**. The difference is that these new procedures play recorded (digitized) sounds, not Logo tones.

PLAYSOUND is one sound represented as a sound-duration pair. **PLAYSOUND**'s first input is the name of some previously recorded sound. The second input is the duration of the sound in **WAIT** units.

PLAYSOUND [*sound duration*]

If one has recorded a low conga drum sound and named it **LOWCONGA**, typing the following will cause the recorded conga drum sound to last 10 **WAIT** units.

PLAYSOUND [lowconga 10] =>

PLAYSOUND also has an **IF**-expression for dealing with rests. Typing the following causes Logo to wait 20 **WAIT** units.

PLAYSOUND [REST 20] =>

PLAYSOUND has the subprocedure **PLAYSOUND2**. If the recorded conga drum sound (i.e. **ACTUALTIME**) is longer than the number of requested **WAIT** units (i.e. **WANTEDTIME**), **PLAYSOUND2** will cut off the excess. If it is shorter than the number of requested **WAIT** units, **PLAYSOUND2** will play the sound and fill up the extra time with silence.

```
TO PLYSOUND :SOUND
IF (FIRST :SOUND) = "REST [WAIT LAST :SOUND STOP]
PLAYSOUND2 :SOUND (LAST :SOUND) WAITDURS (FIRST :SOUND)
END
```

```
TO PLYSOUND2 :SOUND :WANTEDTIME :ACTUALTIME
IF :WANTEDTIME > :ACTUALTIME [PLAY FIRST :SOUND WAIT :WANTEDTIME -
:ACTUALTIME]
SOUNDSELECT FIRST :SOUND 0 BYTEDURS LAST :SOUND
PLAYSELECTED
END
```

In order to use **PLAYSOUND** you also need the procedures **WAITDURS** and **BYTEDURS**. **WAITDURS** converts bytes of memory (i.e. sound samples) into **WAIT** units. **BYTEDURS** does the reverse, converting **WAIT** units into bytes.

```

TO WAITDURS :SOUND
OP ROUND 60 * ((SOUNDLENGTH :SOUND) / SOUNDFREQ :SOUND )
END

```

```

TO BYTEDURS :DURATION
OP ROUND (:DURATION / 60) * (SOUNDFREQ :SOUND)
END

```

PLAYSOUNDS (like PLAYNOTES) is a recursive procedure that takes a list of sound-duration pairs (rather than note-duration pairs) and plays them one by one using PLAYSOUND as a subprocedure. PLYSOUNDS has the following form.

```

PLAYSOUNDS [[sound duration] [sound duration] [etc.]]

```

For example, if one wanted to play a low conga drum sound (lowconga) three times with durations 10, 5 and 5, one would type the following.

```

PLAYSOUNDS [[lowconga 10] [lowconga 5] [lowconga 5]]

```

PLAYSOUNDS also has an IF-expression for spotting a single sound-duration pair. If it spots a sound-duration pair PLYSOUNDS acts like PLAYSOUND.

```

TO PLYSOUNDS :SOUNDS
IF EMPTY? :SOUNDS [STOP]
IF WORD? (FIRST :SOUNDS) [PLAYSOUND :SOUNDS STOP]
PLAYSOUND FIRST :SOUNDS
PLYSOUNDS BUTFIRST :SOUNDS
END

```

Appendix G

An Analysis of Children's Replication of Songs

On the following page one finds a summary of data of a study in which I examined children's ability to replicate popular songs. Along the left one finds an abbreviation of the song names as well as the names of the singers (sometimes one, sometimes two singers). Above each column is a name which stands for a music concept: *key* (for keynote), *meter*, *tempo*, *rests* (non-articulated beats caused by sustained notes, silences at the end of phrases), *contour*, and *melody* (by which I mean "notes of the melody").

A "Y" means that the child is able to preserve the musical concept in that column and an "N" means that a child cannot. A "NA" means "not applicable" and is used when keynote is undetectable (e.g. when a child speak rather than sings the song). A "Y" in all of the columns means the child is able to replicate a song accurately.

There are two exceptions which do not interfere with replication accuracy.

- A child could sing a melody accurately while transposing it up or down slightly. An "N" in column "key" combined with a "Y" in column *melody* identifies this exception.
- A child could embellish a melody that was sung accurately in other respects. This happened twice and is marked "melodic innovation" in the *comments* column.

Data of Childrens' Song Replication

	Key	Meter	Tempo	Rests	Contour	Melody	Comments
Oh Where Oh Where (Del)	Y	Y	Y	N	Y	Y	Text-driven
Row Row (Shirley Darlene)	N	Y	Y	Y	Y	N	Round-structure
Each Camp Fire (?)	N	Y	Y	Y	Y	Y	
Yankee Doodle (John)	Y	Y	Y	Y	Y	Y	
Jimmy Crack (?) innovation	Y	Y	N	N	Y	Y	Melodic
Henry VIII (Two kids)	Y	Y	run	N	Y	Averaging	
Five Hundred Miles (Kora)	Y	Y	N	N	Y	Y	
Fishers of Men (Marlene)	Y	Y	N	N	Y	Y	
Spanish song (Sonia)	N	Y	N	N	Y	Y	Text-driven
There was a Boy..(Cornell)	Y	Y	N	N	Y	N	
I'll Fly Away (Marlene)	N	Y	N	N	Y	Y/N	Angular melody
Spanish song (Sonia) innovation	N	Y	N	Y/N	Y	Y	Melodic
Indians are High (Kora)	N	Y	N	N	Y	N	Text-driven
Camp fire lights (Kora)	N	Y	N	N	Y	N	
Down by O.. (Cynthia-Kora)	NA	Y	Y	Y	Y	N	
Daniel Boone (James-Alan)	N	Y	Y	N	Y	N	
When the Saints, Eng. (Sonia)	Y	Y	Y	N	Y	N	Text-driven
When the Saints, Sp. (Sonia)	Y	Y	Y	N	Y	N	Text-driven
Three Little A.. (Zacharia)	N	Y	Y	Y	Y	Y	Uses Elision
Three Six Nine (Linda-Kora)	N	Y	Y	N	Y	N	Text-driven
Automobile song (Zacharia)	NA	Y	Y	Y	Y	N	Text-driven
Church song (Deborah)	Y	Y	Y	N	Y	Y	-
Diamond Ring (Cynthia-Kora)	Y	Y	run	N	Y	N	-
On a Hill Far (Marlene)	N	Y	Y	Y	Y	N	Angular melody
The Devil is a (Deborah)	Y	Y	Y	Y	Y	Y	-
My Boyfriend (Kora-Caroline)	Y	Y	Y	Y	Y	Averaging	-
I Am a Pre..(Marlene-Linda)	N	Y	run	N	Y	Averaging	-
Davy Crockett (Alan-James)	NA	Y	Y	N	Y	N	-
Henry VIII (Robert-Ronald)	Y	Y	run	Y	Y	N	-
I Will Row (Deborah)	Y	Y	Y	N	Y	Y/N	-
I Met at (Rebecca-Elizabeth)	N	Y	run	N	Y	N	-
Diamond Ring (Cynthia-Kora)	N	Y	run	Y	Y	N	-
I'm Dutch Girl (Cynthia-Kora) (Jennette-Carolina)	NA	Y	Y	N	Y	N	-
	Y	Y	run	Y	Y	Averaging	-
Spanish song (Sonia)	N	Y	N	Y	Y	Y	-
Save a Life (Linda)	N	Y	Y	N	Y	Y	-
Glory Glory (Marlene)	Y	Y	Y	N	Y	Y	-
There Were (Patricia)	Y	Y	N	N	Y	Y/N	Angular melody
Jesus Loves (Deborah)	N	Y	Y	Y	Y	Y	-

Observations from Analysis

Melody depended on contour. While the ability to replicate notes of the melody depended on the ability to replicate melodic contour, the reverse was not true. It is clear that the notes of the melody depended on the structuring done by melodic contour. This is illustrated in the following renditions of *The Saints Go Marching In*.

The Saints Going Marching In (Two versions)

Phrase ending errors marked by arrows; example points where scale is not preserved inside .

The image displays two systems of musical notation for the piece 'The Saints Going Marching In'. Each system consists of two staves. The first system shows a melody line with a phrase ending error marked by an arrow pointing to a note. The second system shows a melody line with a phrase ending error marked by an arrow pointing to a note, and a box highlighting a section of the melody where the scale is not preserved.

In order for a child to produce an accurate copy of the melody notes (*melody* column), the child needed to have both contour and scale knowledge. Conversely, if a child had a correct contour and incorrect melody notes, the child did not have scale knowledge.

Melody depended on contour angularity. Melodies which had greater angularity were more difficult to replicate (see "angular melody" in the *comments* column). This happened in three of the thirty cases. One hypothesis is that melodies that exhibit stepwise motion can use local pitch references whereas those that involve large interval leaps require more global references. However, there is too little data to either confirm or refute this hypothesis.

Meter depended on text structure. In all cases, the children appeared to have a good sense of meter. However, I came to discover that this was more easily attributable to the rhyme structure of the text than to ideas about musical meter. My justification for this observation are the large number of instances where the children were unable to deal with the silences or sustained notes, often at phrase endings ("N" in category *rests* reflects this difficulty). New phrases would often be

rushed or delayed as if the children did not know what to do with the "surplus" time between phrases, "surplus" because, without the text, the child had no way to structure time. These errors often led to distortions in the meter at phrase endings that would disappear at the beginning of the next phrase. For example, the transcription to the beginning measures of *Oh Where, Oh Where* shows a momentary metric change (the 12/16 measure) because the two sustained notes (in boxes) are not held long enough.

Oh Where, Oh Where

Rushed notes inside ; Strange meter marked by ?

The image shows three staves of musical notation. The top staff is a single melodic line in 2/4 time. The middle staff shows a change to 12/16 time, indicated by a question mark above the staff. Two notes in this 12/16 measure are enclosed in boxes. The bottom staff continues the melody in 2/4 time. The notation includes various note values, rests, and accidentals.

The 2/4 measure suggests a correct rendition of the 12/16 measure, one that preserves the metric structure of the song. This problem of preserving time at phrase endings is also found in *The Saints Go Marching In* (shown earlier). The phrase ending errors are marked by arrows. It is easy to hear that changes in text structure caused changes in rhythmic structure (see boxes in transcription).

Meter also depends on text structure in the four cases where the children spoke rather than sang the song ("NA" in column *key*). It is also shown in five other cases ("text-driven" in column *comments*) where expressive nuances seem to come from the text rather than the song.

Keynote is a relatively independent concept. A child could sing a melody accurately but transpose it up or down a little. This occurred a third of the time and is true when there is an "N" in column *key* and a "Y" in column *melody*. In addition, children could produce replication errors while preserving keynote (when there was a "Y" in column *key* and an "N" anywhere else).

Tempo's ambiguous relationship to phrase endings (*rests*). As often as not, tempo errors are accumulations of phrase ending errors marked by an "N" in column *rests*. When a child frequently rushed or delayed the beginning of the new phrase, this sometimes led to the tempo being sped up or slowed down.

Collaborative effects. Sometimes tempo was unstable due to collaborative effects. Fourteen of the thirty-eight songs were sung by two people. In four of these cases it was clear that the melody

was preserved through a collaborative process ("averaging" in column *melody*). In other words, what one singer could not replicate the other could.

In ten cases of collaboration the two singers did not preserve "melody". They were either unable to replicate the melody or replication ability was sufficiently fragile that interactions between the singers made things worse.

In seven cases of collaboration, the attempt of each singer to accommodate the other led to tempo *runaway* (marked by a "run" in *tempo*). Runaway, also known as *positive feedback*, is when one error perpetuates additional errors. In this study, runaway occurred when an acceleration in tempo led to increasing accelerations, or a deceleration in tempo led to increasing decelerations.

Melodic innovation. Two of the children made *melodic innovations* (see "melodic innovation" in *comments*); i.e. errors that were acceptable because they did not violate any replication criteria. For example, *Jimmy Crack Corn* (below) has the innovations found in the two boxes.

Jimmy Crack Corn

Innovations inside



These innovations only violate the most strict definition of the song. Indeed, an interesting, though rhetorical, question is: How many changes can occur before a song loses its identity? This is a slippery question because innovative versions of a song can, themselves, be recursively replicated and innovated upon. An "error" is in the ears of the beholder.

Song selection and gender. In reviewing the material, it seems that song selection shows gender differences. The girls typically sang lyrical songs (e.g. I'll fly away, On a Hill Far Away), church songs (Fishers of Men, Glory Glory) and "women" songs (e.g. Diamond ring, My Boyfriend, I'm a Little Dutch Girl). In contrast, the boys sang songs about men (Daniel Boone, Davy Crockett, Henry VIII) and male kinds of things (e.g. Yankee Doodle, There was a Boy, Automobile song). We can conjecture that songs are not only about singing but about gender roles.

Song selection and ethnicity. There is some evidence to suggest that songs reflect ethnic preferences. The black child (Del) selected a particularly rhythmic song while the spanish children (Sonia, Marlene) selected church songs. However, there is too little evidence to generalize.

Appendix H The Textile Designer

Textile space is in the form of a grid. The turtle moves up, down, left or right while staying within this grid.

```
TO MOVEUP :AMOUNT
  SETH 0
  REPEAT :AMOUNT [FD 20]
  END
```

```
TO MOVEDN :AMOUNT
  SETH 180
  REPEAT :AMOUNT [FD 20]
  END
```

```
TO MOVERT :AMOUNT
  SETH 90
  REPEAT :AMOUNT [FD 20]
  END
```

```
TO MOVELT :AMOUNT
  SETH 270
  REPEAT :AMOUNT [FD 20]
  END
```

The procedure `MANUALMOVE` moves the turtle tile steps up, down, left or right depending on the arrow key pressed. When the space bar is pressed the program outputs the turtle's current position before it stops.

```
TO MANUALMOVE
  IFELSE KEY? [MAKE "CHAR READCHAR] [MAKE "CHAR 0]
  IF (ASCII :CHAR) = "29 [SETH 90 FD 20]
  IF (ASCII :CHAR) = "28 [SETH 270 FD 20]
  IF (ASCII :CHAR) = "31 [SETH 180 FD 20]
  IF (ASCII :CHAR) = "30 [SETH 0 FD 20]
  IF (ASCII: CHAR) = "32 [SHOW POS STOP]
  MANUALMOVE
  END
```

The procedure `TILE` and its supporting procedure `TILE2` are used to construct pattern elements. Notice that they check to see whether a tile is simple or complex and whether it is represented by numbers of names.

```
TO TILE :TILES
  IF EMPTY? :TILES [CURSOR STOP]
  IF WORD? FIRST :TILES [TILE2 :TILES CURSOR STOP]
  TILE2 FIRST :TILES
  TILE BUTFIRST :TILES
  END
```



```

TO TILE2 :TILE
IFELSE NUMBER? FIRST :TILE [SETSH FIRST :TILE] [SETSH THING FIRST :TILE]
IFELSE NUMBER? LAST :TILE [SETC LAST :TILE] [SETC THING LAST :TILE]
PD STAMP PU
END

```

Notice that before `TILE` stops it runs the procedure `CURSOR`. `CURSOR` gives the turtle a black cursor shape so that a user can see where the turtle is once a textile design has been made.

```

TO CURSOR
SETSH 40 SETC :BLACK ST PU
END

```

The procedure `PATCH` remembers the initial position of the cursor before drawing a patch. Its supporting procedure `PATCH2` (below) produces a patch one row at a time, subtracting 1 from the height of the patch each time the procedure recurses. Notice that it uses the subprocedures `MOVERT`, `MOVELT` and `MOVEDN` to navigate between patches, and `TILE` to stamp either simple or complex tiles. When `PATCH2` is done, it returns the turtle to its initial position and gives it the cursor shape.

```

TO PATCH :HEIGHT :WIDTH :PATTERNS
MAKE 'TOPLEFT POS
PATCH2 :HEIGHT :WIDTH :PATTERNS
END

```

```

TO PATCH2 :HEIGHT :WIDTH :PATTERNS
IF :HEIGHT = 0 [SETPOS :TOPLEFT CURSOR STOP]
REPEAT :WIDTH [TILE :PATTERNS PU MOVERT 1]
MOVELT :WIDTH
MOVEDN 1
PATCH2 :HEIGHT - 1 :WIDTH :PATTERNS
END

```

`BORDER` produces a border with dimensions *height* and *width*. `CORNERS` stamps a tile at each of the corners of a textile with dimensions *height* and *width*. Like `PATCH`, `BORDER` and `CORNERS` leaves the turtle at the top-left corner of the textile and gives the turtle the cursor shape.

```

TO BORDER :HEIGHT :WIDTH :PATTERNS
REPEAT :WIDTH - 1 [TILE :PATTERNS MOVERT 1]
REPEAT :HEIGHT - 1 [TILE :PATTERNS MOVEDN 1]
REPEAT :WIDTH - 1 [TILE :PATTERNS MOVELT 1]
REPEAT :HEIGHT - 1 [TILE PATTERNS MOVEUP 1]
CURSOR
END

```

```

TO CORNERS :HEIGHT :WIDTH :PATTERNS
TILE :PATTERNS
MOVERT :WIDTH - 1
TILE :PATTERNS
MOVEDN :HEIGHT - 1
TILE :PATTERNS
MOVELT :WIDTH - 1
TILE :PATTERNS
MOVEUP :HEIGHT - 1
CURSOR
END

```

Like PATCH, BORDER and CORNERS, RANDOMPATCH's first two inputs are the height and width of a patch. However, its third input is a list of tiles which RANDOMPATCH uses randomly to populate the patch.

form

```
RANDOMPATCH height width list-of-tiles
```

using it

```
RANDOMPATCH 3 4 [star oriental]
```

```

TO RANDOMPATCH :HEIGHT :WIDTH :TILE.NAMES
MAKE 'TOPLEFT POS
RANPATCH2 :HEIGHT :WIDTH :TILE.NAMES
END

```

```

TO RANPATCH2 :HEIGHT :WIDTH :TILE.NAMES
IF :HEIGHT = 0 [SETPOS :TOPLEFT CURSOR STOP]
REPEAT :WIDTH [TILE PREPARETILE RANDOMPICK :TILE.NAMES MOVERT 1]
MOVELT :WIDTH
MOVEDN 1
RANPATCH2 :HEIGHT - 1 :WIDTH :TILE.NAMES
END

```

RANDOMPATCH uses RANDOMPICK to pick a tile from the list of tiles (at its third input), and PREPARETILE to make sure that the tile is in a form usable by TILE.

```

RANDOMPICK :LIST
OP ITEM (1 + RANDOM (COUNT :LIST)) :LIST
END

```

```

TO PREPARETILE :TILE
IFELSE WORD? :TILE [OP THING :TILE] [OP :TILE]
END

```

The procedure STARTUP (below) is used to automatically name colors (e.g. red, blue, etc.) or complex tiles (e.g. oriental, star) when the user enters the file containing the textile design microworld.

Appendices

```
TO STARTUP
MAKE "white 0
MAKE "black 1
MAKE "blue 4
MAKE "lightblue 59
MAKE "green 3
MAKE "lightgreen 52
MAKE "red 5
MAKE "pink 6
MAKE "brown 7
MAKE "lightbrown 13
MAKE "gray 9
MAKE "lightgray 8
MAKE "orange 14
MAKE "yellow 25
MAKE "lightyellow 15
MAKE "purple 26
MAKE "lightpurple 20
MAKE "oriental [[31 black] [32 yellow]]
MAKE "star [[7 red] [10 blue]]
PRINT [Type TUTORIAL for a brief introduction or TEXTILEHELP for the commands.]
END
```

TUTORIAL clears the screen of text and graphics, shows the cursor (CURSOR) by blinking it (using REPEAT), lists the textile design commands (TEXTILEHELP), tells the user that these commands can be re-displayed when desirable, then offers to show some examples (EXAMPLES). The WAIT commands are used to give the user time to read the text. The PRINT [] commands makes the displayed text easier to read by adding double spacing.

```
TO TUTORIAL
CTCG
PRINT [Here's the cursor.]
REPEAT 5 [HT WAIT 10 ST WAIT 10]
WAIT 60
PRINT []
PRINT [Here are the commands.]
WAIT 120
TEXTILEHELP
WAIT 300
CT
PRINT [To get a list of textile commands, type: TEXTILEHELP.]
PRINT [To remove the list type: CT (clear text)]
WAIT 240
PRINT []
PRINT [Type EXAMPLES for examples of textile designs.]
END
```

TEXTILEHELP clears the screen of text and displays the textile design commands.

```

TO TEXTILEHELP
CT
PRINT [tile [shape color], or tile [[shape color] [shape color] [etc.]]
PRINT []
PRINT [patch <height> <width> <tile/s>]
PRINT [border <height> <width> <tile/s>]
PRINT [corners <height> <width> <tile/s>]
PRINT [randompatch <height> <width> <tile.list>]
PRINT []
PRINT [moveup <number.of.tiles>]
PRINT [movedn <number.of.tiles>]
PRINT [movelt <number.of.tiles>]
PRINT [movert <number.of.tiles>]
PRINT []
PRINT [manualmove <arrow-keys>]
PRINT [space bar to STOP]
END

```

EXAMPLES draws two designs on the screen while displaying their names.

```

TO EXAMPLES
CT CG
PRINT [Here are some examples of textile designs.]
WAIT 120
PRINT []
PU SETPOS [-150 0]
PRINT [This is procedure DESIGN1.]
DESIGN1
SETPOS [0 0]
PRINT []
WAIT 20
PRINT [This is procedure DESIGN2.]
DESIGN2
END

```

```

TO DESIGN1
PATCH 5 7 [21 4]
PATCH 5 7 :star
BORDER 5 7 [patch 11]
BORDER 5 7 [36 1]
CORNERS 5 7 [patch 4]
CORNERS 5 7 :STAR
END

```

```

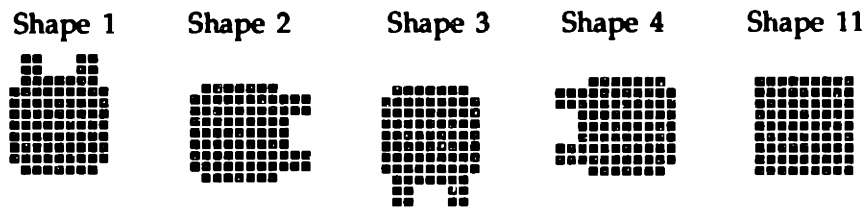
TO DESIGN2
PATCH 5 9 [patch gray]
PATCH 5 9 :oriental
BORDER 5 9 [36 lightblue]
CORNERS 5 9 [patch gray]
CORNERS 5 9 [34 black]
END

```

Appendix I Artificial Life Design

The Two-Bug World

Both bugs use the shapes shown below (shape 1 = heading 0, shape 2 = heading 90, shape 3 = heading 180, and shape 4 = heading 270). Shape 11 is the shape of the trace the bugs leave behind after their moves. The color of the trace or the background color represent the scents each bug uses to determine future moves.



CHANGESHAPE is the procedure used to change the shape of the bugs when their heading changes.

```

TO CHANGESHAPE :HEADING
IF :HEADING = 0 [SETSH 1]
IF :HEADING = 90 [SETSH 2]
IF :HEADING = 180 [SETSH 3]
IF :HEADING = 270 [SETSH 4]
END
    
```

Comments

```

;bug-up
;bug-right
;bug-down
;bug-left
    
```

The procedure SETUPBUG sets up the display by turning it black and gives the turtle the bug shape with a white color.

```

TO SETUPBUG :BUG
CG TELL ALL HT
SETBG 1
TELL :BUG - 1 SETSH 1 SETC 0 ST
END
    
```

Comments

```

;clear graphics, hide all turtles
;make background black
;make bug white
    
```

Both bugs use the Logo command COLORUNDER to pick up the color-scent. This scent is either the background color or the color-scent left behind by the bug's previous moves (using Logo's STAMP command).

Bug 1

The procedure BUG1 uses the subprocedure MOVEBUG1 and the current scent (i.e. COLORUNDER) to determine its next move.

```
TO BUG1
TELL 0
MOVEBUG1 COLORUNDER
BUG1
END
```

The procedure MOVEBUG1 is used to make bug 1 move. It looks more complicated than it really is. Many of the commands within MOVEBUG1 (see the comments) produce cosmetic changes alone. Bug 1 actually has only two options.

1. If it senses black, it leaves a red scent and goes one square to the left (LT 90, FD 9)
2. If it senses red, it leaves a black scent and goes one square to the right (RT 90, FD 9)

	<u>Comments</u>
TO MOVEBUG1 :COLOR	
IF :COLOR = 1 [SETC 5 SETSH 11	;if black, make red, get square
shape	
PD STAMP PU	;stamp shape
SETC 0 LT 90	;make white, turn left
CHANGESHape HEADING	;get shape for new heading
FD 9]	;move forward one square
IF :COLOR = 5 [SETC 1 SETSH 11	;if red, make black, get square
shape	
PD STAMP PU	;stamp shape
SETC 0 RT 90	;make white, turn right
CHANGESHape HEADING	;get shape for new heading
FD 9]	;move forward one square
END	

The reason why the bug moves in 9-step increments is that the scent it leaves behind is a square 9 dots high and wide. To observe the behavior of bug 1, type the following.

```
SETUPBUG =>
BUG1 =>
```

Bug 2

Bug 2 uses the procedure BUG2 and the subprocedure MOVEBUG2 and its current scent (i.e. COLORUNDER) to determine its next move.

```
TO BUG2
TELL 1
MOVEBUG2 COLORUNDER
BUG2
END
```

MOVEBUG2 is similar in form to MOVEBUG1 except that bug 2 has four (rather than two) options.

1. If it senses black, it leaves a red scent and move one square to the right.
2. If it senses red, it leaves a yellow scent and moves one square to the right.
3. If it senses yellow, it leaves a green scent and moves one square to the left.
4. If it senses green, it leaves a black scent and moves one square to the left.

	<u>Comments</u>
TO MOVEBUG2 :COLOR	
IF :COLOR = 1 [SETC 5 SETSH 11	;if black, make red
PD STAMP PU	;stamp shape
SETC 0 RT 90	;make white, turn right
CHANGESHape HEADING	;get shape for new heading
FD 9]	;move forward one square
IF :COLOR = 5 [SETC 15 SETSH 11	;if red, make yellow
PD STAMP PU	;stamp shape
SETC 0 RT 90	;make white, turn right
CHANGESHape HEADING	;get shape for new heading
FD 9]	;move forward one square
IF :COLOR = 15 [SETC 3 SETSH 11	;if yellow, make green
PD STAMP PU	;stamp shape
SETC 0 LT 90	;make white, turn left
CHANGESHape HEADING	;get shape for new heading
FD 9]	;move forward one square
IF :COLOR = 3 [SETC 1 SETSH 11	;if green, make black
PD STAMP PU	;stamp shape
SETC 0 LT 90	;make white, turn left
CHANGESHape HEADING	;get shape for new heading
FD 9]	;move forward one square
END	

To observe the behavior of bug 2, type the following.

```
SETUPBUG =>
BUG2 =>
```

Bug Encounters

I think of bug 1 as the child of bug 2. For one reason, bug 2 has bug 1's "sensitivities" as well as others bug 1 does not have. This can be dramatically illustrated when we cause bugs 1 and 2 to encounter each other. Notice that bug 1 does not know what to do when it encounters the yellow-scent or the green-scent. Also notice that bug 2 appears to help bug 1 out by replacing scents it cannot react to by those it can (namely, black and red).

The procedure SETUPENCOUNTERS uses the subprocedure RANDOMPOS to place the two bugs at random positions on the screen. Notice that RANDOMPOS produces X and Y values that are multiples of 9 between -45 and 45. This is intentional. The color-scents the bugs leave behind are squares 9 dots wide and high. The range of numbers between -45 and 45 (used by RANDOMPOS) start the bugs near each other.

```

TO SETUPENCOUNTERS
CG TELL ALL HT
SETBG 1
TELL 0 SETSH 1 SETC 0 SETPOS RANDOMPOS ST
TELL 1 SETSH 1 SETC 0 SETPOS RANDOMPOS ST
END

```

```

TO RANDOMPOS
OP LIST ((RANDOM 10) * 9) - 45 ((RANDOM 10) * 9) - 45
END

```

The procedure ENCOUNTERS causes bugs 1 and 2 to each make their moves one at a time.

	<u>Comments</u>
TO ENCOUNTERS	
TELL 0 MOVEBUG1 COLORUNDER	;move bug 1
TELL 1 MOVEBUG2 COLORUNDER	;move bug 2
ENCOUNTERS	;do it again
END	

Type the following to observe the encounters between the two bugs.

```

SETUPENCOUNTERS =>
ENCOUNTERS =>

```


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