The Structure, Perception and Generation of Musical Patterns

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ABSRACT

Structure distinguishes music from noise. When formulating that structure, musical artists rely on both mental representations and sensory perceptions to organize pitch, rhythm, harmony, timbre and dynamics into musical patterns. The generative process may be compared to playing a game, with goals, constraints, rules and strategies. In this study, games serve as a model for the interrelated mechanisms of music creation, and provide a format for an experimental technique that constrains creators as they generate simple rhythmic patterns. Correlations between subjects' responses and across experiments with varied constraints provide insight into how structure is defined in situ and how constraints impact creators' perceptions and decisions.

Through the music composition games we investigate the nature of generative strategizing, refine a method for observing the generative process, and model the interconnecting components of a generative decision. The patterns produced in these games and the findings derived from observing how the games are played elucidate the roles of metric inference, preference and the perception of similarity in the generative process, and lead us to a representation of generative decision tied to a creator's perception of structure.

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Introduction: The Generative Process and Games

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1.0 Introduction

The process of generating music may be compared to playing a game, with goals, constraints, rules and strategies. In this study, new insight into the generative process is gained through game comparisons. Games serve as a model for the interrelated mechanisms of music creation, and provide a format for an experimental technique.

The generative process [1] is the process of production through which artists yield artifacts with complex structure. It is not one process but an immensely complex mixture of sensations and cognitive processes; after all an artist has competence in a medium and knowledge of other artists and artworks. Although these types of knowledge can be distinguished for analysis by an observer, these different abilities are mutually informative to an artist as he or she creates an artifact. Much has been written on the structure of music, but very little of that literature addresses how musical creators themselves perceive structure in the compositions they generate.

The music composition games designed for this study involve generating simple rhythmic patterns. Through them we investigate the nature of generative strategizing, refine a method for observing the generative process in situ, and devise a model for the interconnection of the various components of a generative decision. The patterns produced in these games and the findings derived from observing how the games are played elucidate the roles of metric inference, preference and the perception of similarity in the generative process, and lead us to a representation of generative decision tied to a creator's perception of structure.

In many prior studies structure and generative process in music have been compared to language. [2] These semblances do not cover every aspect of the generative process in music, but it remains informative to explore points of convergence and divergence. The fact that there are similarities and differences between music and language should not

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[1] The term generative process has been chosen deliberately and carefully over the more common term "creative process". Creativity is often associated not just with the creation of an idea or an artifact, but also with novelty or innovation. By contrast, this work addresses the cognitive capacities of all creators and not just exceptional creators. This distinction is not merely semantic but essential to the establishment of a grounded experimental methodology.
[2] Lerdahl and Jackendoff's Generative Theories of Tonal Harmony will be discussed in chapter two, as well as, Adorno's critique of the music and language comparisons. There are numerous other studies in this area including the work of Laske, Sundberg, and Roads.

be a source of confusion, but rather mechanism through which we gain a better understanding their respective qualities.
Interestingly, language has previously been compared to a game. The *Language Games*, developed by Wittgenstein, epitomize the generation of complex structure in language [3] - a process, he observes, in which there is an essential connection between function and context. The music composition games in this study reveal similar associations in the generative process of music. It is the lesson of function and context and not any other, more specific structural connection between music and language that we bring to this study, but it is a lesson that fundamentally deepens our ability to understand and subsequently model the processes of music creation.

Language games are primitive and elemental like the process of a child learning a language. A child grasps and then expands word-object-meaning associations. For example, an infant sees a dog, points at it and utters "da". The mother says, "yes, dog." The child maps the features of the dog object to word/symbol/representation "dog". For a while all hairy, dog-sized creatures are "da or dog", but then the child begins to discriminate dog from cat and then Shepard from Husky. Eventually, the child acquires far more complicated abstractions like "dog-eared." Abstractions drawn from specific instances provide us with an arsenal of concepts. Concepts may be augmented. The same word "dog" has multifarious functions.

For music, too, the game model acts as a template for describing the construction of complex structure regardless of how that structure is defined. Be it a vertical relationship, a temporally distributed pattern, or a more general characteristic such as timbre, game-like models preserve the properties of flexibility, context dependence, and expandability of musical patterns. We exploit these properties when generating artistic artifacts, but tend to discard or minimize them in theoretical analysis and discourse where there is a need to manage the complexity of the processes under investigation. Examining the simplest forms of musical organization is also a way to manage complexity while better incorporating the intrinsic plasticity of the generative process into our observations.

There are simple games and complicated games. A simple game is made more complex by adding rules and modifying constraints. Simple forms in language are a foundation for understanding the more complex ones. Of the language games, Wittgenstein wrote,

> The study of language games is the study of primitive forms of language or primitive languages. If we want to study the problems of truth and falsehood, of the agreement and disagreement of propositions with reality, of the nature of assertion, assumption, and question, we shall with great advantage look at primitive forms of language in which these forms of thinking appear without the confusing background of highly complicated processes of thought. When we look at such simple forms of language the mental mist which seems to enshroud our ordinary use of language disappears. We see activities, reactions, which are clear-cut and transparent. On the other hand we recognize in these simple

[3] The precise meaning and applicability of Wittgenstein's "language games" are still topics for debate in the fields of philosophy and linguistics. We will neither support nor refute the opinions of experts in either of these fields.

> processes forms of language not separated by a break from our more complicated ones. We see that we can build up the complicated forms from the primitive ones by gradually adding new forms. [Wittgenstein 1958 p.17]

Similarly, to best understand the generative process in music, we must find a way to clear the "mental mist" of music theory and the conventions of common performance practice. In order to grasp the complexity of musical composition, we must strive to understand the processes through which the primitive forms emerge.

1.1 Goals and Scope: A New Way to Study the Generative Process

Architect Habraken notes,

> Wittgenstein's introduction of 'language-game' was not just a more expansive way of looking at language than representing a language by logic. His emphasis on speaking a language as part of human activity was intended as a way of understanding what people mean by examining what they say. [Habraken p.2-7] [4]

Extending this insight, in the realm of artistic expression, we can we understand what people mean or intend by observing what they do in situ. A primary goal of this study is to find an experimental method through which musicians can be observed in the process of making aesthetic, generative decisions. Through these experiments we hope to gain a better understanding of the processes that come to bear on those decisions, and better understand artists' perception of structure as they generate artifacts. In designing these experiments and developing a method for analyzing the results we will transverse several fields, including cognition, perception, aesthetics, design theory, music theory and artistic practice. We begin with the uncomfortable assumption that music theory and Gestalt psychology provide only a partial and skewed model of an artist's conception. The middle ground is indistinct and volatile.

There is presently a paucity of experimental data [5] on the generative process, and very few previous attempts at developing a methodology from which to draw. Following from this dearth of objective data is our lack of ability to draw comparisons between one musical creator in various situations, and/or various creators in similar situations. Constructing an experimental paradigm that brings these processes out into the light where they can be observed is no trivial matter.

The musical creator is not only a listener. We do not want to observe a creator's auditory perceptions alone, but try to understand how structure is conceived. Unveiling the process of conception is a far more difficult procedure, and process far more difficult to measure. What is the nature of the negotiation between the physical act of perceiving aspects of an emerging musical creation and the imaging of possibilities for

[4] Similarly, William James's pragmatism emphasizes that understanding the meaning of something comes from understanding how it is used and applied in context.

[5] Music theory often touches on generative process, but has no tradition of experimentation. Psychology and cognition are obviously rooted in experimentation, but the generative process remains a particularly difficult human behavior to measure. This dissertation suggests several ways of overcoming that obstacle.

that artifact? [6]

In the study presented here, we will emphasize rhythmic structure and use only very primitive musical constructions comprised of few very pitches, timbres, and durations. Using such simple forms simplifies the task of making comparisons among artists both because the artifacts themselves are easier to analyze and the cognitive complexity artists bring to the generative task is minimized. These simple forms provide a solid footing for investigating more complex aspects of the generative process. At this primitive level, structure can be analyzed and described without explicit explanation by the creators or conjecture about the creators' artistic processes. Primitive structure is style independent, and independent of varying production constraints such as economic factors and limitations of the media or tools. Nonetheless, even the most unsophisticated generative decisions are the result of many distinct yet co-dependent criteria. The authors (as will be discussed in chapter two) of previous generative theories believed some level of enumeration, quantification, and qualification of the generative process were possible, and we will follow suit.

1.2 Structure, Context and Meaning

The complex relationship in any art form among structure, context and meaning makes the generative process a challenging phenomenon to observe. Any perception of structure is filtered through a particular context. Context is all the interrelated conditions under which an object or in this case an artistic gesture exists. Just as there are numerous possible ways to characterize a given structure, there are also numerous ways of characterizing the context. For an artist, the context is in constant flux as concepts are grasped, expanded and transfigured. An artist engaged in the generative act interprets and reinterprets relationships between objects and objects and context.

In the artistic experience, the link between perceiving structure and perceiving meaning cannot be eschewed. Perceiving structure is always dependent on perceptual saliency. However, theoretician and author of many treatise on art, creativity and learning, Nelson Goodman notes, "Denotation is the core of representation and is independent of resemblance." [Goodman 1968 p.5] This disconnection between denotation and connotation complicates how we analyze and subsequently model the process of mapping features to an object or categorizing objects based on a set of features.

External structure arises when features of an object within an artifact overlap with features of objects external to the artifact itself. The internal representation denotes the external object. Alternatively, features might relate, self-referentially to other objects contained within an artifact forming an internal structure. Both internal and external structure may be relevant to a particular artifact or the processes that render it, as is the

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[6] Perceptions are biased by prior experience and knowledge. A belief that is heavily supported by experience or knowledge has a high *prior* and strong likelihood of occurrence. Perceivers have different sorts of *expertise* for certain types of tasks. [Minsky 1986] For example, a listener in the audience may know Japan was hit by an atomic bomb in WWII before hearing "Threnody for Hiroshima" by Penderecki. A composer may know the range of the bassoon and have studied serial composition. The architecture of the generative process acts as a non-expert system that balances the flow and impact of the experts involved.

effect of combining these elements. Gestalt psychology introduced the idea of "holism" which posits that the whole is something different than the sum of parts. An artistic artifact requires a macro structure to provide coherence and to hold together the various elements contained within. During analysis, we can distinguish between these types of structure, but we do not yet know which or when each type of structure becomes the most important to an artist.

1.3 Previous Approaches

One way to study the generative process is to analyze and deconstruct artistic artifacts. Somewhat removed from artistic practice and primarily the province of music and art theorists, this approach has provided a sophisticated understanding of similarity in structure across works, and enumerated the variety of ways structure can be perceived in these works. The artistic artifacts these fields generally study are extraordinarily complex and multifaceted, too much so to clearly help us reconstruct, or reverse engineer, the generative process. In other words, current definitions of structure are created almost exclusively a posteriori to the creative act and divorced from a composer's conception of structure and function. Furthermore, these definitions depend highly on an artificially constrained context. These stratified definitions of structure lead to limited generative models because they are grounded so deeply in the extremes of either low or high level processes, [7] or confine the perceiver to one or another preferred mode of perception. They are often applicable to only one style.

1.4 Lessons from an Art Forger

Wittgenstein observed of spoken language, "When we *mean* (and don't just say) words it seems to us as if there were something coupled to the words." [Wittegenstein 1974 p.5] When a draughtsman draws a line he *means* to draw the line in a particular way. The line itself has a particular character, and the character of that line has a *function* in relationship to the lines surrounding that line. When we rely on theoretical, a posteriori definitions of structure to describe the generative process we squash the artists'

[7] Humans are active and passive perceivers. When confronted with stimuli, humans automatically utilize both top-down (learned, utilizing long-term memory, schema driven) and bottom-up (pertaining to the signal itself, data driven, involuntary) processes to recognize the object that confronts them. These processes are co-dependent. There are no clear delineating breaks along the perception-cognition continuum. Perception starts at the stimulus signal, there is a process of feature detection, and then there is a categorical process that utilizes non-continuous or learned representation. [Snyder] But, the impact of the higher level processes on the lower level ones at the instance of signal detection or feature detection is not well understood. (Low-level processes engage in the analysis of whatever is being perceived. High-level processes are associated with memory and understanding context.)

[8] The evidence for intentional acts is more apparent in some media and artistic techniques than in others. For example, a process like photography incorporates many causal features that are simply by-products of working in that medium. A photograph is linked to a subject that is a real object, and the technical constraints of the camera impose limitations and/or properties on features like focus or field of view. Painting by contrast is neither bound by these causal properties, nor can a painter rely on them for creating an artifact. Therefore an artist's intentions are more readily apparent in this form of artifact. [Mitchell 1992 (in particular, the discussion of Roger Scruton's argument about intentional and causal components in photography p.29-30)]

intention or ignore it completely. We fail to recognize what concepts are pertinent to an artist at the moment of creation, and we do not fully understand the intended function of each element or structural relationship. Is it possible to recognize and characterize an artist's intention?

The craft of art forgery provides a highly instructive inlet into the generative process because the forger possesses insight into artistic strategy. Art forgers imitate the intention [8] of other artists. There are at least three kinds of fakes: copies, pastiche and forgeries. Each relates to the act of creating an artifact in a different way, and suggests a different sort of model for the generative process. The apparent strengths and failures of each method illuminate more clearly the processes of the imitated artists. Eric Hebborn (1934-1996) was a masterful forger of works by the "Old Masters." His notoriety came not from copies of existing works, but rather exceedingly convincing drawings and paintings in the personal styles of other artists.

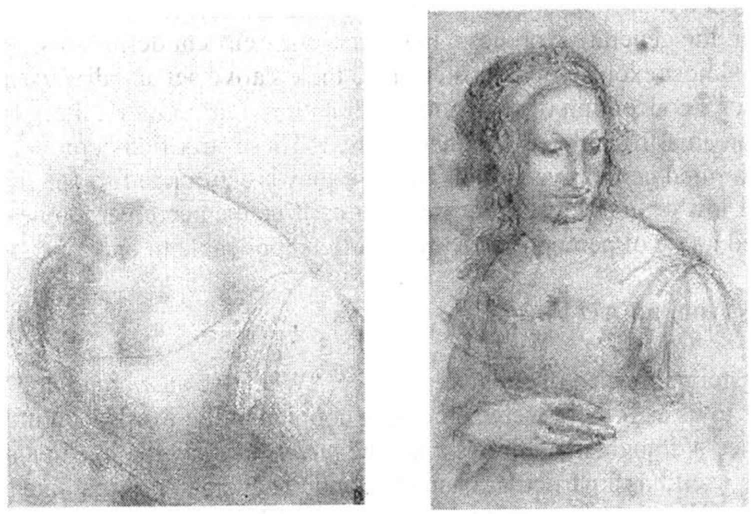

Figure 1: Leonardo da Vinci (1452-1519) *Study for Madonna of Yarn-Winde,* Royal Library, Windsor (left), Eric Hebborn *Decorative Drawing in the Style of Leonardo da Vinci,* [Hebborn, 1997, plate 25] (right) Hebborn's forgeries are not only convincing in terms of imagery and draftsmanship, but in the attention to detail he applied to the materials he used.

At times, Hebborn also copied copies in order to better understand the synthetic process. He was especially interested in the preparatory drawings of engravers. Scholars often mistake these drawings for preparatory studies by the original artists. Hebborn writes,

> All but the very best of these engravers' drawings can be distinguished from the original productions by a certain lifelessness in the line. Every line is meticulously copied, but in the process something of the spontaneous touch of the creative draughtsman is lost. The reproductive engraver does not as a rule really know how to draw, and can therefore only produce the outward appearance of the lines… [Hebborn 1991 p.213]

Hebborn attributed this difference to the speed with which a line was drawn. The engraver, by necessity, works much more slowly than the original artist. The spontaneity of which Hebborn speaks is not simply the speed, technique and trajectory of the charcoal pencil as a line is drawn. An artist draws each line with particular speed, technique and trajectory because he *means* something by drawing the line in this way. The speed of the engraver's stylus betrays the authenticity of the work in two ways. Not only are the traces overtly methodical leaving telltale signs of studied pressure variations, but they also divulge an unnatural languidness and a misappropriated attention in the aesthetic decision it attempts to imitate.

Additionally, Hebborn observes, recombining elements is not a convincing model of the generative process. Hebborn noted, "Combining elements from different drawings by the same master, a technique known as pastiche, will not fool a serious scholar for a minute." [Hebborn 1997 caption plate 25] The structure in artistic artifacts does arise from a potentially vast but finite set of possibilities. However, these possibilities are constrained only by what an artist is capable of conceiving and reproducing in a medium. These potentials cannot be limited with any accuracy to a set of theoretical conventions, nor can the rules for their potential combination be predefined in absolute terms. There is no assurance in pastiche that the intentions of an artist are preserved. When we behold a work of art, it is not the surface features but the underlying structural relationships that convey humanness. Architects Habraken and Gross suggest, "how we use 'designing' points not to an object of design, but to a process." [Habraken p.2-10]

The forgeries for which Hebborn are best known are something all together different from decorative pastiche. A forgery is the synthesis of something new that appears to capture the intention, bias, preference and structural perceptions of the imitated artist. The success of Hebborn's forgeries and fakes lies not in his ability to copy line for line the strokes of another artist, but in his ability to imitate the generative process of another artist. The apparent authenticity of a fake is a measure of success. Unfortunately, a forger's structural analysis exists primarily as a visual analog. The imitation possesses as much complexity as the original likewise barring it from objective analysis. Is there another, more controlled way to observe the generative process, and more specifically through what methods might we best gain deeper insight into how an artist perceives structure in the artifacts he generates? It is this problem that this dissertation will explore through concept design games.

1.5 Concept Design Games: Observing the Generative Process In Situ

Concept Design Games are games with a pre-determined format through which players generate artistic artifacts with particular attributes. They have been used in Visual Arts and Architecture programs to engage students in a designing task for the purpose of teaching fundamental Design principles. The games have also been used as a research tool in design studies.[9] What makes a design game game-like is an explicit goal and a constrained set of rules and materials.

For example, in the "silent" game developed by Iversen and Buur, two players work

[9] The concept design games have a somewhat murky history. Their use as a teaching tool reaches back decades. Similar constructivist strategies can be found in many design methodologies. More recently, the games have been used in design studies research.

together, taking turns, without speaking to establish and embellish a pattern. This exchange is similar to what musicians do when they "jam" in quick interaction. The two players are given a limited set of materials (i.e. coins, paper clips, etc.). These objects are to be organized into a pattern. One player starts by arranging a few elements to express an organizational idea. The other participant adds to this pattern attempting to follow the character or rules set out by the first player. If the first player feels the second player has understood or captured the basic principle of the pattern then he can expand on the theme. If he feels the second player has not understood then he must try again to make the pattern rules apparent to the second player. Often the game is followed by a discussion where participants deconstruct what was and was not apparent during the game. The silent game shows that participants often respond similarly to structural relationships, and that the development of a pattern can be negotiated without explicit description. [Iversen and Buur]

The specification of a concept in the concept design games directs all the creator/players of a particular game to some comparable goal. Habraken and Gross in the Architecture Program at MIT have used concept design games extensively as a research tool in design studies. Habraken and Gross observed,

> Learning a language is like learning a technique in the sense that, by examining what we say and how we learn a concept, we can get information about the use of that concept. In general, we can begin to understand a concept by looking at its accepted use. [Habraken p.2-8]

A musical concept, as it will be described here, is a type of constraint. We will see when we observe subjects playing the music composition games that we can distinguish between types of constraints and their impact on the processes of generating artifacts. High and low-level constraints both separately and in combination facilitate the generative decisions. Concepts in the musical games are conditions placed on the relationship between objects. They are described at a high, or fairly abstract, level.[10] These high-level constraints work in consort with creators' low-level perceptions of the musical patterns. Ideally, to meet the goals of this investigation, music composition games could be constrained by some measurable criterion facilitating consistent comparisons across games and creators. Through successive refinements to the games this dissertation identifies criteria suitable for this purpose.

Habraken and Gross compare their games to board games by contrasting designing with the actions of board game participants. They observe,

> As when designing, players must fit pieces into an existing field; rules, conventions, and principles limit how they may move...players make projections for configurations to be constructed...In contrast to real-life experience, the game enables us to study design actions by providing an environment that is manipulable and well-bounded. [Habraken p.1-2]

[10] For example, in chess there are concepts like the hierarchical ranking of some pieces over others. There is only one queen and one king, and these pieces are more important than pawns. There are also lower-level rules in chess governing how these various pieces move about the board, like the rook can only move in horizontal or vertical lines and cannot jump over other pieces.

Habraken and Gross's games build on Wittegenstein's correlation between understanding and explaining. They attempt to show "comparative uses of a concept…by comparing the different outcomes of playing the same game, or by comparing the outcomes of a game with variation in its rules." [Habraken p.2-1] Like Habraken and Gross, we are suggesting games can be used as a research tool for understanding the generative processes in music.

1.6 Music Composition Games

By leveraging games as a means to communicate about structure, the work presented in this dissertation utilizes music composition games as a format for experiments. Through these games, we are able to observe the generative process at work in a fairly naturalistic, music-making environment.

As in their visual counterparts, music composition game "rules", limitations on materials and the functional capacity of the game's interface will serve to constrain participants' degrees of creative freedom providing a basis for comparisons across subjects' responses. Admittedly, the relative structural simplicity demanded by the design game approach (i.e. external control imposed on materials, limited degrees of freedom, and the guiding of intent and conceptualization) likely colors the processes being studied. Nonetheless, we assume as did Wittgenstein, Habraken and Gross that simple forms in music are not separated from the more complex by some clear break, but rather that complex forms emerge when the simple forms are augmented. The games give us far more privileged access to the generative process than musical compositions or artistic musings obtained outside a controlled environment.

1.7 Chapter Breakdown:

To better understand possible components of the generative "game", Chapter Two provides an overview of the generative theory and generative system literature. Generative theories tend to be more human-centric while generative systems focus predominantly on machine systems capable of synthesizing musical artifacts or directly participating in that process. Both of these approaches are highly interdisciplinary and utilize findings from music theory, perception, artificial intelligence and cognitive science.

Chapter Three describes the first of three music composition games used in this study. This game focuses on the process of attending to internal and external structure. Through this study of the various components of a generative decision become more clearly delineated and the nature of their interrelation more apparent. The clarification provided by observing this game establishes a more robust framework for utilizing the games as an experimental format.

The second and third games, described in Chapter Four, are used to investigate the impact of certain types of perceptions on the generative process, specifically preference and similarity. These experiments also investigate the transmutability of an artist's perception of context through a game in which participants increase their preference for a particular pattern by manipulating some of its components. Chapter Five offers concluding observations on this research pertaining both to the generative process and the methods used to observe it.

By the end, we will have presented an experimental format for observing a generative, musical decision; observations on attending to internal and external structure; a reassessment of the components of a generative decisions and their interrelation; some findings on the impact of preference and similarity on a generative decision; and a visual representation of a generative decision which maps a newly generated pattern to a particular creator's perception of similarity. We will have also explored aspects of the creator's perspective of context. All of these insights will add to our current understanding of the generative process and the nature of musical expression.

Background: Perspectives on the Generative Process

2

2.0 Modeling Structure in Artistic Artifacts for Humans and Machines

There is a diversity of previous work exploring the generative process on which to build. The proceeding pages contain a representative sampling of these diverse approaches, sketching key trends, in efforts to model generative process. These discussions follow several intertwining and mutually informative threads. This review emphases musical studies, but findings from design theory provide additionally invaluable insight. By comparing generative processes, we can with great advantage build intellectual bridges among media and disciplines.

The term "generative" has been used numerous ways in the music cognition literature. West, Howell, and Cross differentiate between these meanings based on what is generated and the origin of that particular process. Their categories are distinguished as follows [West, Howell, Cross 1991 p.12]:

- The creation of an artifact by an artist. In the case of music, this is the creation of a composition or an actual musical performance
- The creation of surface patterns derived from a more compact representation
- The interpretation of surface structure relative to underlying structure
- The generation of musical corpus within the constraints of a specific style

What roles do these varying perspectives on structure play in an artist's production process? Descriptions of structure will vary according to each definition, but also depending on whether the term is applied to a cognitive behavior or a machine model; after all, the constraints for man and machine differ significantly. Additionally, bottom up and top down approaches emphasize different sorts of constraints and structural attributes. Each of the following approaches reveals different aspects of structure and the generative process.

2.1 Lerdahl's and Jackendoff Generative Theory of Tonal Music

Linguistic theory, in particular the generative grammars of Noam Chomsky, has greatly influenced the study of generative process. Drawing close parallels with generative grammars in language, Jackendoff and Lerdahl investigated formal grammars for tonal music. Their Generative Theory of Tonal Music (GTTM) supports many of the theoretical explanations for musical structure in the Western tonal harmony system while also drawing close parallels with generative grammars. The theory distinguishes between competence knowledge, the knowledge of structure and lexicon, and performance knowledge, or the knowledge of how to make logical phrases according to a particular grammar. The GTTM suggests music may be represented in terms of syntactical rules. Generative grammars and subsequently the GTTM are sensitive to a finite set of plausible options necessitating a relatively fixed and narrow definition of context.

The GTTM attempts to account for a broad spectrum of relationships through one form of reduction, *hierarchies*.[1] Temporal sub-divisions are described rhythmically or metrically. Rhythmic structure accounts for the formation of "groups" in the Gestalt sense, and divides the composition into identifiable phrases, motives, etc. Metric structure accounts for strong and weak beats. Pitch hierarchies are formed by key relationships between harmonic and melodic tension and relaxation, as well as accents on strong and weak beats.

The theory does not consider timbre and dynamics, nor does it offer a structural reduction of transformations of motives and themes. Jackendoff and Lerdahl called these non-hierarchical structures *associative*; such structures cannot be represented by the GTTM. This rigidity limits how we can describe the composer's view of structure. We do need some model explaining how timbre and dynamics lend themselves to structural coherence because these are obviously principal considerations for the composer. The mapping of linguistic structure to musical structure is a tricky matter. Clearly, many analogies can be drawn between music and language, but identifying the structural level at which these comparisons can be made robustly requires further investigation.

2.1.1 Adorno's Comparisons Between Music and Language

Applying this idea of a generative grammar to a model of generative process is problematic in several ways. As mentioned above, rules for the construction of musical phrases that closely imitate a language-like syntax lead to grammars applicable to only narrowly defined musical categories. The similarity between language and music, Adorno suggests, arises from the entirety of a musical work rather from the relationships of its constituent elements. More generally, Theodore Adorno writes,

> Music resembles language in the sense that it is a temporal sequence of articulated sounds which are more than just sounds. They say something, often something human. The better the music, the more forcefully they say it. The succession of sounds is like logic: it can be right or wrong. But what has been said cannot be detached from the music. Music creates no semiotic system. [Adorno, 1956]

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[1] Much of Lerdahl and Jackendoff's inspiration for hierarchical reduction can be traced back to Heinrich Schenker. Schenker worked strictly in the domain of Western tonal harmony in the 18th and 19th centuries. He was interested in the formation of coherent structure and intentionality in the compositions of notable European composers. Schenker focused on the techniques of only the most skilled practitioners (i.e exceptional rather than normative behavior). His approach is rooted in the idea that compositions are strata of detail layered on top of a basic tonal structure. His contributions have had a profound and pervasive impact on music analysis, and have been scrutinized in detail in the music theory literature.

He likens musical elements to epistemological "primitives" in language. Adorno warns us that although there clearly are structural parallels, we should not accept that language and music function similarly or have the same goal. He makes the observation:

> If musical structure or form is to be more than a set of didactic systems, it does not just embrace the content from outside; it is the thought process by which content is defined. Music becomes meaningful the more perfectly it defines itself in this sense - and not because its particular elements express something symbolically. It is by distancing itself from language that its resemblance to language finds its fulfillment. [Adorno, 1956]

Didactic may be too narrow a description in many areas of expression. An artist may of course have numerous reasons to make reference to external objects, but the focus of Adorno's argument is on some internal coherence integral to artistic structure.

Like Wittgenstein, Adorno stressed the link between context and function. The concept, responsible for binding words to meaning, further gives a musical element function and is inextricable from context. Any inference made about that function by an artist or listener shifts with that context. When we listen to a piece of music (for the first time) it is in some ways like inferring the rules to a sports game without any detailed a priori knowledge of how that game is played. What is observed in situ in the stadium sets the context for the actions of the players. Understanding a composition is in part a process of inferring explanations for the interrelation of musical elements. This does not obviate the role of other forms of knowledge in understanding or generating music. It merely adds to our understanding of the artistic expression.

The tighter the correlation between observed actions in the sports game and the inferred strategy of the players, the greater the game plan coheres in a spectator's mind. If we want to understand how structure in art is generated, then it behooves us to understand the nature of the game plan. "Music becomes meaningful the more perfectly it defines itself ...," claimed Adorno. Musical structures distilled from the context are not pointers to a process, but only symbols without intended meaning.

2.2 Schoenberg's Grund Gestalten

Composer Arnold Schoenberg was interested in the generative process, and sought descriptions of structure that could better explain the way we perceive coherence in music. Schoenberg, who published extensively on music theory, hypothesized that a composer's perception of structure was not bound to the specific harmonic relationships espoused in music theory, but rather to more fundamental patterns of organization. Schoenberg's approach is not game-like in the Wittgenstein sense. Rather he was interested in the emergence of form and structure through exploiting an inherent flexibility in musical components.

Besides writing numerous treatises on music theory, the composer published extensively on the more philosophical concerns of musical structure, and attempted to lay down a framework for describing internal structure in music. The various components of this framework are quite distinguishable from his pedagogical writings.

Schoenberg clarified the distinction between theory and practice thus,

> What is meant is not that a composer must somehow compose this way but, as I say, only that he does compose this way. Theory must be always be somewhat stricter – reality does not concern itself with it very much...[Music] Theory is guided by an ideal case...but it does not aim to arrive at one. For if it were reached, one would recognize that it is anything but an ideal case; not a creative one, obviously, not even a theoretical one. [Schoenberg 1995 p.89]

Schoenberg did not discount that theoretical tenets are in some ways an elaboration on these basic patterns, but he did free composers' minds from the trappings of theory. He further suggested that a composer conceived of fairly primitive patterns that could appear in various guises throughout a composition. For example, a melodic phrase might have a particular character that could not be sufficiently described by intervallic relationship. This character could reappear as a rhythmic motif or as a juxtaposition of timbres; these sorts of relationships, Schoenberg believed, governed composers' decisions.

In his book, The Musical Idea, Schoenberg dissects music into its most elemental components. The *motive* is the smallest part of a musical piece or section of a piece. It is recognizable regardless of variation and transformation. Motives have features. Schoenberg described features as musical characteristics such as intervals, rhythms, harmony, contrapuntal combinations, accents, and dynamics. He left open the possibility that less quantifiable attributes like sonority or mood might also constitute a feature.

Gestalten consist of multiple instances of the motive and/or its variations. Gestalten have one or more characteristic features to justify their distinction yet their function within a piece may be limited to a specific section. *Grund Gestalten* serve a function throughout an entire piece, and all gestalten originate from grund gestalten. A grund gestalt consists of several different forms of the motive. The interoperability of these components creates coherence. Coherence, he emphasized, is essential to the integrity of a musical work. Comprehension is not possible without coherence. Schoenberg remarked,

> Musical art, after all, consists of producing large and small images, which cohere by means of the motive, which in their individual contents likewise cohere with it, and which are assembled so that the logic of the total image is as apparent as that of its single part and of their combination. This logic rests on the meaningful and purposeful exploitation of musical coherences with a view to the total goal. [Schoenberg 1995 p.149]

Schoenberg described a generative process in which coherence emerges through an interrelation of elements on multiple levels. Coherent structure emerges through the modal relation between features of these elements. Structural interpretation becomes vague when we introduce interoperability. For example, how many rectangles appear in the image below, two or three?

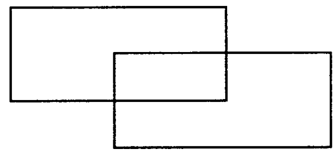

Figure 2: How many rectangles?

The answer is ambiguous. It also highlights a motif that binds the two, large rectangles. Humans, artists and audiences, can easily perceive structural similarities between distinct elements of an artifact while a computational system relying on a generative grammar will only be sensitive to clearly, pre-defined structures. The generative grammar model is capable of representing how we recognize two rectangles in this picture.

2.3 Stiny's Shape Grammars

George Stiny is interested in addressing and modeling the ambiguity of structure, and has offered the field of design theory an alternative to rigidly defined notions of syntax. These approaches hold implications for structure in musical patterns as well as visual designs. Stiny's "Shape Grammars" [Stiny, Stiny 1972, Stiny 1978] uses algebraic descriptions as a basis for defining shape primitives that transform according to rules into more elaborately structured graphic (and/or potentially physical) compositions.

The basic shape on the left may be interpreted as two squares or as four triangles with equal plausibility, the small rectangle the mechanism through which the entire figure coheres.

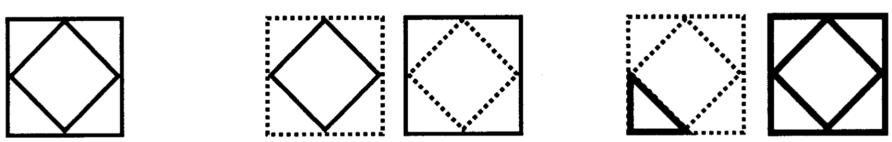

Figure 3a: Possible interpretations of a shape (These drawings and the drawings in figure 3b were based on examples created by Mine Ozkar who has worked on numerous illustrations for George Stiny)

In the shape grammar, fundamental components are not defined in terms of definite parts, but rather as linear relationships defined through coordinate geometry. Boolean operators describe the relationships of parts. In a shape defined by algebra U_{ij}, i denotes the dimensionality of the basic shape. i = 0 indicates that the most basic element is a point, i = 1 the elements are lines, i = 2 the basic element is a plane, and i = 3 the basic element is a solid. j describes relationships between basic shapes.

A shape has a distinct, non-empty part, and/or every shape is a distinct part of another shape, or neither. When j = 0 neither criteria is satisfied. If i = 0 and j > i, every shape is part of another shape. And, if i > 0 and j > i both criteria are satisfied.

Figure 3b: Linear relationships are defined through coordinate geometry. The image on the left comes from an algebra in which i = 0 and j = 2. An algebra in which i = 1 and j = 2 could yield the image on the right.

A rule in the shape grammar constitutes a Euclidean transformation through which a primitive shape evolves into more complex forms. [Stiny] By taking this approach, Stiny's grammar potentially generates an enormous number of possible configurations, and allows for ambiguity in the definition and interpretation of structure and components. What Stiny describes as ambiguous is what allows for interoperability of Schoenberg's motives. Elements in artistic artifacts have many features, subsets of which form modal relationships with other elements. A single element may form different relationships with different elements. The ability to reconfigure artistic elements is noteworthy because it can be leveraged to generate more complicated forms.

2.4 Eno and Schmidt's Oblique Strategies

As apparent in the previous example of overlapping rectangles, patterns of organizations are apparent in the feature overlaps. Two overlapping rectangular shapes form a third rectangular shape. Stiny's shape grammars help to formalize this type of relationship. This section focuses on building feature overlaps. Artistic elements have features. Subsets of features form relationships with other elements or objects. Identifying and cultivating these overlaps is a key aspect of generative strategy.

In 1975, Brian Eno and Peter Schmidt (artist) created *Oblique Strategies (over one hundred worthwhile dilemmas)* as a tool for the generative process. The Oblique Strategies prescribe the mapping of features of particular objects onto the elements within artistic artifact (of a creation presenting a dilemma). How and why Oblique Strategies works are linked to an artist's perception of structure in the artifacts they create and patterns of overlapping features. Eno and Schmidt never intended the Strategies to be deconstructed as they are here. They published the Strategies as a tool for the creative process. But by analyzing what constitutes an Oblique Strategy and how the Strategies can be employed to solve a creative dilemma, we gain insight into how a generative decision is made. In particular, we develop insight into the role of strategy in generative scenarios. [2]

The Strategies are compelling for several reasons. First, their origin is very practical and applied. They are presented as a tool for creativity (across media) rather than a generative theory or the basis of a generative system. The collection of strategies is

[2] There are undoubtedly many ways an individual could choose to employ the Oblique Strategies to solve a creative dilemma. This analytical exercise attempts to address what constitutes an Oblique Strategy, and subsequently how those findings can shed light on the process of generative strategy.

neither random, nor arbitrary. To the contrary, it is highly redundant. These are very specific strategies that encourage the user to identify, alter and re-contextualize elements without specifying element, context or features of the alteration. They do this with virtually no limitations on the medium.

Oblique Strategies is a deck of cards. Each card has a printed instruction that suggests a strategy for solving a creative dilemma. The strategies are applicable to almost any creative scenario. A few strategies reference the recording studio environment, the locus of most of Eno's work from this period, but even instructions that refer to "tape" or "channels" can be interpreted for other types of production scenarios. The fact that such specific connotations exist, however, should not be disregarded as it suggests an interesting connection between process and medium. The deck's instructions read,

> These cards evolved from our separate observations on the principles underlying what we were doing. [creatively] Sometimes they were recognized in retrospect (intellect catching up with intuition), sometimes they were identified as they were happening, sometimes they were formulated. They can be used as a pack (a set of possibilities being continuously reviewed in the mind) or by drawing a single card from the shuffled pack when a dilemma occurs in a working situation. In this case, the card is trusted even if its appropriateness is quite unclear. They are not final, as new ideas will present themselves, and others will become self-evident. [Eno[3], Schmidt, 1975]

The instructions are intentionally ambiguous. For example, they include: "Only one element of each kind," "Assemble some of the elements in a group and treat the group," "Emphasize the flaws," "Water," and "What would your closest friend do?"

These instructions presume that an artifact can be broken into numerous sets of elements each with a clear set of malleable features, but different Oblique Strategies assume that the generative process is one in which an artist navigates through structural relationships, and manipulates objects and groups of objects with separable or integral structure to yield the intended results. This system is not only sensitive to the variety of factors that bias how an artist perceives these structural relationships, but directly incorporates these variables. Oblique Strategies may be applied to high or low level perceptions and decisions[4].

The wording of each strategy is somewhat arbitrary. It is not so much what The Strategies instruct the creator to do, as much as how they instruct the creator to do it. Although the one hundred and twenty seven Strategies point to different objects of

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[3] Eno, who has worked extensively on generative systems and generative music, has in recent years professed an interest in Conway's "The Game of Life" and has applied game theory to generative music systems. While interesting artistically, this work should not be linked too closely the study of generative process. The hard-wired aspects of these systems reflect an aesthetic rather than critical predilection.
[4] Low-level processes engage in the analysis of whatever is being perceived. High-level processes are associated with memory and understanding context
[5] The term "affordance" was coined by James Gibson to describe an ecological relationship between perception and the physical environment. This is analogous to an animal's symbiotic relationship with its environment.

imitation, there seems to be a limited number of ways through which that imitation might be achieve. The entire (original) set of one hundred and twenty seven strategies can be reduced to two broad classes of strategy.

The first class is *psychological strategies.* This class of strategy addresses the behavior of the strategist.

Psychological Strategies include bias, method, shared context. Examples of each follow below.

1. **Bias:** What would your closest friend do? Put in earplugs.
2. **Method:** Make a sudden, destructive, unpredictable action; Incorporate, use unqualified people.
3. **Shared Context:** Lowest common denominator; What is the reality of the situation?

Bias suggests modifying the mental filter through which preferences are made. *Method* prompts an alteration or examination of the procedures used produce the artifact. *Shared Context* suggests (re)defining the inter-subjective or shared understanding of participants.

Psychological strategies are in essence ways or techniques for getting the strategists to conceive of structure within the framework set out by the next class. *Structural Strategies* in contrast are applicable to the artifact itself and nature of its construction.

Sub categories of Structural strategies include: External Structure, Frame, and Internal Structure.

4. **Frame:** Not building a wall but making a brick; Making a blank valuable by putting it in an exquisite frame.
5. **External Structure:** Water; Think of the radio
6. **Internal Structure**: Don't break the silence; Remove specifics and convert to ambiguities.

Frame suggests altering the context through which the artifact under construction is perceived or imaging an entirely new context. Frame strategies imply kinds of constraints. They characterize the affordance [5] relationship with the context while leaving both constituent elements and contextual constraints ambiguous.

External Structure creates (modal) links between the structure in the artifacts and concepts encountered outside the context of the artifact and/or the production process (i.e. heroism, quiet evening, water). These strategies are pointers to objects. External strategies generate structure by suggesting feature overlaps between objects within and without the artifact.

Alternatively, *Internal Structure* directs an artist to change the (modal) relationships between objects in reference to other constituent objects. *Internal Strategies* imply types relationships between elements within the artifact, and/or a process that describes a transformation of the elements within the artifact (i.e. accretion, turn it upside down). "Stress" and "Elements" can be folded into the Internal Structure category because the number of elements and emphasis on particular elements both describe types of internal structural relationships. Additionally, two particular types of internal structure occur often.

7. **Stress:** Emphasize differences; Don't stress one thing more than another.
8. **Elements/Objects:** Only one element of each kind; Use fewer notes.

Stress instructs an artist to focus attention on specific objects or categories of objects. *Elements/Object* directs an artist to alter the number or kind of object in the artifact. These instructions are more global in direction.

A given Oblique Strategy may trigger different responses, interpretations and decisions for various users or situations. Therefore, many strategies fit into two and sometimes three categories. It is not surprising that the largest category is Method, but Internal Structure is a very close second. External Structure and Bias are also quite prominent. Few strategies address the shared context. Of note is the number of categories is relatively small.

Furthermore, types of categories are obvious in their absence. There are no strategies that directly prompt deduction, for example, or direct an artist to consider the decisions that led to a particular dilemma. There is a strategy that suggests, "Make an exhaustive list of everything you might do and do the last thing on the list," but this does not prompt any sort of conscious weighting of one decision over another. Oblique Strategies do not address the problem of optimization. The emphasis is on how structural relationships are perceived, and how they might be perceived otherwise.

At the lowest level, the mechanism that solves the creative dilemmas is the reduction of discrepancies between the imagined and realized. The Oblique Strategies provide – albeit indirectly – schemes for associating the imagined and the realized. The implications are indirect because each strategy has multiple possible interpretations. Each artist must strategize techniques for reconciling what is present in the artifact and what the artifact might become. It is like a game in which one toys with both the rules and the goal, or the meaning of artistic representation and the outcome after organizing elements in certain ways.

2.4.1 External Structure

Many Oblique Strategies seem overtly referential (i.e. "water" or "think of the radio"). The notion of external structure is reminiscent of what Adorno called didactic. In application of the Strategies, however, denotation can be independent of resemblance. Other practitioners, such as record producers, have pointed to similar mechanisms for generating coherent structure by referencing objects external to the artifact. The following example serves to further illustrate how musical elements function within a context to generate structure.

External structure is a crucial component in much popular music where sonic and lyrical references to commonly experienced objects and knowledge are an essential characteristic of the song's structure.[6] This emphasis is a conscious and documented activity. Following is an excerpt from record producer Wayne Wadhams's analysis of the Rolling Stone's song "Sympathy for the Devil."

> "Sympathy [to the Devil] opens with a loose samba beat tapped out on tom-toms, quickly joined by congas and maracas. As if from the jungle, [Mick] Jagger screams in falsetto, like a parrot or chimpanzee, his voice repeated seductively by a long, repeating tape delay. The rhythm cooks on, a syncopated, brittle sounding shaker adding another syncopated layer of tribal ambience. Is this the beach at Ipanema, a voodoo ceremony in Haiti, or a sacrificial dance in the darkest Africa in the Hollywood sense? Jagger grunts as though dancing with the natives, when suddenly his voice enters, calmly requesting permission to introduce himself in verse 1." [Wadhams 2001 p. 224] [7]

The choice and combination of elements and the overtly dramatic interpretation, Wadhams suggest, are intended to engage the listener's knowledge of the jungle and establish the singer's persona. In contrast to the Oblique Strategies, production, according to Wadhams, attempts to create relationships such that artists' and audiences' perceptions align. This example does, nevertheless, illustrate how in actual generative scenarios features of objects external to an artifact are mapped on to musical elements. This type of structure integral to the generative process in many scenarios though the mapping technique in each scenario can only be analyzed relative to context of the particular composition, performance or production.

These mappings of the features of one object onto another can be described on many levels perceptually and conceptually. A motive can be a characteristic interval, but it can also be the juxtaposition on sonorities. Some have an immediate perceptual saliency. Others are more conceptually relevant, and are either culturally dependent or associative based on more general experiences. Feature mappings across elements, as Schoenberg observed, can cross form-bearing dimensions (such as pitch, rhythm, etc). This structure can be defined internally as well as externally, and some features of one musical element can be mapped to different musical element contained within the work. Nonetheless, the crucial characteristic is redundancy.

2.4.2 Tautologies

Oblique Strategies is a mechanism for the repetition of an idea – an idea that two objects share similar features. In language, the (often unnecessary) repetition of an idea

[6] It is not productive to use external structure as a distinction between a high and low art. There are many places for referential techniques in music composition ranging from opera to Hindustani classical music. In the latter, for example, each raga or mode is intended to invoke or represent a predefined mood or ethos. These moods are culturally defined outside the characteristics of any particular performance.

[7] Wadham's general hypothesis is that the purpose of music production is to elaborate on the literal meaning of the song's lyric and the image of the artist performing it. This analysis combines his personal experience in music production, features observed in the recordings themselves, and observations drawn from secondary sources such as interviews with musicians, producers and engineers. He synthesizes these observations into an explanation for content and structure of each recording.

is called a tautology. Wittgenstein liked tautologies. He felt that although they are either false or meaningless, through them the essential structure of language was revealed. In art, the repetition of an idea is essential to the generation of structure and coherence. [8]

Oblique Strategies are pointer to potential modal relationships. The semblance between the elements within the artifact and the object specified within the Strategy is like a repeated idea. The specific nature of the overlap is an instance of a concept. When applying the Strategies, these concepts bridge language space and music space. Feature overlaps could also be generated across other representational spaces. For example, Jeanne Bamberger uses pictures to represent listeners' perceptions of musical structure. As Wittgenstein observed in tautologies, through these drawings certain structural relationships become more apparent. We do not yet know how to characterize that structure, but the transfer between spaces can more clearly disclose patterns of perceiving structure.

2.4.3 Bamberger's Rhythmic Draughtsmen

In her book The Mind Behind the Musical Ear, Bamberger describes a series of psychological experiments conducted with children that attempt to measure their perceptions of the emergent structural properties in rhythms. In these experiments she asks them to make "rhythmic" drawings of musical segments. These drawings facilitate structural comparisons. Unlike Oblique Strategies, the emphasis is on representing the perceived features of the target objects (rhythms), rather than applying these observations to the construction of a novel artistic element. Through these experiments Bamberger observes patterns of perceiving structure, and through the resultant drawings the nature of that perceived structure. This approach proves informative in the next chapter when we look at the first set of musical composition games.

Bamberger divided the resulting drawings into three categories: "Type 0", "Figural" and "Formal/metric." Type 0 drawings consisted of scribbles, dots or a sketch/trace of hands. These were the drawings of four and five year olds. As Bamberger watched the children scribble she observed that they kept time with their heads or some other body part. She, therefore, linked their responses to rhythmic structure. But the scribbles and dots did not distinguish individual sounds or variations in tempo "nothing that would help player/drawer or another recognize the features of *this* clapped rhythm." [Bamberger p 49]

The drawings of the older children (8-12 year olds) fell into "figural" and "formal or metric" categories. Figural drawings were far more linear and functional in structure. Generally, they consisted of circles or zigzag lines that represented musical events organized right to left. The number of objects correlates directly to musical events, and gaps between shape objects correspond to silences. Here Bamberger assumes discrete shapes refer to specific events. Formal or metric rhythmic draughtsmen also draw circles organized left to right, but here the number of objects corresponds to metric unit rather than musical event. Certain events might be distinguished by size or subdivision

[8] In music truth cannot be equated to logical construction as in language without accepting the previously mentioned limitations of a musical generative grammar.

in which a large circle might surround two smaller circles.

Of the dots, Bamberger noted that this imagery is a "result" of a rhythmic event rather than reference to specific events. "That is, in transporting actions directly to paper, the children are not concerned with following some orderly transformation rule whereby actions in "performance time/space" become recognizable in static, two dimensional "paper-space" [Bamberger p 49] Bamberger does have a particular interest in notation systems, and this observation may be pertinent to many psychological factors or stages of development. Regardless, the inter-dimensional exchange, the transfer to "paper-space", reveals something quite powerful about the processes and mental representations at play.

2.5 Bregman and Perceptual Organization in Music

How we listen to and understand music is linked to how we parse, at the lowest levels of perception, elements into distinct yet interrelated auditory streams. In his study of auditory scene analysis, Albert Bregman contrasts the experience of listening to music, a highly structured stimulus, to more unstructured perceptual experiences. He recognizes the basic horizontal and vertical dimensions in music, melodic elements juxtaposed against the harmonic, as a governing structural property in the musical experience, and stresses the importance of this basic patterns in perceptually organizing the musical auditory scene,

> Both sequential and simultaneous organizations actually *create* certain aspects of musical experience. Sequential grouping creates rhythms and different aspects of melodic form. Vertical organization gives us not only the experience of chords but also other emergent qualities of simultaneous sounds, e.g. timbre, consonance, and dissonance. These phenomena arise when certain acoustic components are perceptually grouped into the same vertical organization… the sonic objects of music derive only in a very indirect way from the real instruments that are playing. We have to take into account the effects of both sequential and simultaneous organization in forming the streams that we hear and their emergent qualities. [Bregman p.459]

These emergent properties are a form of high-level organization. He uses the example of a triangle to illustrate his point. Three lines connected "in the right way" form a closed shape. The triangle form is an emergent property of this configuration of objects. The perceptual process is scalable and groups objects of different "size". Larger objects are made up of smaller objects.

The form of each is governed by the principles of primitive grouping. The auditory system seeks coherence in interpretation just as a composer seeks coherence in the generation of structure. [Bregman, Chapter 5] One way to consider generative process is to consider how we hear and look at patterns salient to us. From there we can draw comparisons and explanations for the composition of music. In other words, Bregman is suggesting the sort of coherence Schoenberg sought is in both a top down and bottom up process.

2.5.2 Narmour's Melodic Archetypes

Taking a bottom up approach, Eugene Narmour sought to base his generative theory of melodic structure on perceptual phenomena. Emphasizing the importance of gestalt principles, he applied similarity, proximity, and good continuation to coherent patterns of melodic organization. Through this reasoning he reduced melodic structure into five basic categories of melodic contour. He calls these categories melodic archetypes. These are iteration, reversal, registral return, dyads, and monads. Narmour suggests that pairs of these archetypes communicate to the listener and realize or surprise expectation. These triads have characteristic pairs interval size and registral direction. Narmour goes further to describe conditions under which these triads chain together forming longer phrases. Still, he points out that Gestalt psychology does not offer clear definitions of unified wholes in which different types of groups or chains appear to form more complex, coherent structures thereby providing no explanations for structural relationships between melodic patterns across sound sources. Gestalt, thus far, has not adequately explained how primitive groups form multi-tiered structures or how these structures might be represented mentally.

2.6 Preference

Gestalt psychology points to perceptual mechanisms that are common to all musical creators. Bamberger at a higher level also categorized different ways of perceiving structure, motivic and metric. To some extent, a listener's choice of perceptual approach is based on preference and experience. Interesting to note is the fact that the Oblique Strategies rarely attempt to color an individual's preferences. In the few exceptional strategies that indicate preference (i.e. "What would your best friend do"), the strategy does not diminish or obscure the role of preference but instead positions it as an object of imitation.

Jackendoff and Lerdahl's GTTM illuminated the preferential component of the generative process in their distinction between musical surfaces and preferred analysis. The musical surface consists of plausible explanations for the structures contained within a musical work. All plausible structures conform to gestalt well-formed rules. The preferred analysis of particular musical structure depends on the listener's experience. Preferred structures are an indicator of bias. Jackendoff and Lerdahl observe,

> We have found that a generative music theory, unlike a generative linguistic theory, must not only assign structural descriptions to a piece. But must also differentiate them along a scale of coherence, weighting them as more or less "preferred" interpretations (that is claiming that the experienced listener is more likely to attribute some structures to the music than others). [Jackendoff and Lerdahl p. 9]

Along similar lines, C.S. Lee remarked on the role of preference in metric interference. Certain grouping rules can be observed in sparse rhythmic contexts, for example the perceived note duration is linked to metrically strong beats. Also, short notes occurring after long silences are perceived as accented. But Lee observed, as in the case with language where grammatical interpretations are always not possible for all sentences, preferred rhythmic interpretations are based on agreement between high and low structure.

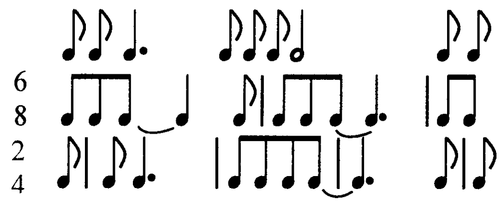


Figure 4: example of possible interpretations of the same rhythmic pattern (recreated from Lee 1991)

Elaborating on the notion of the preferred analysis of an experienced listener, we can consider the influence of *biases, preferences,* and *priors* in an artist's perception of musical structure. In the generative process, each decision an artist makes is a transition point relative to time and the state of the work under construction. The hidden markov model (HMM) is a probabilistic model for data observed sequentially, and it can have numerous orders of complexity. It has often been applied to the design of generative systems. For example, David Cope's style specific Experiments in Musical Intelligence used Augmented Transition Networks, a variant on the HMM that abstract semantic models. The application of HMM's to generative system design is predicated on the assumption that regularly occurring surface features in human generated artifacts of the same style have a high prior or probability of occurrence in stylistically similar artifacts.

HMM construction presumes that the weights for any transition point can be calculated or inferred a priori. This is problematic for the creators of generative systems and theories because many aspects of the human generative process are in continuous transformation. In a human composer, the preferences that bias decision-making change at every decision point, as do the number of factors considered. HMMs do give us a way to break the creative process down to instances of decision making, but in order to represent the generative process with any accuracy, a system needs to change weights and orders at each transition point based on all previous decisions. How this process happens in humans is not at all well understood, and is indicative of an apparent difficulty in computationally modeling the generative process.

2.7 The Caveat of Style

Researchers studying generative process have dedicated much attention to the deconstruction and analysis of (human generated) artworks, and the subsequent synthesis of artificial artifacts that resemble those analyzed. Validation for analysis through synthesis comes from comparing features between real and artificially synthesized artifacts. One prominent proponent of this approach is composer David Cope. Based on an exhaustive analysis of a catalog of compositions, Cope created several music systems that generate pieces in the styles of famous composers. Cope's work provides us with ample structural analysis of the original artifacts, and a tremendous body of research about the computational modeling of musical structure and style. Nevertheless, it leaves us with unsatisfying answers about the human processes behind the generation of these artworks. At present, designing a style-based generative system requires detailed statistical analysis of artifact features such as intervallic relationships in the melodies of a particular composer. These statistical observations are far more involved than any observations made by a human composer for the purposes of his or her own generative process. Additionally, system builders taking this approach unavoidably emphasize their own preferences for structural analysis in the original compositions. Such choices may make for compelling generative art, but do not render hard evidence for cognitive science.

The issue of modeling style heightens the complexity of investigating the generative process. Style clearly is related to the generative process, and it presents another way to describe structure. If we describe style as a set of features independent of the generative processes that yield them (as a music theorist might), our models of style are ideal collections of surface features lacking convincingly complex structural frameworks. So, there is no escaping the need for robust descriptions of modal relationships between constituent objects in artistic artifacts. We must also bear in mind that style's utility varies for the artist and the audience. Style is plastic and variable over time. A particular style's attributes wax and wane during and after the historical period of its popularity. For the individual, style is both a by-product of and utility for active perception.

Style is nonetheless pervasive and not easy to dismiss. Although different forms of media engage different sensory mechanisms, ecological practicality compels us to believe all artistic experiences must share similar cognitive processes at some level. Style is indicative of this juncture. Style can and frequently does cross media. This reveals a danger for those who focus on one media, one aspect of production, or one style when using style as mechanism for understanding the generative process. Style is a substantial component of formal training in any media, and it obviously can bias an artist's preferences. Still, it is premature to assume that stylistic priors weight all aesthetic reasoning [Lefford and Ozkar 2002] even though the style of an artifact cannot be wholly divorced from its creator's generative process.

2.8 Artist-centric Definitions of Structure

Several descriptions and basic models of the generative process can be synthesized from the findings presented in this chapter. These include layers of abstract, modal relationships (Schoenberg); structural algebras (Stiny); perceptual primitives with chaining rules (Narmour); reductions/expansions (Jackendoff and Lerdahl); and style-based grammars (Cope). Aspects of generative strategizing are also represented by the Oblique Strategies. Which ones have the closest affinity to an artist's perception of structure as he creates an artifact? How and when does an artist use the various approaches individually and in conjunction? The various definitions of structure used in the studies above help us conceptualized the multi-tiered nature of the generative process. All these perspectives represent integral aspects of the generative process. Our challenge is to widen the limitations on defining context as we make our observations.

These approaches and theories offer numerous methods of addressing a study of the generative process, but when considered collectively they reveal two glaring omissions in methodological approach. The first is the lack of experimental data pertaining directly to generative process (in contrast to perception and the listener). The second is that they emphasize an a posteriori perspective. These studies focus on deconstructing artifacts as a vehicle for explaining the generative process. It remains unclear what the artist perceives as strategy, and more importantly optimal or effective strategy, at the time a particular generative is executed. It is not until we understand strategizing on multiple levels that we can redress the problem of optimization. The experiments presented in the next chapter delve deeper into the nature of artistic strategizing.

Generative Strategy

3

3.0 Components of the Composing Game

This chapter discusses the use of musical composition games as a format for experiments in generative process. Through the application of game-experiments we are able to overcome some of the limitations of earlier approaches. As revealed in chapter two, many formal theories of the generative process pre-define what constitutes structure in an artistic artifact or limit the processes impacting a generative decision in their models. These restrictions facilitate clear descriptions of the relationships and transformations under investigation. Lerdahl and Jackendoff's GTTM and Narmour's melodic archetypes are good examples of this approach. The GTTM restricts musical structure to that which can be defined in terms of hierarchies. Narmour's melodic archetypes describe musical coherence in terms of gestalt grouping. Alternatively, Stiny's Shape Grammars address the inherent ambiguity in artistic structure. Eno and Schmidt's Oblique Strategies do not attempt to identify the constituent structures of an artistic artifact at all, but rather facilitate the processes of organizing and patterning. It is this aspect of generative strategizing that will be further investigated through the composition games presented in this chapter.

The early sections of this chapter discuss games and the challenges of designing a musical composition game. The later parts provide an analysis of what happened when subject/players generated patterns through a musical composition game. Both sections will leverage the generative process-game analogy to distinguishing between the constituent processes of a generative decision and the nature of their interoperability. The game framework helps us devise better experiments, and approach observation and analysis from an informed perspective.

The musical games discussed throughout this study impose tremendously artificial restrictions on the generative environment. Unlike Schoenberg' Grund Gestalten, in which it is presumed that the artist has some control over orchestration, key, the number or notes, temporal subdivisions, etc., the musical game nomenclature must represent an especially restrictive and sparse domain. To make the distinction from more encompassing theories, the musical building blocks in these games will be referred to more simply as *elements* because the games circumscribe even the most fundamental musical freedoms. This terminology links the compositional games to other types of games. Games generally have elements (physical or imagined) that are acted upon like chess pieces or a ball.

Additional components and characteristics further distinguish games from other types of activities. Games require direct or implied opposition[1]. Likewise, the composer is working through a set of compositional decisions towards an artistic goal. In both games and the generative process there are *strategies* for achieving an end. There are both short and long-term strategies.

Games have *constraints* that govern the transformations and functions of elements. *Rules* are only one type of constraint. In music there are normative rules like style and form. Such rules remain predominantly constant throughout the process of generating a work. However, there are also constraints that apply only locally to a particular musical passage or gesture. *Concepts,* with respect to musical composition games, are a form of constraint that can be imposed on the construction of patterns, as is often the case in concept design games. But musical concepts are also a device naturally utilized by the artistic creator, and this particular function of concepts will become more apparent in the findings presented.

The role of *technique* in the generative process is crucial. A technique is a method for structuring elements. A technique is not a concept. It is a means through which a concept may be realized. In the generative process techniques are the technical methods used to obtain an artistic effect or produce an artistic representation.[2] (Techniques include methods such as bowing a stringed instrument for a particular effect, or using heavy or light pressure on a paintbrush.) Techniques are tied directly to a medium, an artistic tradition, style, or practice. This basic understanding of the primary game components facilitates the design and analysis of music composition games.

3.1 Designing Musical Composition Games

To facilitate comparisons across players and generated patterns, the music composition games in this chapter provide subjects with strategies and elements. The patterns produced are techniques for realizing those strategies given the constraints set forth in the games. Along with musical patterns, subjects were asked to provide written descriptions of their generative criteria. Although the accompanying written responses provide varied, high-level descriptions, through them we can identify the similar concepts and techniques across subjects, and gain insight into the roles of various game components within a generative decision. By refining the functions of the various components, we achieve more precise control of games as an experimental tool, compare the generative strategies and the use of concepts across creators, and study rhythmic inference in a generative scenario. Building on Habraken and Gross's method, conclusions are drawn from contrasting multiple versions of a game. These variations engage subjects in slightly different tasks, and also test how game constraints might impact subjects' generative process.

3.1.1 Constraints and A Priori Knowledge

The considerations set out in this section both inform the design of the games in this

[1] Opposition may simply be the difference between the imagined and the real. It is an indicator that a change of state is desirable. The nature of the opposition impacts strategy and preference. "Doneness" no matter how fleetingly defined, is comparable to the level of opposition.
[2] It is interesting to note that while good technique is praised in art, works are often criticized for having good technique but little substance. Technique alone is not enough to generate a coherent work of art.

chapter and suggest how games can be devised using a completely different interface or set of constraints. The constraints and rules, more so than the elements, shape the character of a music composition game. Game rules and constraints set what *a priori* knowledge can be brought to bear on the analysis of subjects' responses. Even seemingly simple musical patterns may come from complex generative decisions and vice versa. The level of complexity in games and the patterns they produce can increase substantially with the addition of just a single element or degree of freedom. Resulting patterns can only be interpreted against the set of limitations and freedoms available to each subject.[3] In these games, we attempt no measurement of subjects' sensitivity to the degree of limitation these constraints imposed.

Establishing a clear objective is one mechanism for imposing consistency across creators. However, the gaming task needs to be free enough that the subjects become genuinely engaged in the generation of these artifacts, and imbibe some individuality into the process. Otherwise, comparisons across creators are far less informative. Each creator must employ the same materials and be comparably restricted in each game variation. An observer's ability to identify structure and a creators' intent is dependent upon privileged knowledge about the malleability of the materials provided. In any musical game, the number of pitches provided and their intervallic relationship clearly play a substantial role in the production of patterns through the games. Even more elementary, however, is that each degree of freedom allowing the use of accents, dynamics and performance techniques add layers of complexity to even simplistic musical patterns.

In natural composition scenarios, creators utilize numerous form-bearing dimensions and, as Schoenberg noted, motives are not always conveniently compartmentalized. A motive may be characterized, for example, by the combination of intervallic motion and rhythmic pattern. A composer perceiving the possibilities for a motive's multi-dimensional features is integral to the generative process. Similarly, even within the confines of a musical game, techniques, concepts, a creator's definition of structure, or even an element may cross dimensions. In other words, a subject's technique may exploit both pitch and rhythm if those degrees of freedom are available. To analyze the structure of such a pattern and understand the decision process that led to such a construction, the realm of possibility must be understood by the experimenter a priori. The games in this chapter will not test the strength of one form-bearing relationship over another.

A great deal is understood about how a listener groups and parses an auditory stream, and this is helpful in selecting constraints. However we cannot predict artists' generative process by analyzing their listening habits. The degrees of freedom in the games limit the types of techniques it is possible to employ in generating a pattern. The degrees of freedom may allow for the construction of one or more types of perceptually salient groupings. For example, in the game that follows, sequential and vertical integration as well as proximity are controlled.

---

[3] As we saw in Wadham's analysis of the Rolling Stones, each production must be analyzed against an inferred or reconstructed context and set of constraints circumscribing the generation of that particular piece. The better our a priori knowledge of the context, constraints and degrees of freedom available to the creator, the more meaningful our subsequent analysis.

Temporal subdivisions, pattern length and phase are other crucial considerations. With too much temporal freedom, the complexity of the patterns increases significantly. Musical patterns incorporate not only sonic events but also silence. The duration of this silence should be considered a degree of freedom in creating patterns. The games are a powerful tool for studying the generative process because form-bearing dimensions can be isolated and combined in a controlled way.

3.1.2 Strategic Games

The Oblique Strategies play a central role in the following music composition games. The Strategies offer a direct mechanism for both constraining the generative process and maintaining procedural consistency across creators. It is obvious that any given Oblique Strategy can be interpreted and applied in different ways and to different scenarios. But without further testing, it is not possible to predict how constraints might color how the Strategies' possible interpretations. If incorporated into a music composition game, given that each subject faces the same constraints and elements, will the Oblique Strategies trigger similar responses? Would generated artifacts reveal similar structure and features?

In this game, subjects create musical patterns by positioning icons on a computer screen, thereby, like Bamberger, we take advantage of representing musical structure in non-musical space. By transferring event structure to a visual space, we force the musical creator to represent musical form in a reduced format. The transference to visual space is an aide for analysis, a means for the observer/experimenter to contrast features. It is not strictly a focus of the generative task. In playing the game, subjects' attention is not deliberately directed towards the features of the visual representation. The composition task involves building more complex structures from a fixed set of unalterable elements. It is not possible to modify the timbre, volume or duration of the provided sound elements. Instead, the game emphasizes temporal positioning.

3.2 Interface and Implementation Method

The following section describes the interface and implementation of the Oblique Strategy games. There were six versions of the game experiment. Each used the same basic interface and procedural protocol. Sections 3.2 through 3.2.2 described these basic features. Section 3.3 goes into detail about the six variations. Humans naturally map time to space (clocks, timelines, flow charts, etc.). Thus, musical events are plotted along a graphic grid representing a timeline. This type of interface is a familiar workspace to many musicians who use computers for composition or music production. This familiarity adds to its appeal as a tool for experimentation. The GUI interface and basic procedure is the same for all versions. Using ProTools hard disk recording/editing software, subjects are presented with three tracks on which they can arrange sound samples.

The samples were created using the Reason Soft Synthesizer sample bank NN19. The playback loops automatically at the set loop length (inserting silence where no sample has been placed). The samples are listed in a frame on the right hand side of the screen. Using the mouse, subjects click on the name of the sample, drag it over to any of the tracks and release the mouse. Samples automatically concatenate to the beginning of the track or the end sample that falls latest chronologically. Samples can be overlapped in time by placing them on adjacent tracks, but they cannot be placed directly on top of one another. Silent samples are provided so that subjects can distribute sound events over the entire loop length.

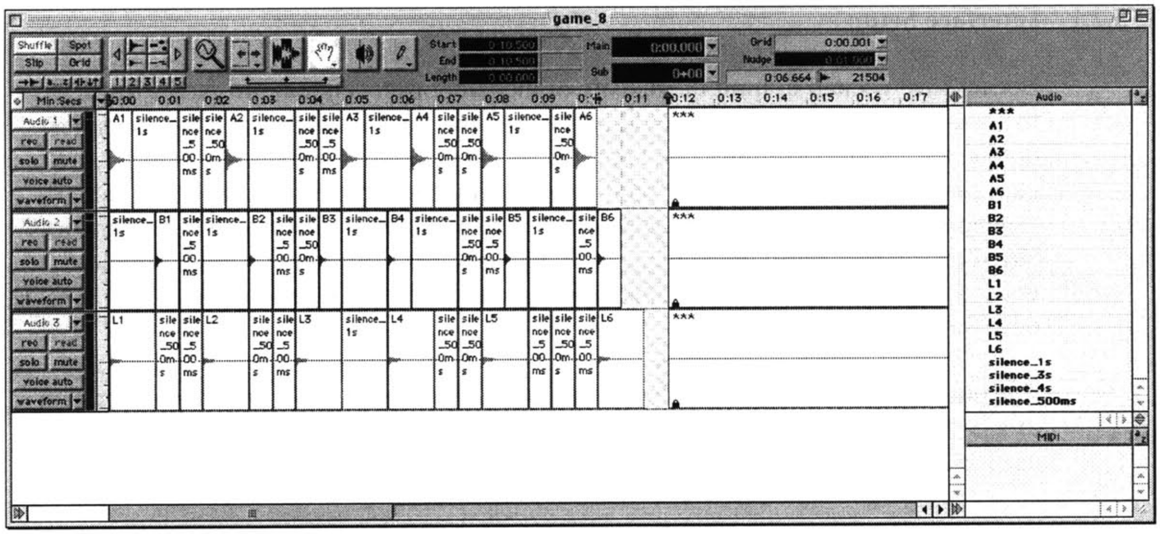


Figure 5: example interface with samples

Each version of the game drew from the pool of synthetic sounds (each sound is followed by its pitch and duration in seconds): Low tom drum , c3, .5 second; log drum, c4, .5 second; log drum, g3, .5 second; vibraphone, c3, .5 second; vibraphone, g4,
.5 second; log pattern: low log – hi log – low log, g3-c4-g4, 1.5 seconds; Digeridoo, c3, 8 seconds; Rainvox (synthetic voice blended with a granular, rain stick), c3, 8 seconds; Drmdecay (drum attack with processed delay), c3, 1 second; and a sweep/flanged guitar, c3, 6 seconds.

Two sets of Oblique Strategies were used. Set A included: Cascades; Ghost echos; Turn it upside down; Fill every beat with something; Water; and Distorting time. Set B included: (Organic) machinery; Infinitesimal gradations; Imagine the piece as a set of disconnected events; A line has two sides; Children – speaking – singing; and Twist the spine.

Each version also contained a set of silent samples. One set used very regular durations. The second offered far more variety. These blocks of silence were included to constrain the metric possibilities, and enable more robust comparisons across subjects. The first set of silences included .5 second; 1 second; 3 seconds; and 4 seconds. The second set included: .125 second; .250 second; .383 second; .434 second; .5 second; .686 second; .818 second; 1 second; 1.333 seconds; 2.121 seconds; 3 seconds; and 4 seconds.

Subjects were asked to describe their formal musical training, instruments studied and preferred musical genre by means of a questionnaire. The questionnaire provided instructions for each game and asked a question about the subject's criteria for constructing each pattern. The time constraint was deliberately left loose. It was assumed some combinations of samples and Strategies might be more difficult to work with than others. The patterns themselves are the focus of the study not the effort required to create them.

3.2.1 Interface Setup

Because we wanted to limit the density of the patterns generated, the games restricted the number of times a sample could be used. In the frame at the right listing samples, duplicate samples have the same letter name, but different numbers. (i.e. E1, E2, E3, etc.) Each letter named sample could be used only once in a pattern. Samples called "silence" could be used without restriction. The number of permitted duplications was based on sample length. Each game included only three different sounds. Samples under 1.5 second in length could be used up to six times. Longer samples could be used only three times.

The questionnaire provided subjects with an Oblique Strategy to guide the generation of a pattern. Only structural strategies pertaining to Internal, External, and Frame are used in these experiments. Below are several example questions:

> **Game 1:** Please arrange the three sounds to make a loop you like.
> As you do so, think of *cascades.*
>
> 3. Explain the factors that guided your decisions. (i.e preferences, strategies or something you thought about that shaped how you created this pattern)
>
> **Game 2:** Please arrange the three sounds to make a loop you like.
> As you do so, think of *ghost echoes.*
>
> 4. Explain the factors that guided your decisions
>
> **Game 3:** Please arrange the three sounds to make a loop you like.
> As you do so, consider the strategy *turn it upside down.*
>
> 5. Explain the factors that guided your decisions

3.3 Constraint Variations in Versions of the Oblique Strategy Games

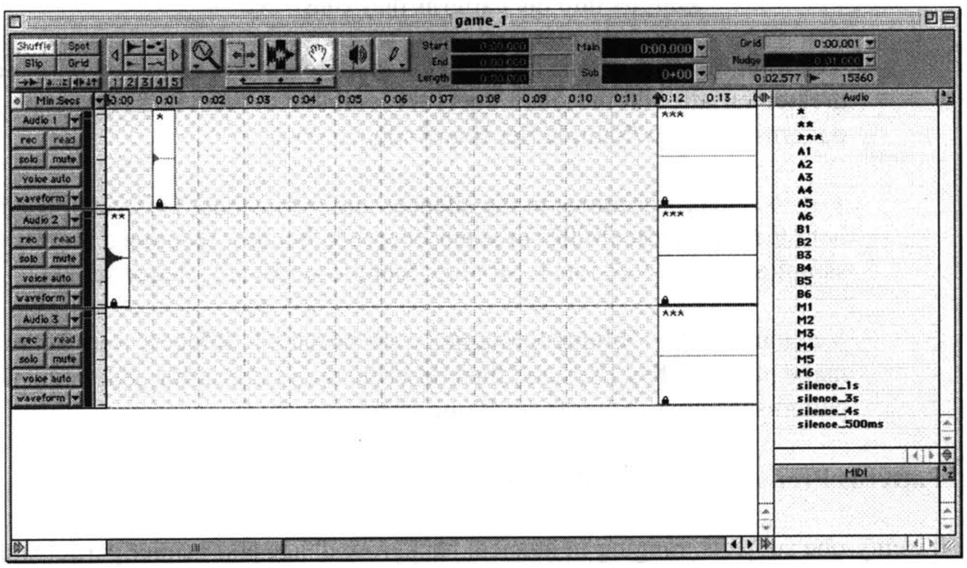
Following is a summary of the constraints in the six versions of the Oblique Strategy games. The appendices provide a comprehensive chart detailing the samples and strategies in each version.

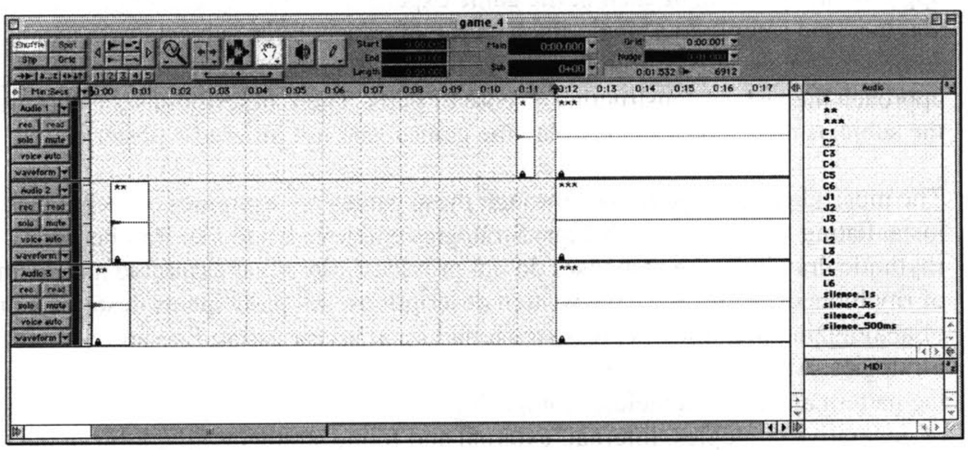
> Version One: Three Samples and Oblique Strategies used Strategy/Sample Set A and Silence Set 1. The combination of loop length, 12 seconds, and limited number of samples was intended to encourage sparse, simple patterns. In the event that subjects might think in terms of temporal subdivisions, 12 seconds is

suggestive of several obvious divisions.

Version Two: Time Reduction used the same strategies, samples, and set up as version one. However, the loop length was reduced to six seconds and the length of each sample was halved (including the durations of the silent samples). The main goal of this variation was to determine if loop length had any significant impact on the experimental procedure or results. The following chart indicates the new sample lengths.

Version Three: Beginning, Endings and Occlusions. In this variation, subjects found samples placed on the tracks when they launched the game. Subjects could add more samples around these, but they could not move or change the initial set up. Below are examples of occluded games. The subjects could not move these samples. Strategy/Sample Set B and Silence Set 1.





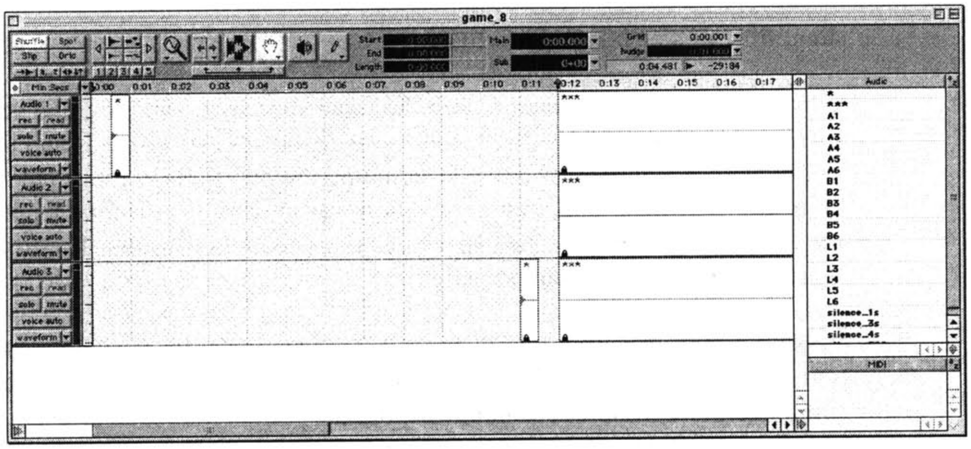


Figure 6: these samples are locked into position in this version. Subjects must incorporate these samples into the patterns they construct.

Version Four: Variations in Silences. This provided the subjects with much greater variation in the silent intervals available to them in constructing these patterns. Strategy/Sample Set B and silence set 2.

Version Five: Variations in the silences and occlusions. This version combined both the greater flexibility in silent intervals, but also contained the fixed samples used in Version 3. Strategy/Sample set B and silence set 2.

Version Six: No Oblique Strategies were provided. Subjects were instructed to make patterns they likes and then describe their criteria for generating the patterns. Strategy/Sample set B and silence set 2.

3.4 Patterns Produced in the Oblique Strategy Games

Twenty-one subjects, ranging in musical background, age and gender participated for approximately one hour each in the game experiments. Rarely did subjects relegate a single sound sample to a single track on the interface. Even subjects with extensive formal training scattered samples about. It might then be assumed they did not approach the task as constructing a score or parts. These descriptions are chronicled by the subjects themselves as they play the games, and not inferred a posteriori.

The musical patterns generated through these games are examples of techniques for instantiating the particular Oblique Strategies employed, and like Bamberger's rhythmic drawings, the responses do not provide a directly measurable metric. Instead of rhythmic drawings we have written descriptions. All participants describe a process of analogizing that mirrors processes found upon investigating Eno and Schmidt's Strategies. An observer or casual listener will most likely not identify the Strategy from the pattern alone. Nonetheless, comparing creators' written responses reveals categories of generative strategies. Internal, external and frame strategies all appear in the results.

To review, in chapter two's analysis of the Oblique Strategies, external strategies are pointers to objects external to the artifacts under construction. These objects act as a structural template and the strategy is realized by producing a feature overlap between the internal elements and objects indicated by the Oblique Strategy. In these games, external strategies manifest themselves as kinds of events, physical objects, musical forms, and structural descriptions from other media such as languages, etc.

Internal strategies describe a relationship between elements internal to the artifact. The Oblique Strategies have two prevalent sub-categories of internal strategy. These include "element" strategies that suggest ways to identify elements, and also "stress" strategies that describe the relationship between elements in terms of emphasis on particular elements over others. In the game results, the internal strategies generally appear in the guise of spatial descriptors and hierarchies. Lastly, a third category of Strategy "frame" is also represented in the results. Frame strategies indicate ways to constrain a context.

The following excerpts from the written response illustrate how subjects used internal, external and frame strategies. Examples of internal strategies include "try to center the long sound," "asymmetrical placement of all sounds," and "bunches of sound followed by silence." The subjects also reported using "stress" strategies, a subcategory of internal strategy described in chapter two. "Emphasis on the voices as much as possible but especially the J sound" is an example of a stress strategy. (The voice and J refer to the provided samples.)

A substantial number of responses referred to external strategies, for example, "a slow, clocklike beat," "improvisation that sometimes more than two kids speak at the same time at random, like collision," "Unexpectedness," and "pallindrome." Some responses such as "an A – A' structure" were hard to categorize clearly as internal or external. Subjects may have been making use of a familiar musical form, or they may have been trying to describe an internal relationship they generated. Frame strategies were also represented in the responses, for example, one subjects wrote "Structurally, I was trying to just create something totally different [from previous games?]"

All of these strategies are linked to an observable procedure or techniques for structuring time. These techniques are revealed in the patterns generated. For the creator, these patterns have the characteristics of a tangible or abstract object, transformation or sonic event; or imitate the structure of another medium or type of artifact or process. Comparing strategies and techniques shows us a link between perception (top down or bottom up) and generative process.

The several categories of *generative strategies, internal, external and frame,* are represented in the patterns following. (The associated audio files are found on the accompanying CD.) These Strategies can be categorized further is based on the particular objects or decisive criteria indicated in the each subject's description. These refined categories include: events or objects, imitating linguistic structure, spatiality, and hierarchies. Each pattern presented is drawn from the pool of subject responses and is accompanied by the subject's written response.

Events or Objects:

Often, subjects based the structure of the patterns on either envisioned events or planned event sequences in which the generated pattern conforms to an imagined structure. Subject 16 had twelve years of piano lessons as a child, and is an amateur DJ.

He imitates an event in game 5 (version 3, oblique strategy "children speaking or singing.") Subject 16 explains, "It's sort of improvisation (*external*) that sometimes more than two kids speak at the same time (*external*) at random (*external*), like collision. (*external*)" In this example, the object of children singing or speaking is augmented by the notion of a collision."

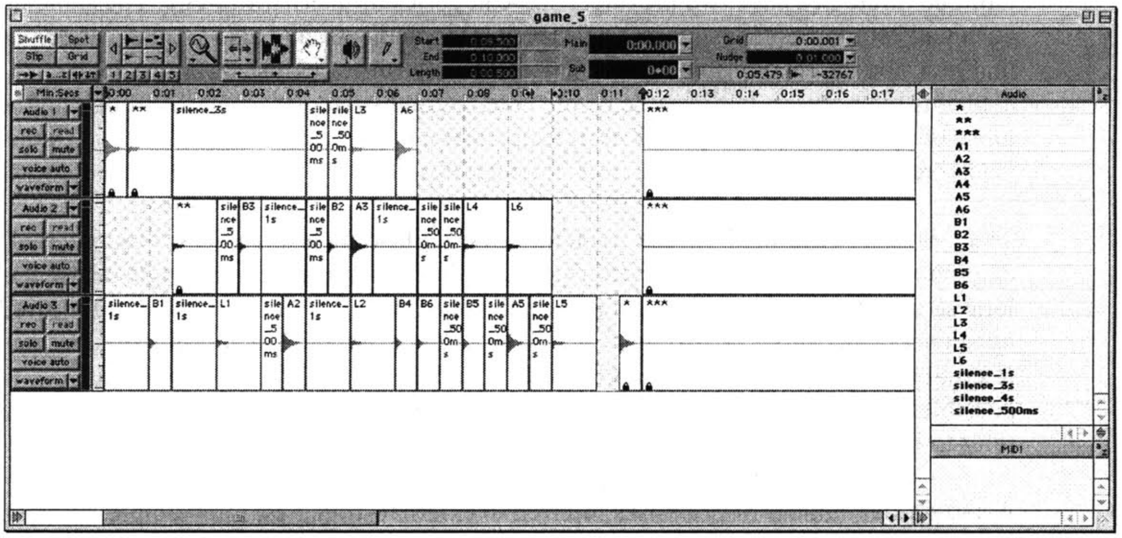


Figure 7: Subject 16, game 7 (CD track 1)

Subject 13 is an amateur guitarist, composer, and recording engineer. In game 3 (version 2, oblique strategy "turn it upside down") he notes, "Structurally, I was trying to just create something totally different [from previous games?]. (*Frame*) Silence at the beginning and end, with all the loops crunched together in the middle. (*Internal*)" In this example, the subject's strategy is framed by the previous games. The context for generating this pattern is based on the structure of previously generated patterns.

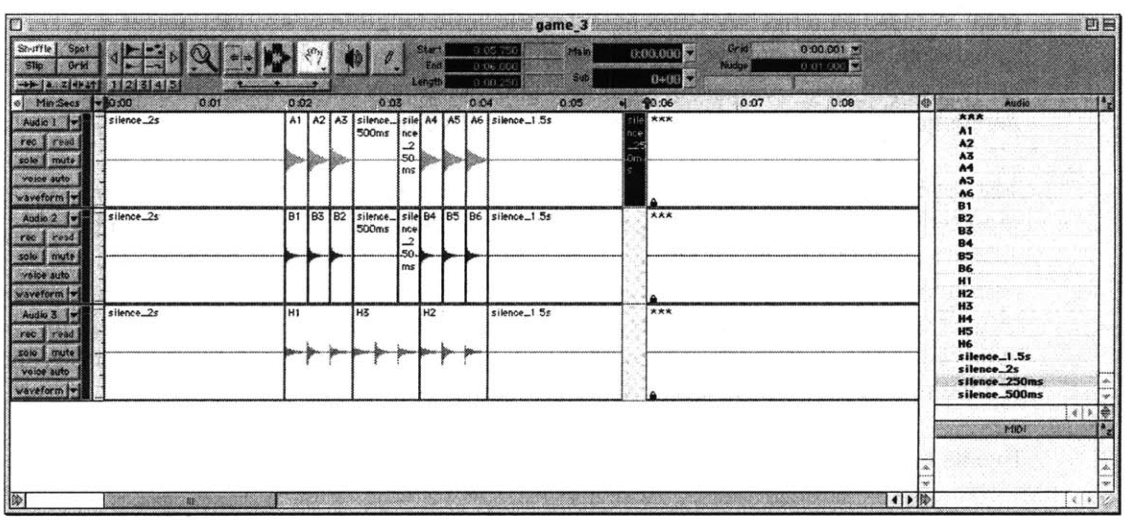


Figure 8: Subject 13, game 3 (CD track 2)

Subject 7, an amateur guitarist, composer, and recording engineer, reports in game 2 (version 1, oblique strategy "ghost echos") that he "Wanted as much emphasis on the voices as possible (*internal-stress*). Created a slow, clocklike beat (*external*) so that the listener can concentrate on the voices while getting a sense of rhythm." In this example, clock-like provides a structural prototype. Additionally, this is an interesting use of foreground-background, demonstrating a fairly complex, high-order structural relationship in a very simplistic pattern.

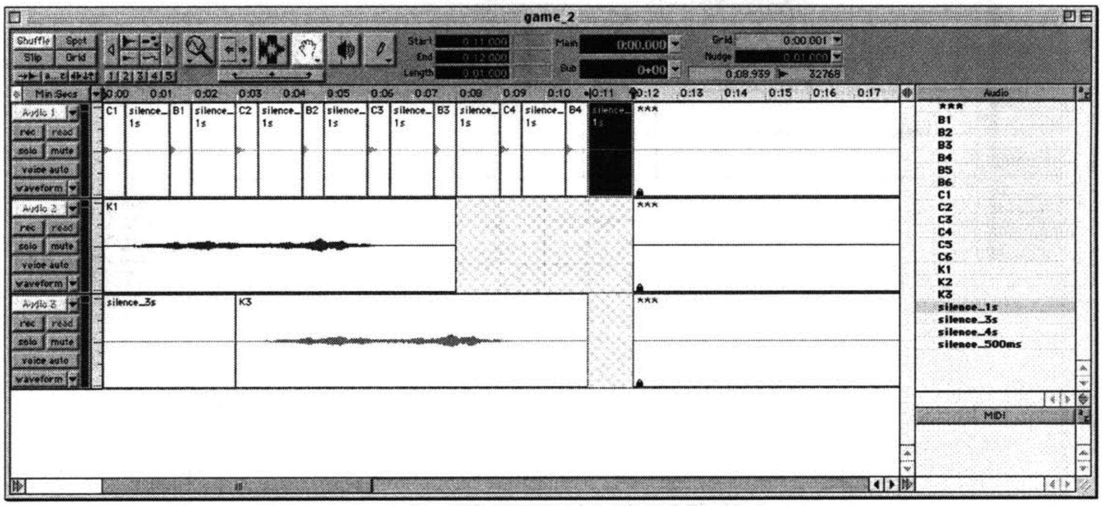


Figure 9: Subject 7, game 2 (CD track 3)

Similarly, in game 3 (Oblique Strategy "turn it upside down"), Subject 7 strategically "put silence at the beginning (*internal*). To create a sense of unexpectedness (*external*). Otherwise, I more or less randomly selected the loops, trying to create "bunches" of sound followed by silence. (*Internal*)" Here there is both the construction of bunches distributed between intervals of an absence of bunches.

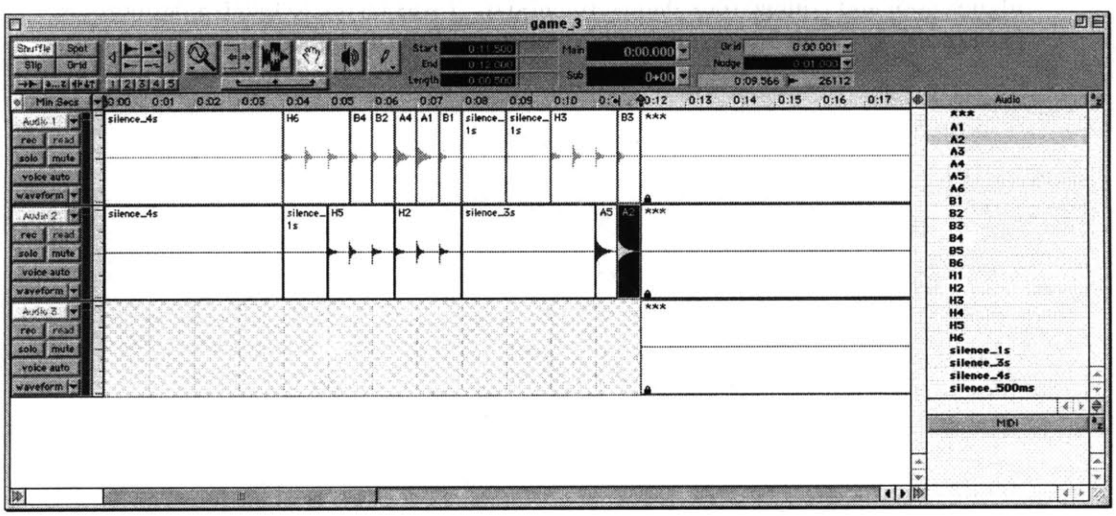


Figure 10: Subject 7, game 3 (CD track 4)

Subject 21 was a Berklee College of Music graduate, and teaches Jazz guitar. In Game 7 (version 6, oblique strategy "distorting time") Subject 21 " tried to make this loop sound as random (*external*) as possible." Random is a particularly interesting object to imitate. It is a fairly dense pattern with numerous short offsets between samples, and no repetition.

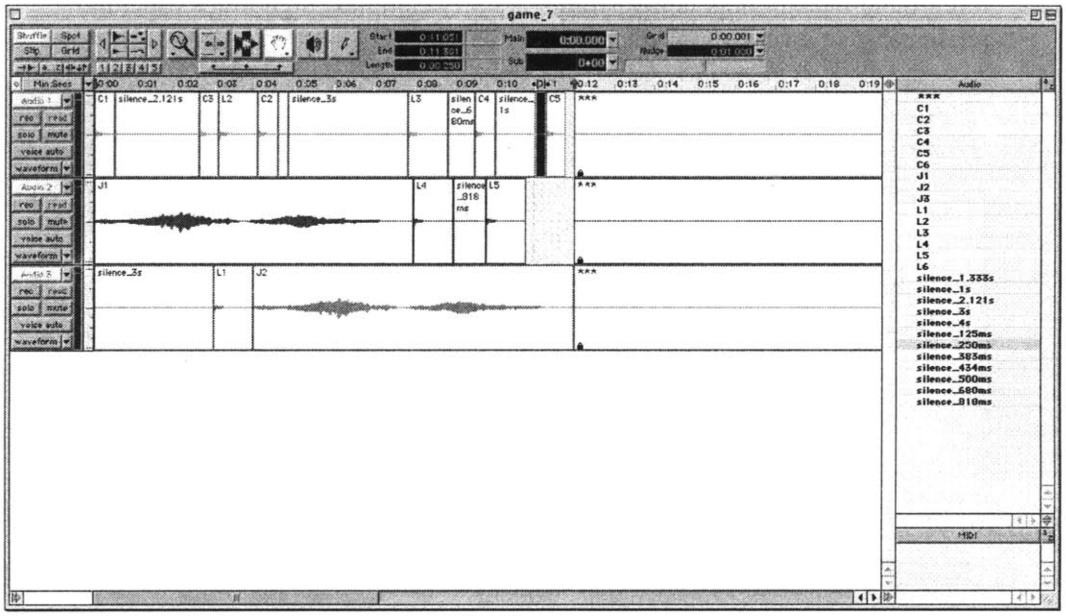


Figure 11: Subject 21, game 7 (CD track 5)

Linguistic structure:

Few subjects remarked on similarities between linguistic structures or grammatical constructs and the patterns they generated. However, there were examples where unusual linguistic structures were employed as models. *Subject 12,* a guitar player in high school and college rock bands, remarked, "I was trying to make a palindrome. (*external*)" in Game 3 (version 2, oblique strategy "turn it upside down")

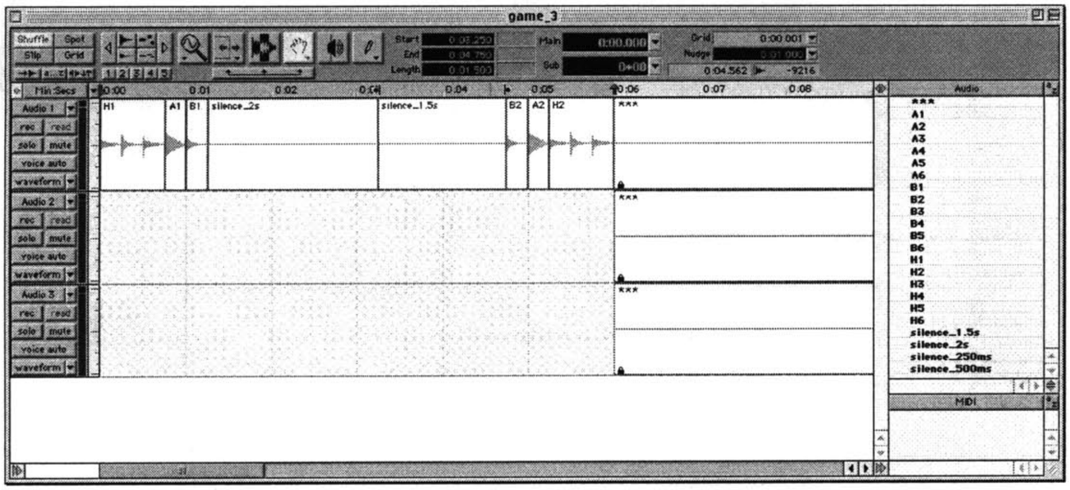


Figure 12: Subject 12, game 3 (CD track 6)

Similarly, few subjects used stylistic features as guiding criteria, which is not surprising given the lack of flexibility in the games. Few stylistic imitations were possible. Subject 20, a harpist who played in a school orchestra, participated in a version with no Oblique Strategies (version 5), but she created her own strategies which emulated the previously described strategy types. In game 5 she listed "rhumba" (*external*) as her guiding factor. In game 6 she says, "dropping water", in game 7, "try to center the long sound," (*internal*) and in game 8 "make crescendos." (*external*)

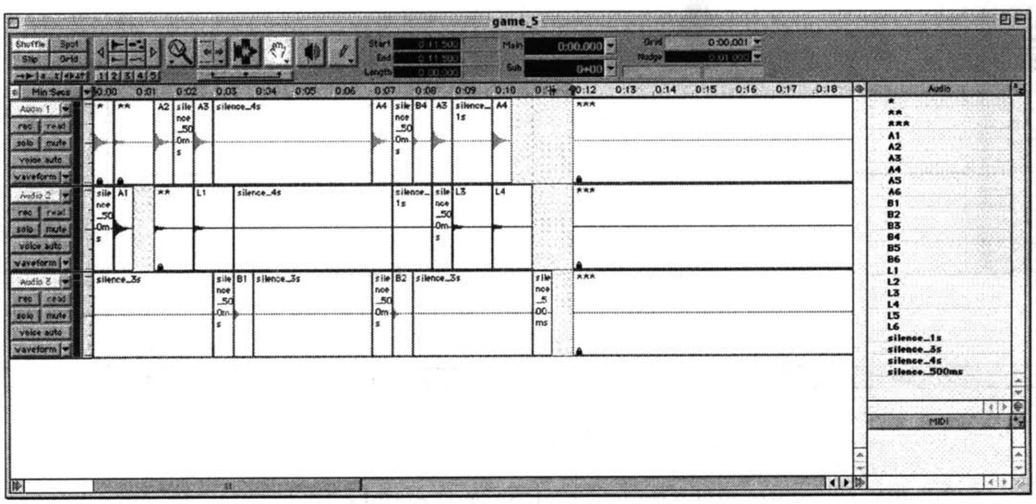


Figure 13: Subject 20, game 5 (CD track 7)

Spatiality:

Spatial words like asymmetry, ascending, or descending appear often in results. Subject 5 is a professional trumpet and string bass player. In Game 7 (version 1, oblique strategy "distorting time"), his strategy consists of "finding asymmetrical placement of all sounds (*internal*) – but especially the J sound." (*internal- stress*)

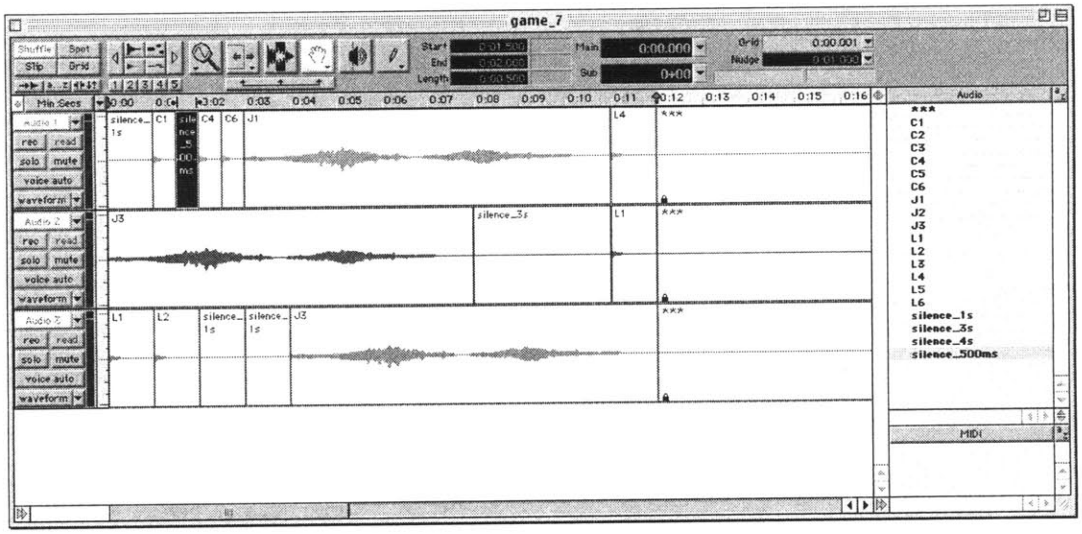


Figure 14: Subject 5, game 7 (CD track 8)

In game 6 (Oblique Strategy "water") *Subject 5* remarks again on a spatial relationship, "The very subtle difference in space of silence between drops… " (*Internal*)

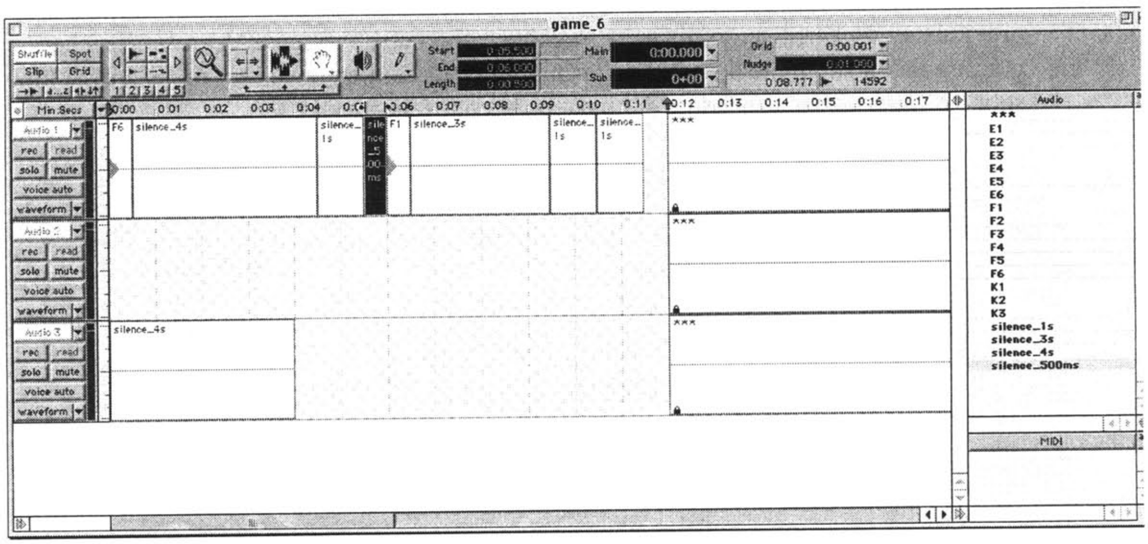


Figure 15: Subject 5, game 6 (CD track 9)

Subject 8, an intermediate guitarist, also used spatial relationships. In game 1 (version 1, oblique strategy "cascade") he describes, "at first I wanted to place ascending or descending (*internal*) notes in succession, to make a kind of waterfall sound (*external*). Finding my note choice limited I decided the | m | sound (*internal – stress*) reminded me of a cascade, so I used it, and put accent notes in."

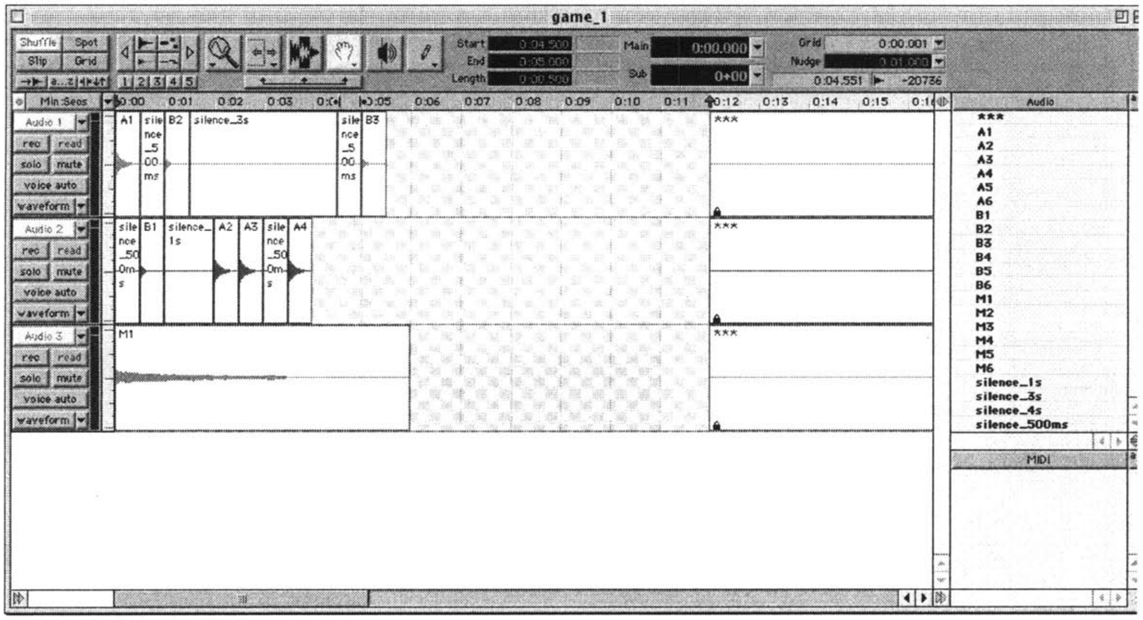


Figure 16: Subject 8, game 1 (CD track 10)

Hierarchical Structures:

There were almost no references to hierarchical structures in the results. However, Subject 15, who studied piano in college and performed with Jazz and experimental groups did conceive of his pattern in an A – A' structure. (*internal and/or external*) In game 1 (version 3, oblique strategy "organic machinery"), he describes the pattern as consisting of "two repetitions of the same rhythmic idea." The first part more condensed than the second part. The "machinery" obtained by regular repetitions." Furthermore, he includes a diagram of the structural breakdown.

A	A'
1,2	1,2

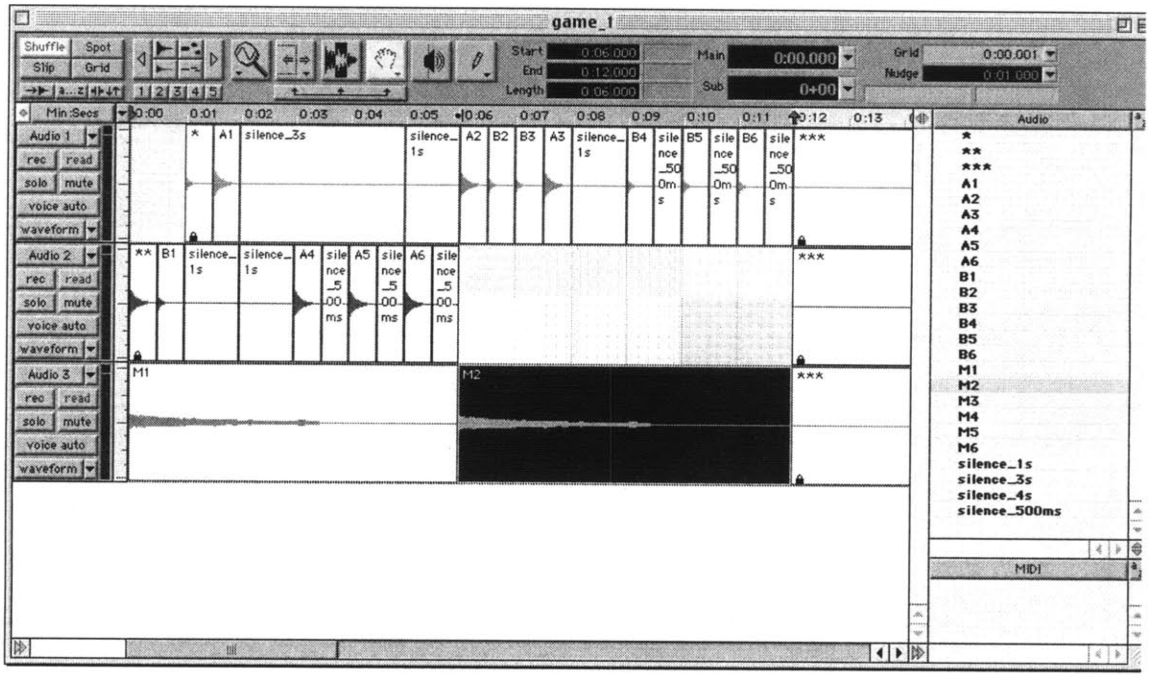


Figure 17: Subject 15, game 1 (CD track 11)

Subject 15 did not follow this formal procedure in all the games, however, and utilized many of the more "oblique" strategies in the other games.

Even in these very simplistic games, the wide variation prevents us from making robust comparisons between the patterns themselves. However, given that multiple creators often indicated similar generative criteria, we can make some basic observations about their techniques. One interesting and reoccurring technique is the generations of "random" sounding patterns, as is the case with subjects 21 and 16. Both have strategies for distorting metric inference although they are using different samples and responding to different Oblique Strategies. Subject 21 (figure 18) makes greater use of minute offsets between samples, and thereby avoids establishing meter. Alternatively, subject 16 (figure 19) favors more of an odd meter, odd divisions in the 12-second loop and irregular accents. At 5.5 seconds three samples are aligned and two samples aligned at 8 and 9 seconds. Both subjects created dense loops and filled up all 12 seconds.

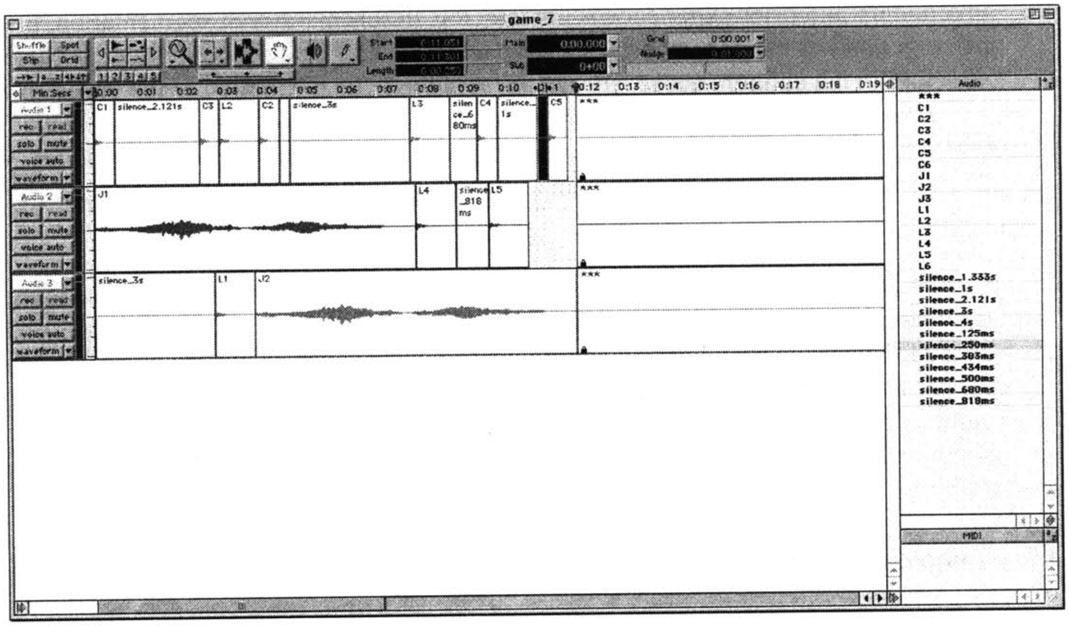


Figure 18: Subject 21's random pattern (CD track 12)

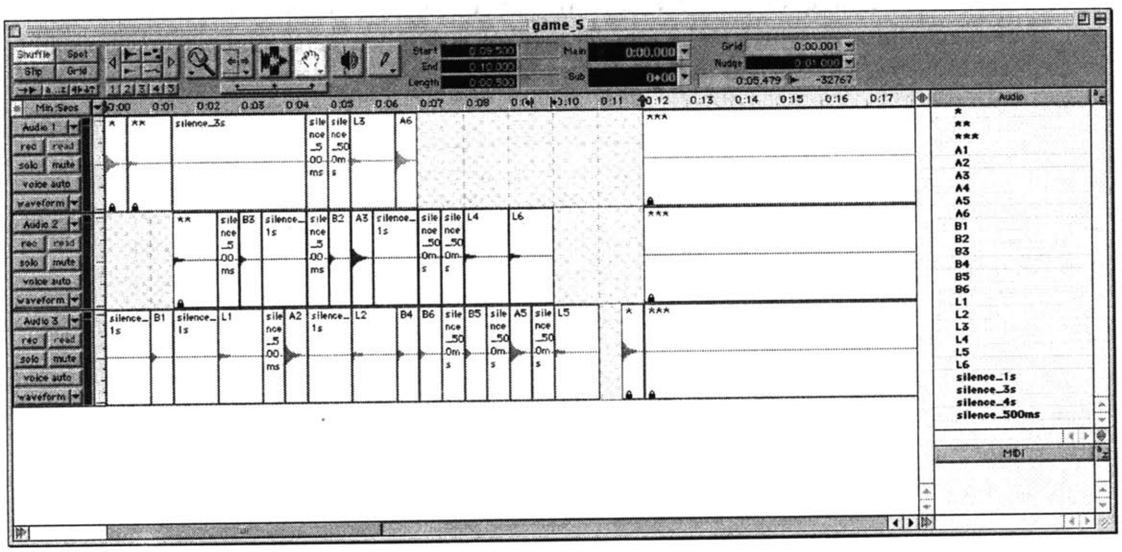


Figure 19: Subject 16's random pattern (CD track 13)

By contrasting these two different techniques for generating random sounding patterns, we gain insight both into generative strategizing as well as the Oblique Strategies. When a strategist chooses how to apply a Strategy in the context of a specific artifact, the strategist plays a language game. Both subjects 21 and 16 interpreted "random" in different ways as they do the Strategies themselves. This does not necessarily mean that they would as listeners respond to stimuli in drastically different ways. But when in control of the context while generating a pattern, they constructed different functions for the elements.

Bregman distinguished between two types of segregation in scene analysis, primitive segregation or schema-driven segregation. In primitive segregation attention is involuntary and prior experience is not a factor. In schema-driven segmentation, the perceiver makes use of memory, selective attention and knowledge in order to parse structure in the auditory scene. [Bregman] Although the distinction in the generative scenarios we have manufactured here is not yet as clear as we would like, we have begun to uncover multiple factors for shaping structural organization. Techniques employed in music composition games utilize both sensory and socially prescribed features.

By employing the generative process-game analogy as a model, and further refining each function of the game components, we begin to clarify the role of processes on both ends of the perceptual-cognitive continuum. Through these clarifications, we develop a deeper understanding of the generative process, and are better enabled to control the game experiments. The next section ties together the game component functions enumerated at the beginning of the chapter with the processes observed in the previously described music composition game.

3.5 Components of the Music Composition Game

There is great flexibility among elements, concepts and techniques when we compose in natural musical settings. Strategies devised by the creator balance which elements and which techniques best serve a particular concept, or which concepts connect which elements through which technique. This relationship between elements, concepts and techniques is represented in figure 20.

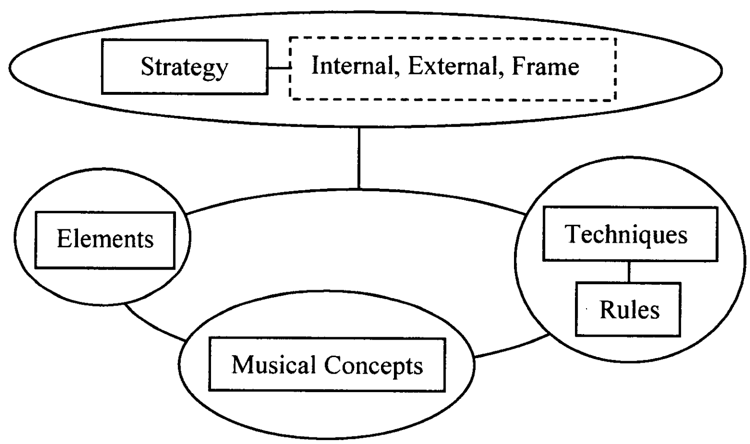


Figure 20: Elements, concepts and techniques are flexible in natural compositional scenarios.

The music composition games greatly constrain the creator thereby limiting the transitory relationship among elements, concepts and techniques. Figure 21 illustrates the various components apparent in this first music composition game. The goal in this game is to create a musical pattern, and the opposition is the difference between the imagined and the realized pattern. The strategies are supplied in the form of an Oblique Strategy. The Oblique Strategies, however, induce an additional sub-process – a language game, through which subjects interpret each Oblique Strategy. However, as apparent in the written responses, these interpretations can still be reduced to three basic mechanisms for perceiving structure, internal, external and frame relationships.

This game has several types of constraint. There are rules strictly enforced by the interface controlling the degrees of freedom available in placing the sounds. Also, the number of times a sound can be used, and the sounds, or elements, available to create a pattern apply globally. Unlike Habraken and Gross's games, concepts are not universally imposed constraints, but rather something creators select and impose individually. The musical concepts revealed in the game results take the form of feature relationships, overlapping characteristics between objects, subjects chose to highlight in implementing the Oblique Strategy. Both the language game and the selection of highlighted features indicate the role of individual's preferences in decision-making process.

The interrelation of the distinct processes works as follows: if the Oblique Strategy provided was "water", for example, the subjects making water-like patterns had to select a feature of water to imitate such as a "dripping" sound. A technique, such as regularly spaced, short, percussive attacks, was the specific means of instantiating that "dripping" concept. Techniques can be described according to specific parameters, or in other words according to rules of execution within the medium.

These games did not significantly clarify what constitutes an element in the ears and mind of a creator. Some subjects referred to particular sounds as having a function such as *subject 8* in game 1 which uses the Strategy "cascade." The subject wrote, "I decided the | m | sound reminded me of a cascade." Alternatively, *subject 20,* who was given no strategies, noted of game 8 that she intended to "make crescendos," and this description suggests a very different way of defining elemental components.

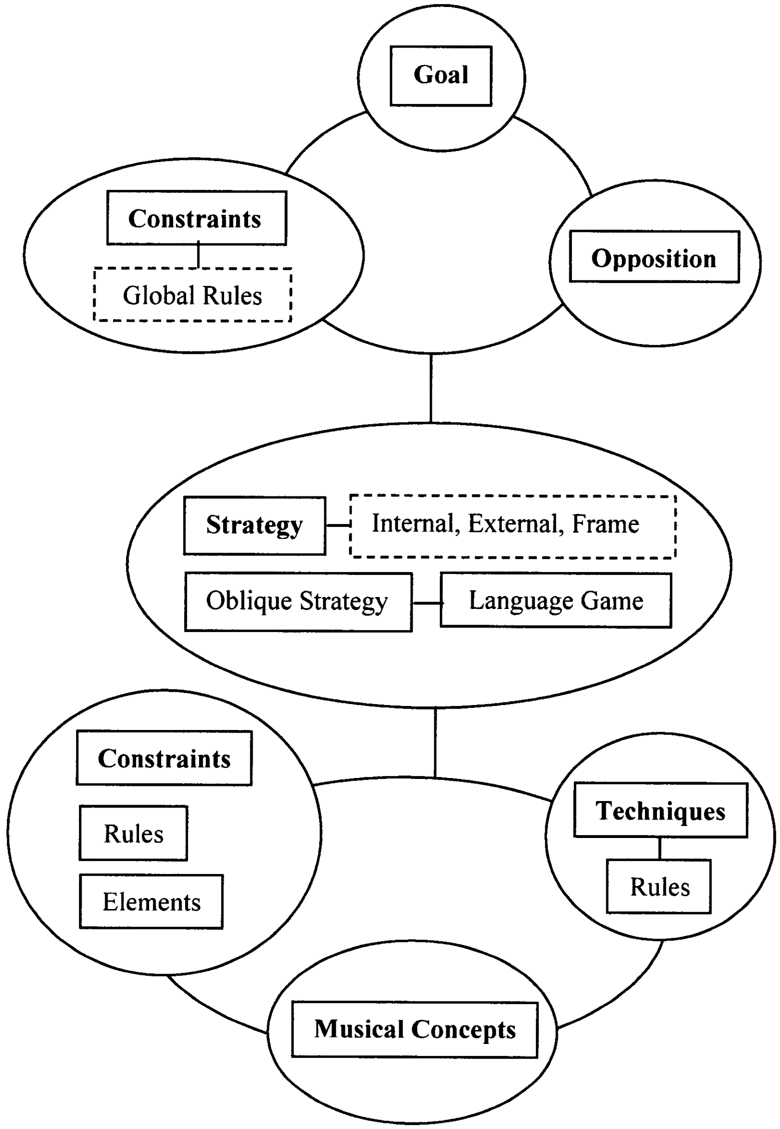


Figure 21: Components of the Music Composition Game

These hard distinctions between strategies, concept, techniques and rules allow for more accurate analysis of the generative process. Each of these components has a distinct function in the music composition games. The interrelation of these components gives rise to the complex structure in artistic artifacts. What ties all the game components together is a strategic process.

3.6 Structure, Preference and Rules from an Artist's Perspective

In a standard game, a board game or sports game, no preference is revealed in the preset rules. But in the generative process where there is flexibility in when a rule is defined and when and for how long it is in effect, preference plays a distinct role. Preference's purpose is not only important in the creation of rules, but in determining the strategies that navigate through those rules.

This assessment of the role of rules in the music composition game contrasts the sort of stylistic rules David Cope developed for his synthetic composers. Cope used statistical analysis to represent an imitated composer's preferences and biases towards certain types of combinations. It must be remembered that Cope is using his findings to develop artificial musical intelligences. He must define everything a priori in his ATM and Markov chain models or implement some specific learning algorithm. He must also predefine all the rules and weight the preference of a rule given a very limited definition of context. If the notion of a concept is included at all in this model, it is only as a small, finite library of concepts. Whatever preference is represented in the Markov chain is a preference for a rule and not preference in strategy.

The music composition games afford us a more open and less predetermined view since we are examining human behavior and cognition. In the games, although the provided sonic materials were not malleable, the definition of an element retained a certain amount of flexibility. Cope, in contrast, must predefine what constitutes an element. The degrees of freedom and limitations are fixed as they are in Cope's models. Unlike traditional games, there are no static, low-level rules governing the organization of elements in the composition games. Subjects had no choice but to create rules after formulating a technique. There are only fixed rules in Cope's models. In Cope's models long-term strategy is inflexible. And, short-term strategy is imitated only superficially at each transition point.

In the music composition games, a particular strategy and set of constraints produced great variability in identifying elements, utilizing concepts, and employing techniques. Creators' preferences were linked to contexts through which structure was perceived. These music composition games begin to indicate how strategy might be tracked through the generative process. If we can learn to better measure preference along side structural perceptions then we will be able to draw more detailed comparisons across creators. The next chapter will introduce games centered on preference and similarity. Through these games we will enhance our understanding of the relationships between preference, context and feature overlaps. Do musical creators share similar ways of perceiving structure? How can we describe these patterns?

Preference and Similarity

4

4.0 Similarity and Preference in the Generative Game

This chapter goes into greater depth about the role of preference in the generative process, and explores two basic premises; namely, that preference is important in setting the context for the artist, and preference biases how the artist perceives structure in the artifacts they create. Similar patterns of perceiving structure can be noted across creators, not just in terms of conventions such as chords or key relations, but also within far more sparse contexts. This sparse context will be investigated through two additional musical composition games. In these simplistic games, subjects use only one timbre to generate short, rhythmic patterns.

The first of these games emphasizes the relationship between preference and context. It has an antecedent/consequence format. The referent structure offers an improvement on the previously presented games.[1] One key challenge in using concept design games to observe the generative process entails clarifying the context through which a game player makes a musical pattern; This procedural transparency is directly linked to our abilities both to analyze the results and correlate findings across groups of players.

The first game has two parts. The first part's objective is to create an antecedent rhythm and rank preference for a given set of possible consequences. In the second part, using the least preferred consequence as a starting place, players try to make a new antecedent that makes the least preferred sound the most preferred.

The second game focuses on examining biases towards perceiving structure and the impact of those biases on generating patterns. In this game, nine rhythms are provided in the form of sample blocks (as in the games of the previous chapter). Players chain rhythmic blocks to make longer musical patterns. These do not necessarily take on an antecedent consequence format, but rather use shorter components to make longer elements.

As in the previous music composition game, control over the sonic material and the degrees of freedom available to the creator are of paramount importance. A priori knowledge of the constraints allows comparisons to be drawn across game responses.

[1] There are natural musical scenarios in which context is relatively constrained and mutually defined by participants. For example, in a "jam session" it is presupposed that concurrent or successive elements are part of a large whole. In this improvisatory format there is an implied connection between parts (either simultaneous or referent).

The sonic materials provided in this chapter's games are the nine rhythmic patterns. The patterns do not loop. Each pattern is two seconds in length, and contains four attacks of a synthetic log drum sound. Longer patterns would greatly lengthen the time required to complete the game.
In order to minimize the variability between rhythms, these two seconds are subdivided into eight equally spaced "slots" (of 250 ms.). The four attacks were distributed across these eight slots. All nine rhythms all have an attack in the first slot to ensure equivalent down beats when played in succession as antecedent and consequence pairs. All the patterns also have an attack in the fifth slot to further limit the variation. The nine patterns (figure 22) are therefore distinguished from each other by the placement of two attacks only. (Henceforth, these nine patterns will be referred to collectively as the Nine.)

The rhythms throughout this section are presented in a timeline grid and not in any sort of standard musical notation because they were not presented to the subjects in standard notation to avoid biasing the subjects towards particular forms of representation or musical conventions. Accordingly, temporal subdivisions in these games are quantized to the following "slots" in seconds: 0, .25, .5, .75, 1.0, 1.25, 1.5, and 1.75. Where two rhythmic patterns are concatenated the following eight slots proceed: 2, 2.25, 2.5, 2.75, 3.0, 3.25, 3.5 and 3.75. Of course, subjects superimpose their own metric inferences on to these patterns, but the choice of interpretation is left as open as possible.

Pattern		Time	0	.25	.5	.75	1.0	1.25	1.5	1.75
1	1 2 - - 5 6 - -		•	•	-	-	•	•	-	-
2	1 2 - - 5 - 7 -		•	•	-	-	•	-	•	-
3	1 2 - - 5 - - 8		•	•	-	-	•	-	-	•
4	1 - 3 - 5 6 - -		•	-	•	-	•	•	-	-
5	1 - 3 - 5 - 7 -		•	-	•	-	•	-	•	-
6	1 - 3 - 5 - - 8		•	-	•	-	•	-	-	•
7	1 - - 4 5 6 - -		•	-	-	•	•	•	-	-
8	1 - - 4 5 - 7 -		•	-	-	•	•	-	•	-
9	1 - - 4 5 - - 8		•	-	-	•	•	-	-	•

Figure 22: "The Nine" patterns that are the stimuli for the preference and similarity tests

These games begin with two tests that help establish a baseline for analyzing the patterns subjects generate. The first test is a preference test that asks subject to rank antecedent and consequent pairs. The second is a similarity test that measures subjects' perceptions of the similarity between pairs of the Nine rhythmic patterns. Both similarity and preference are things that can be measured by scalar or total ranking.

These baselines provide us with consistent metrics through which game responses can be compared.

Antecedents and consequences are pitched a fourth apart. (The antecedent is always pitched higher.) In tasks involving similarity judgments, antecedent and consequence rhythms are pitched identically. The tempo was in no way perceptually taxing, yet also kept the game well paced. The rhythms have no dynamic/accented variations. Subjects impose their own perception of metric division and beats per minute.

No restrictions were imposed on the length of time subjects took to complete the baseline tests and the games. Most subjects completed the baseline tests and the first game in 60-90 minutes. The subjects that participated in the second game generally required approximately 30 minutes.

Sixteen subjects participated in the first game run in January and February 2004 (the data collected from 2 subjects was discarded for not following directions). The preference and similarity baseline information was collected from all participants. In March and April, eight subjects were called back to try the second game. Subjects varied in age (from 18 to 50), gender, musical experience and education, instruments played and genre preferences.

4.1 Preference Metric

How can we take a measurement of preference? For the artist, preference is determined within a given set of options. Preference is highly situated. Through this preference test and the games in this chapter, we will try to further explore how preference impacts the generative process.

To gather a preference baseline, subjects are presented with pairs of the Nine in antecedent-consequence format and asked to rank their preference for each pairing. There are eighty-one pairs in total. Using the same ProTools GUI interface, subjects are asked to shuffle nine possible consequences in relation to a fixed antecedent. The results are a total ranking of preferred antecedent /consequence pattern pairs.

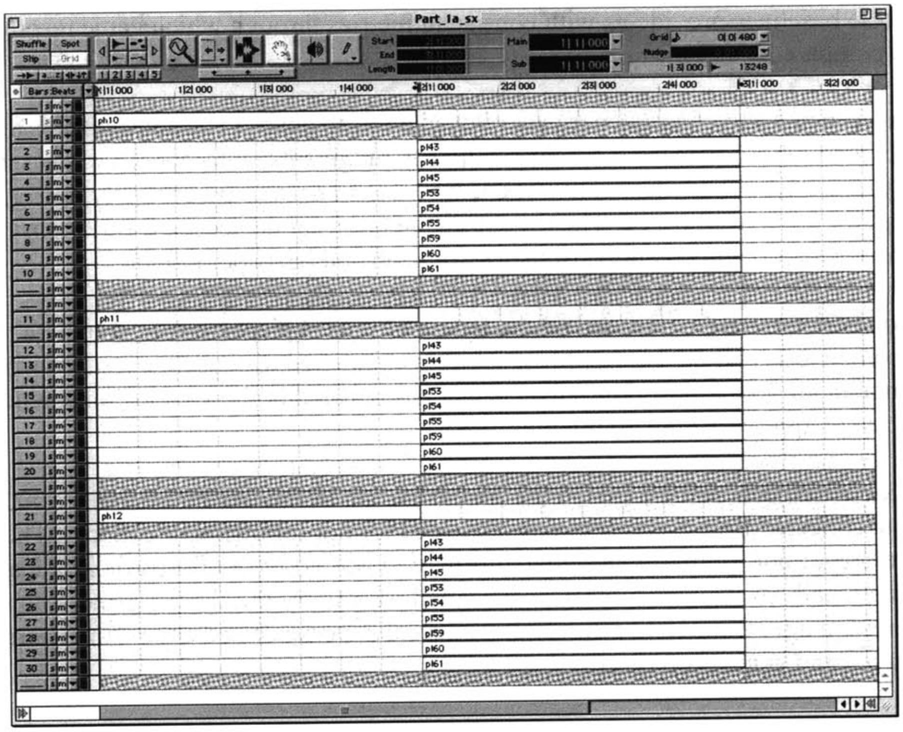


Figure 23: preference test gui

4.1.1 Preference Test Results

It is noteworthy that people have such strong preferences for the very primitive patterns used in these games. There was a tremendous amount of variation in the preference responses both within the eighty-one pairs ranked by each subject and between subjects. Clear patterns of preference did not emerge. Nonetheless, despite the simplicity of the stimuli, subjects did have decided preferences for pairing of the Nine. Notable is that there were points of high agreement.

For the most preferred pairings several areas of high agreement occurred within this subject population. For example, pattern 1 followed by pattern 4 (figure 24) is the most preferred by 50% of the subjects. Also, several patterns are perceived as most favorable followed by the same pattern. Examples of this trend include pattern 4 followed by pattern 4 (figure 25) most preferred 44% of the time, and pattern 7 followed by pattern 7 (figure 26) preferred 50% of the time.

Antecedent **1** Preference for Pattern in %

1	2	3	4	5	6	7	8	9
31	<1	6	**50**	<1	<1	<1	6	6

time	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
attack	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-

Figure 24: Pattern 1 followed by pattern 4

Antecedent **4** Preference for Pattern in %

1	2	3	4	5	6	7	8	9
19	31	6	**44**	<1	<1	<1	<1	<1

time	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
attack	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-

Figure 25: Pattern 4 followed by pattern 4

Antecedent **7** Preference for Pattern in %

1	2	3	4	5	6	7	8	9
13	6	6	13	<1	6	**50**	6	<1

time	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
attack	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-

Figure 26: Pattern 7 followed by pattern 7

Also interesting are antecedents for which there is relatively little diversity in preferred consequences. In other words, all the subjects converged on just a few consequent possibilities. For example, only four patterns received high ranks as consequences for antecedent 4. Pattern 4 preferences are ranked as follows: pattern one 19% agreement, pattern two 31% agreement, pattern three 6% agreement, pattern four 44% agreement. These preferred antecedent/consequence pairings are notated in figure 27. Preference for pattern 8 consequences preferences are ranked as follows: pattern one 25% agreement, pattern two 13% agreement, pattern three 25% agreement, pattern four 13% agreement, pattern five 25% agreement (figure 28).

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
19%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
31%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
6%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
44%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-

Figure 27: preferred consequences for pattern 4

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
25%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
25%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
13%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
25%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-

Figure 28: preferred consequences for pattern 8

Alternatively, there are pairings that draw a wide range of responses indicating disagreement amongst subjects such as antecedent pattern 5 (figure 29) and antecedent 9 (figure 30). In both these pairings at least seven consequences received high ranks.

Antecedent **5** Preference for Pattern in %

1	2	3	4	5	6	7	8	9
19	13	13	<1	6	6	19	19	6

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
19%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
<1%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
19%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
19%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
5%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Figure 29: consequence preference for antecedent pattern 5

Antecedent **9** Preference for Pattern in %

1	2	3	4	5	6	7	8	9
13	19	6	25	<1	6	19	<1	13

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
13%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
19%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
6%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
25%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
<1%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
19%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
<1%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
13%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Figure 30: consequence preference for antecedent pattern 9

Some trends of like and dislike can be roughly codified even though this experiment represents relatively small sample population. For several of the antecedents, high preferences for particular consequences are consistently accompanied by low preferences for certain other options. These combinations of high/low preferences trends are illustrated in figure 31. In general, as expected, subjects favor patterns pairings in which inferred subdivisions are likely to be similar for both the antecedent and consequence.

Following is a summary of the finding presented in the proceeding chart: for the antecedent pattern 1, a high preference for consequence pattern 1 is accompanied by a low preference for patterns 3 and 6. A high preference for consequence pattern 4 is accompanied by a low preference for consequence patterns 6 and 9; for antecedent pattern 2, a high preference for consequence pattern 1 accompanies a low preference for pattern 5, and a high preference for consequence 2 accompanies a low preference for pattern 6; for antecedent pattern 3, a high preference for consequence patterns 1, 4 or 7 accompanies a low preference for pattern 9; for antecedent pattern 4, a high preference for consequence pattern 4 accompanies a low preference for pattern 9; for antecedent pattern 6, a high preference for consequence pattern 1 accompanies a low preference; for patterns 9 or 6. For antecedent pattern 7, a high preference for consequences 7 accompanies a low preference for pattern 9; and for antecedent pattern 9, a high preference for consequence 4 accompanies a low preference for consequence 9.

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
Antecedent 1																
High	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
Low	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
Low	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
High	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
Low	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
Low	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•
Antecedent 2																
High	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
Low	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
High	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
Low	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
Antecedent 3																
High	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
High	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
High	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
Low	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•
Antecedent 4																
High	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
Low	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•
Antecedent 6																
High	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
Low	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
Low	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•
Antecedent 7																
High	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
Low	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•
Antecedent 9																
High	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
Low	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Figure 31: trends for likes and dislikes

Age, gender, musical experience and education, instruments played, and genre preferences are not factors in preference ranking. (Within this relatively small population.) These findings suggest preference and context are changing from antecedent to antecedent.

4.2 Similarity Metric:

Throughout this discussion of preference we have implied that perceiving structure in an artistic artifact is a choice. We need some clear and simple way to make comparisons across artists without pre-defining what constitutes a pattern of organization. One way to do this is through similarity. We can get a sense of how an artist is perceiving structure by asking him or her which elements are similar and how similar are they to each other.
There are numerous kinds of similarity. Various features in the musical surface can quickly generate overall impressions of a musical segment. Any form-bearing dimension may provide a set of features that could be contrasted or weighted for similarity, but less definable attributes are also highly salient such as energy, timbre, and mood. Similarity of course harkens back to feature overlaps in the Oblique Strategies, as well. However, as we have already observed, in the Oblique Strategy offer tremendous variation and flexibility in feature mapping.

Subjects are given a similarity test to establish which patterns they perceived to be similar and how similar they perceived them to be. The similarity baseline test consisted of forty-eight questions. Twelve questions are used as a warm up and not included in the subject's response profile. The remaining thirty-six questions cover similarity between pairs of the Nine (81 minus identical pairs and inversions). Subjects rank the perceived similarity on a scale of 0 to 10 marking their answers on a questionnaire. A score of zero indicates that the pairs are not in anyway similar, and score of ten indicates that they are perceived as identical. The same GUI used in the preference test is used to administer the similarity test, although subjects simply listened to pairs of rhythms without needing to drag samples into position.

We would like to find patterns of perceiving similarity, to know how individual subjects perceive similarities between the stimuli patterns, and if groups of subjects have similar ways of perceiving structure. But, we do not want to influence the subject's perception in order to obtain the response. We do not want to test whether a specific type of relationship is perceptible. Rather we would like the subjects to self-define their perceptions.

To find these patterns we can use multidimensional scaling, a technique from multivariate statistics often used in sociological studies. Multidimensional scaling is a means of reconstructing the distances of all the elements in a group of objects relative to one another from the distances of pairs of objects in the group. The classic MDS example is the reconstruction of "city blocks". By taking a set of streets with the distances between each pair of streets in the set, we can reconstruct the relationships in the entire set. The plotted reconstruction might not be exactly map-like with appropriate north/south orientation, but the relative distances between streets will representative of the relationships. MDS thus provides an excellent visual representation for similarity between objects and grouping similar objects.

4.2.1 Plotting Similarity Responses:

When we plot similarity distances between the Nine, we get plots such as figure 32. The nine dots labeled 1 through 9 on each graph correspond to the Nine rhythmic patterns. Their position in the plot represents their perceived proximity to each other in similarity space.

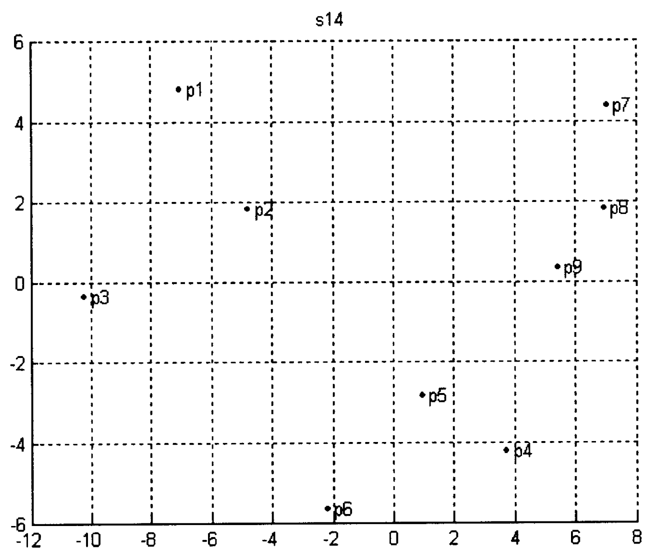


Figure 32: MDS plot of similarity response

4.2.2 Similarity Groups:

Unlike the preference baseline, clear, categorical tendencies emerge in subjects' responses to the similarity tests. These trends are readily apparent in the MDS plots. We see in the plots several reoccurring patterns. First, in nearly all the plots the Nine are segregated into clusters of three based on the position of the first two attacks in each of the nine rhythms. As illustrated in figure 33 which shows subject 7's responses, patterns 1,2 and 3 which all have the first two attacks in common are in closer proximity to each other than to other patterns. Patterns 4,5 and 6 and 7, 8 and 9 are also clustered respectively according to the first two attacks of each rhythm.

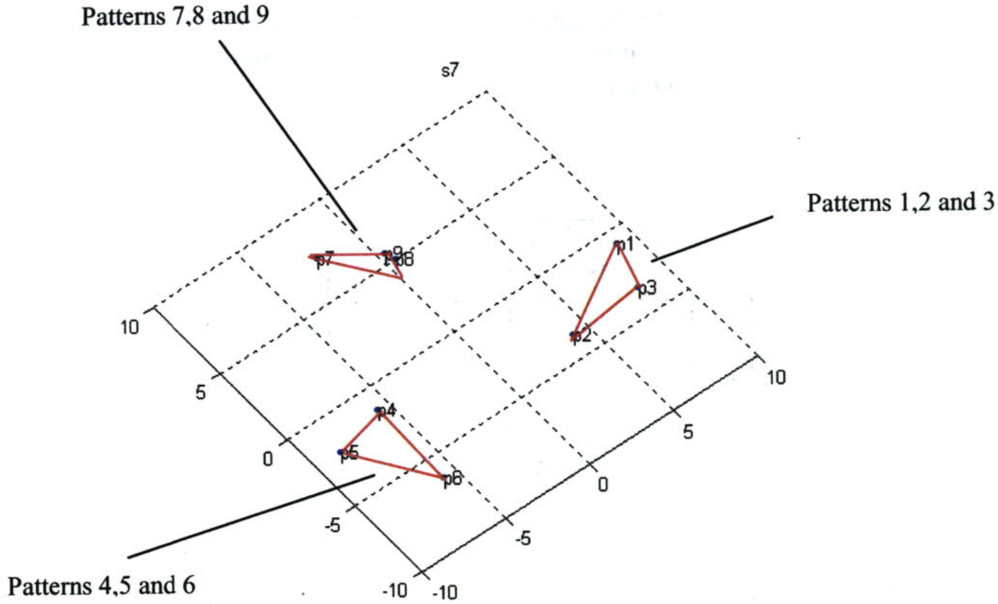


Figure 33: Nine clustered by first two attacks

Three patterns of proximity emerge in the subjects' results. In group I, clusters 1-2-3, 4-5-6 and 7-8-9 are distributed in relative isolation from one another. In group II, two of the three clusters are proximal. In group III, the clusters are less distinct and all the patterns are grouped close to each other.

The following examples are drawn from the test results. In the first group, the clusters are relatively equal distances from each other (figure 34). Eight of the fourteen subjects fell into this category.

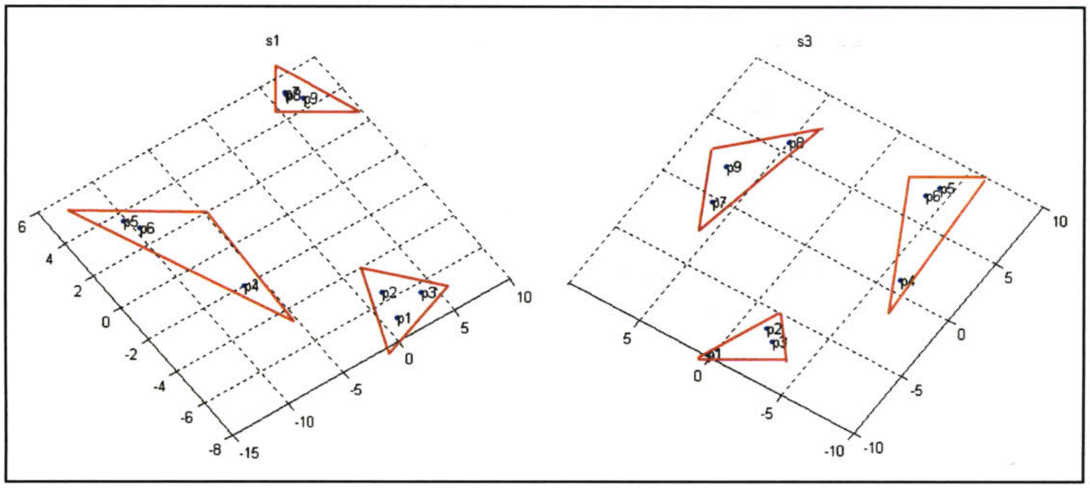


Figure 34: Group I equally distant

In the next group, which contains two subjects, two clusters are in closer proximity than a third. There are variations in closest pairs. Some subjects place patterns 1-2-3 close to patterns 4-5-6 or patterns 7-8-9. Alternatively, some subjects perceive patterns 4-5-6 and patterns 7-8-9 in closest proximity. (figure 35)

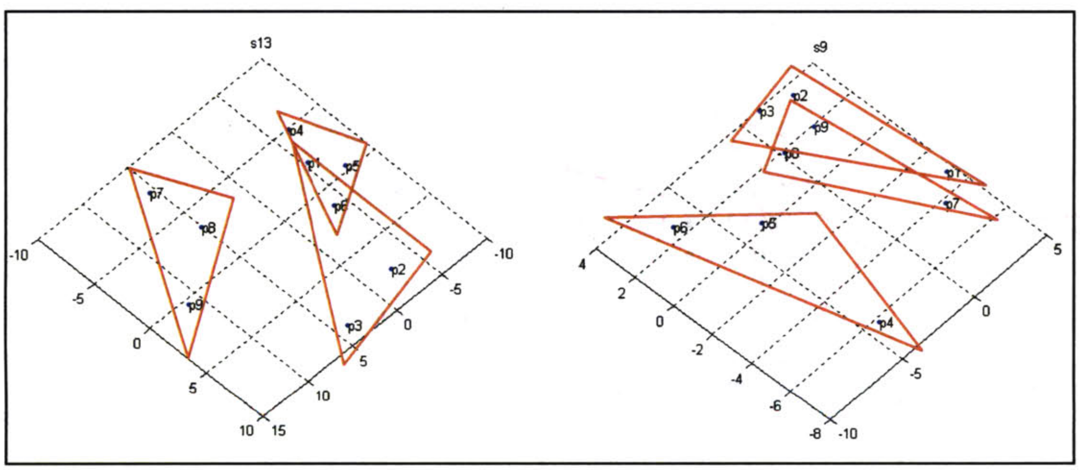


Figure 35: group II two clusters more similar than the third

Lastly, four subjects did not segregate patterns into clusters based on the position of the first two attacks. Instead, the clusters overlapped or grouped in close proximity as in figure 36.

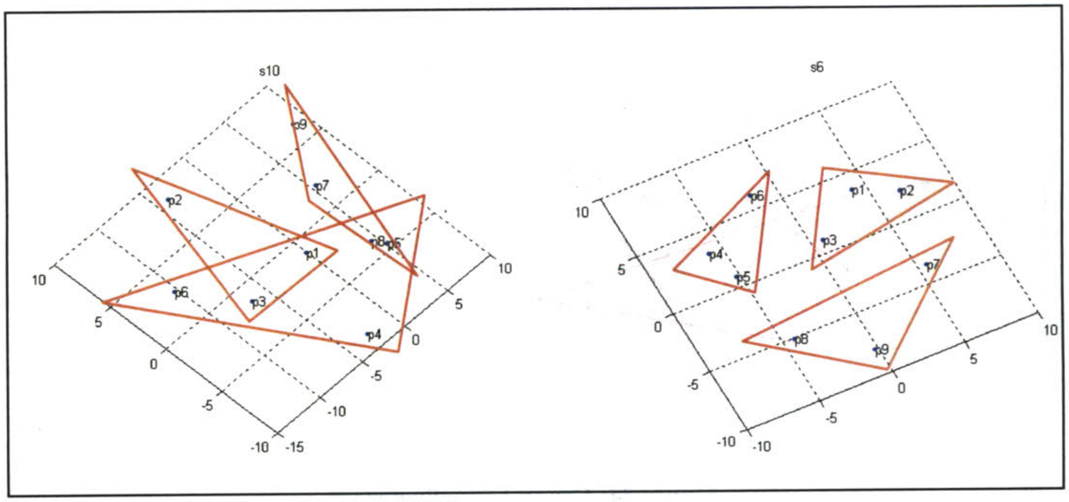


Figure 36: group III overlapping or close clusters

Subjects' age, gender, musical experience and education, instruments played and genre preferences varied within each category. None of these factors appears to be good predictors for perception of structure in this sparse, rhythmic space.

As most subjects divided patterns into groups based on the first two attacks, it might be assumed that some of the features they responded to were regularity and density. The most basic rhythmic inference subjects can make is the perceived metric subdivisions.

	0	.25	.5	.75	1.0	1.25	1.5	1.75
Pattern 1	•	•	-	-	•	•	-	-
Pattern 4	•	-	•	-	•	•	-	-
Pattern 7	•	-	-	•	•	•	-	-

Figure 37: inferred subdivisions

Subjects may also group rhythmic attacks in twos or threes. (figure 38) Particularly since the patterns are not looped in the similarity test, subjects were faced with layers of interpretive challenges despite the sparseness and simplicity of the stimuli.

	0	.25	.5	.75	1.0	1.25	1.5	1.75
Pattern 1	•	•	-	-	•	•	-	-
Pattern 4	•	-	•	-	•	•	-	-
Pattern 7	•	-	-	•	•	•	-	-

Figure 38: inferred subdivisions

Concatenating these patterns in antecedent consequence pairs presents the creator/listener with multiple levels of complexity. (Figure 39) Given the variation in the results, it is obvious that subjects demonstrate different tendencies towards interpretation.

0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-

Figure 39: Inference with mixed two and three groups, Pattern 1 followed by pattern 7

4.3 Make An Antecedent Game

This game explores the connection between preference and context. Building on the strength of the referent structure exemplified in the silent game and in keeping with the format of the preference test, in this game subjects create antecedents that are followed by given consequences. [2] As discussed at the opening of the chapter, this referent structure is a means of constraining the context increasing the distinction between objects. As in all the games it is crucial that the patterns themselves are important as data, and that we do not rely on subjects' descriptions of the generative act alone. The game's objective is to create an antecedent, and then rank the Nine as potential consequences. [3]

To make an antecedent, subjects clicked and dragged four sound icons and dropped them into four of the potential eight (250 ms) slots. The sounds are identical to the log drum samples in the preference test as is the pitch variation between antecedent and consequence. The length of the antecedent is two seconds, and is equal to the Nine patterns used as stimuli in the baseline tests. Because there were no loops in these games, a sound in the first slot was required. The remaining three samples could be arranged in any of the remaining seven slots. All four sounds had to be used, and two samples could not be placed in the same slot. There was no way to add accents or change any other parameter of the sound, nor could subjects modify the temporal subdivisions. Thirty-five patterns are possible given these constraints.

After they created an antecedent pattern, they ranked their preferences for the Nine patterns (sound events in slot 1 and 5) as potential consequences. They recorded their ranked preferences by clicking, shuffling and dragging the patterns into position, the most preferred in the highest position. Subjects were also asked to notate on a questionnaire which of the Nine consequences sounded worst (least preferable) paired against the antecedent they created.

Given the relatively small number of subjects, it was somewhat surprising that there was a fair amount of redundancy in the responses. The left hand side of the chart in figure 41 illustrates the patterns created by the fourteen subjects. They are organized into clusters of related patterns.

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[2] None of the subjects indicated have any problems understanding the concept of call and response and/or antecedent -consequence. All accept that pre-defined relationship as naturally musical, and had not problems with the idea of the second patterns sounding better or worse as a complement to the first.

[3] Since the preference and similarity tests were run at the same time as the games, no foreknowledge of patterns in similarity and preference were used to design these games.

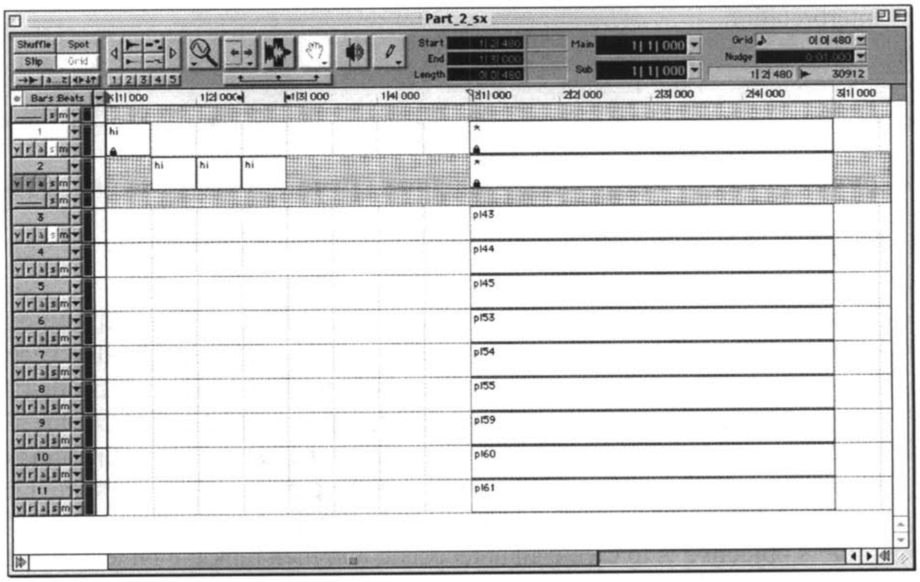


Figure 40: make an antecedent game gui

	Newly Generated Antecedent Patterns								Consequence Patterns by Preference Rank								
time	0	.25	.5	.75	1.0	1.25	1.5	1.75	Most								Least
S4	•	•	-	•	-	-	•	-	**2**	3	1	6	7	4	9	8	**5**
S6	•	•	-	-	•	-	-	•	**3**	4	1	2	7	6	8	9	**5**
S14	•	•	-	-	•	-	-	•	**1**	5	8	4	6	3	9	2	**7**
S5	•	•	-	-	-	•	•	-	**4**	7	1	8	2	5	3	6	**9**
S1	•	-	•	•	-	•	-	-	**3**	9	8	7	4	1	2	6	**5**
S8	•	-	•	•	-	•	-	-	**1**	8	2	7	5	4	3	6	**9**
S3	•	-	•	•	-	-	•	-	**1**	2	4	8	7	5	6	9	**3**
S10	•	-	•	-	•	•	-	-	**2**	7	1	4	6	8	5	9	**3**
S12	•	-	•	-	-	-	•	•	**3**	8	2	7	4	9	6	1	**5**
S2	•	-	-	•	-	•	-	•	**7**	1	4	2	5	3	6	8	**9**
S7	•	-	-	•	-	•	-	•	**8**	4	2	7	1	5	6	3	**9**
S9	•	-	-	•	-	•	-	•	**1**	4	8	3	2	7	6	9	**5**
S11	•	-	-	-	-	•	•	•	**8**	4	6	5	9	3	7	2	**1**
S13	•	-	-	-	-	•	•	•	**7**	3	4	6	2	5	8	1	**9**

Figure 41: Make an antecedent game results. The antecedents are newly generated patterns. The consequence pattern numbers correspond to the "Nine" patterns in the chart on page 46

It is also interesting that there is great variation in consequence preference ranking even for identical or similar patterns. In five cases, the first two attacks in the antecedent match the position of the first two attacks in the consequence. All subjects who positioned attacks in the first and third slots in the antecedents selected a consequence with attacks in the first and second slots. Patterns 4,5,and 6 from the Nine also have attacks in the first and third slots. In the preference test, there was an indication of preference for consequences with attacks in the first two slots. Preferred consequences for pattern 4 include pattern 1 for 19% of the time, pattern 2 for 31% of the time, but and pattern 3 only 6% of the time. There is a preference for patterns 1,2 and 3 19, 13 and 13% of the time respectively. Patterns 1 and three were preferred as consequences 31 and 19% respectively. But these correlations are not quite clear. For example, subjects 7 and 9 created antecedents that differ from patterns 7 and 9 by only one attack. The top preferred consequences for these patterns are 5, 1 and 4 for antecedent 7 and 4, 7 and 2 for antecedent 9. In the context of this game, however, subjects' top preferences are different.

A high preference rank is an indicator of a consequence that supports the creator's rhythmic inference. It is of course possible that the metric interpretation of either half of the newly generated antecedent and now familiar consequence pairs changed as the creator ranked the consequences according to preference. But the final rankings provide some indicator of the coherence the pairings hold for the creator. In the generating antecedents, it does not seem as if creators attempted to eliminate metric ambiguity altogether. Rather that creators generated musical interest in the pattern pairs by introducing an ebb and flow from a particular metric interpretation. The lower in preference a consequence, the stronger the indicator that it pulled the metric interpretation too far from the creator's design. In comparing a subject's most and least preferred consequences, the key metric positions supporting or confusing their interpretations are evident. These are highlighted in figure 42 in which most and least preferred antecedent-consequences are juxtaposed.

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
Most	•	•	-	•	-	-	•	-	•	•	-	-	•	-	•	-
Least	•	•	-	•	-	-	•	-	•	-	•	-	•	-	•	-

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
Most	•	-	•	-	-	-	•	•	•	•	-	-	•	-	-	•
Least	•	-	•	-	-	-	•	•	•	-	•	-	•	-	•	-

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
Most	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
Least	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-

Figure 42: Subjects most and least preferred antecedent-consequence pairs. Subject 4's most preferred consequence was pattern 2 and least pattern 5. Subject 12's most preferred consequence was pattern 3 and least pattern 5. Subject 14's most preferred consequence was pattern 1 and least pattern 7.

4.3.1 Make the Least Preferred the Best

In the second part of this game, the objective is to take the least preferred consequence from the previous game and create an antecedent that makes that pattern sound the most preferable as a consequence. This game makes three variants each with a different set of constraints available to the creator. In essence, subjects have three tries at making the "worst" or least preferred sound the "best" or most preferred. Each try has a separate workspace. The first variant mirrored the previous "make an antecedent" game exactly. In the second variant subjects are given the freedom to arrange the four sounds in any of the eight slots thereby loosening the requirement of having a sound event in the first slot. In the last variant, the antecedents and consequences are reversed making the worst consequence the antecedent. On this workspace subjects make an effective consequence.

Subjects are asked to stop, forgoing further game variants, if they succeed in making the worst sound best. (i.e. If they succeed in the first variant they do not continue onto the second or third workspace). Regardless of success, subjects rank their preference for all nine patterns against the pattern they create. Some subjects may feel that they can only marginally improve the ranking of the worst or not at all. The amount of time a subject spends on making the worst the best must have had some impact on their success. Given the lengths of time the subjects spent on this game, it is highly improbable that they ran through all possible configurations in each variation. This highlights the importance of generative strategy in constructing these patterns.

All subjects could make the worst better, not all could make it best. For the most part, subjects were either able to make the worst the best on the first workspace, or they continued through all three workspaces achieving the greatest success where antecedents and consequences are reversed. Subjects who started with the target optimal consequence pattern 5, 1-3-5-7-, seemed to have the most trouble making it sound best.

The table in figure 43 shows all workspaces in both parts of the game (the second game's workspaces are labeled 1-3 in the second column). This provides an overview of the kind of data collected. A complete chart of all fourteen subjects appears in the appendices. The results reveal a pattern of preferences. Additionally, it elucidates a set of transitions that in the creator's mind improves the least preferred. (Please note, that in the third workspace the antecedent and consequence have been reversed.)

	Work space	New Pattern								Preference Rank								
		1	2	3	4	5	6	7	8	Most								Least
S2																		
Part 1		•	-	-	•	-	•	-	•	**7**	1	4	2	5	3	6	8	**9**
Part 2	**1**	•	•	-	•	-	-	•	-	9	1	4	3	2	7	5	6	8
S7																		
Part 1		•	-	-	•	-	•	-	•	**8**	4	2	7	1	5	6	3	**9**
Part 2	**1**	•	-	•	-	-	•	-	•	8	9	4	1	2	5	3	7	6
	2	-	•	-	-	•	•	-	•	4	7	9	6	2	5	3	1	8
	3	•	•	•	•	-	-	-	-	9	3	4	6	5	8	7	2	1
S14																		
Part 1		•	•	-	-	•	-	-	•	**1**	5	8	4	6	3	9	2	**7**
Part 2	**1**	•	-	-	•	•	•	-	-	1	5	7	3	6	4	8	9	2
	2	•	•	-	-	•	•	-	-	1	6	7	5	4	3	2	8	9
	3	•	-	-	•	•	-	•	-	8	7	1	3	5	4	6	9	2

Figure 43: Make the Worst the Best responses and consequent ranking

Depicting the transition from one preferred pairing to another reveals the specific changes in attack placement and their impact on preference (figure 44).

Part	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
2	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
	•	-	-	•	•	-	•	-	•	•	•	•	-	-	-	-

Figure 44: Subject 7 Make the Worst the Best

We can then plot out complete transitions from the preferred pattern combination in the first part of the game through configurations where the least preferred improves. Meanwhile, we preserve the ranking of all possible consequences. Subject 2 was able to reconfigure the antecedent so that pattern 9 goes from sounding the worst to the best in just the first workspace (figure 45).

Subject 2

antecedent	consequence	antecedent	consequence
1 - - 4 - 6 - 8	1 - - 4 5 6 - -	1 2 - 4 - - 7 -	1 - - 4 5 - - 8
	1 2 - - 5 6 - -		1 2 - - 5 6 - -
	1 - 3 - 5 6 - -		1 - 3 - 5 6 - -
	1 2 - - 5 - 7 -		1 2 - - 5 - - 8
	1 - 3 - 5 - 7 -		1 2 - - 5 - 7 -
	1 2 - - 5 - - 8		1 - - 4 5 6 - -
	1 - 3 - 5 - - 8		1 - 3 - 5 - 7 -
	1 - - 4 5 - 7 -		1 - 3 - 5 - - 8
	1 - - 4 5 - - 8		1 - - 4 5 - 7 -

Figure 45: Subject 2's antecedent and preferred consequences in both parts of the game

Interestingly, some subjects come up with patterns that work well for both the original and new antecedents. Subject 2's preference for 12--56-- and 1-3-56- do not change. These are highlighted in figure 46. For Subject 2, however, all low ranking consequences do not improve with the change antecedent. The 1--45-7- pattern remains poorly preferred in both parts of the game.

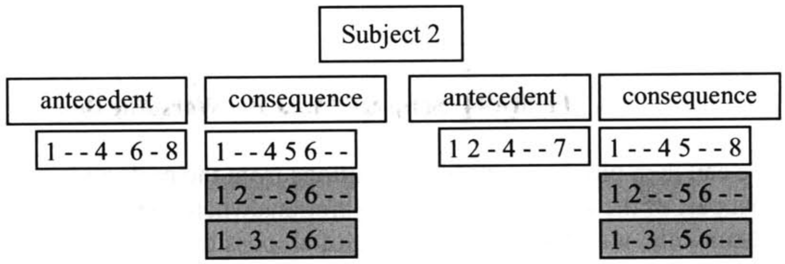


Figure 46: Subject 2's consequences that work for multiple antecedents

In Subject 3's responses, high-ranking consequences for the first and second antecedents are the top preferences for the third antecedent. These patterns are illustrated in figure 47.

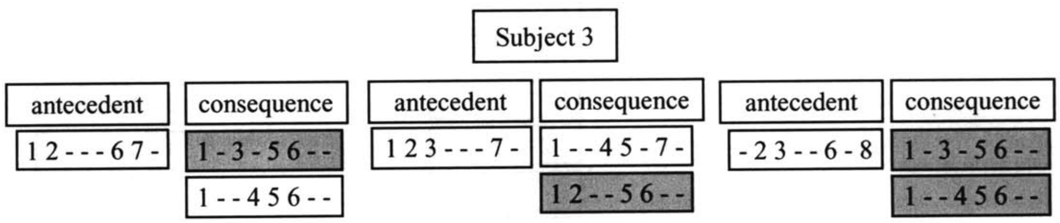


Figure 47: Subject 3's antecedent-consequences preferences

Examined in greater detail, the time compression between the first group of attacks and the second factors in the how patterns 1 and 4 are perceived as consequences. Represented in each chart are the two most preferred and least two preferred antecedent-consequence pairs from three consecutive workspaces. The antecedent remains the same for each workspace.

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
High	•	•	-	-	-	•	•	-	•	-	•	-	•	•	-	-
High	•	•	-	-	-	•	•	-	•	-	-	•	•	•	-	-
Low	•	•	-	-	-	•	•	-	•	-	•	-	•	-	-	•
Low	•	•	-	-	-	•	•	-	•	-	-	•	•	-	-	•

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
High	•	•	•	-	-	-	•	-	•	-	-	•	•	-	•	-
High	•	•	•	-	-	-	•	-	•	•	-	-	•	•	-	-
Low	•	•	•	-	-	-	•	-	•	•	-	-	•	-	-	•
Low	•	•	•	-	-	-	•	-	•	-	•	-	•	-	-	•

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
High	-	•	•	-	-	•	-	•	•	•	-	-	•	•	-	-
High	-	•	•	-	-	•	-	•	•	-	•	-	•	•	-	-
Low	-	•	•	-	-	•	-	•	•	•	-	-	•	-	•	-
Low	-	•	•	-	-	•	-	•	•	•	-	-	•	-	-	•

Figure 48: Subject 3's top and bottom two antecedent-consequence patterns

It is interesting to note that both subjects 2 and 3 began with somewhat unconventional antecedent patterns. The next pages show the responses from Subjects 7 (figure 49) and 8 (figure 50) who needed all three workspaces in order to optimize antecedent-consequence pairs.

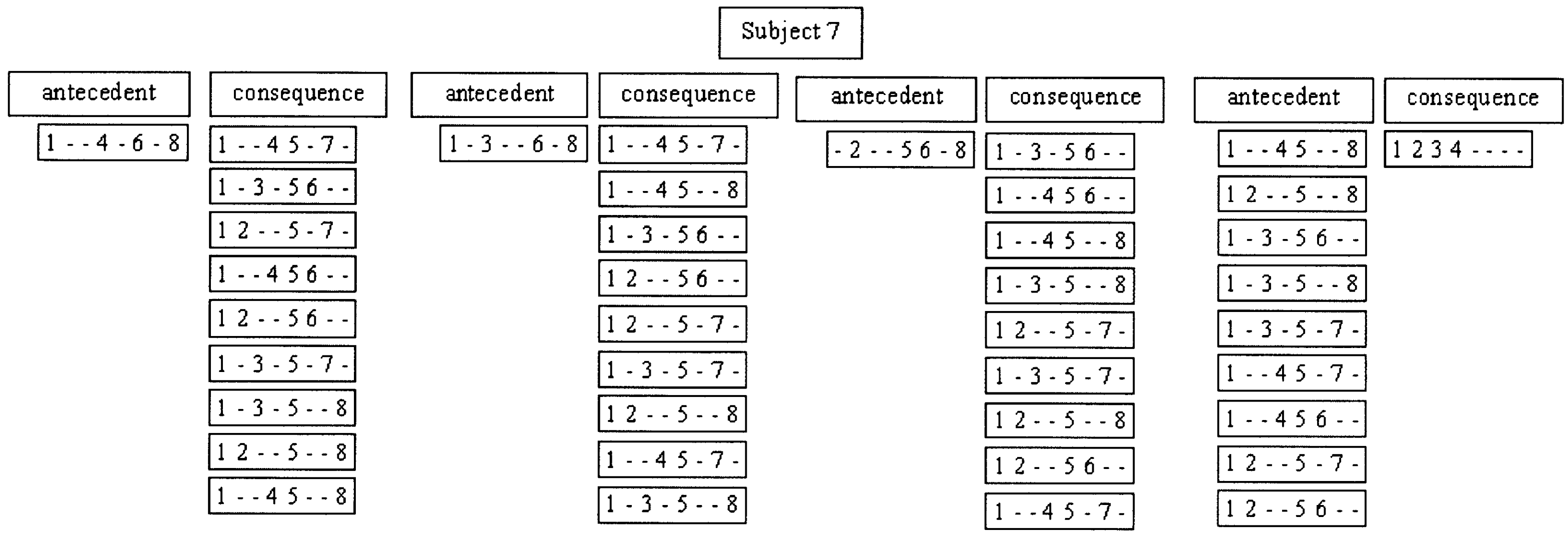


Figure 49: Subject 7's responses to parts 1 and 2

Subject 8

antecedent	consequence	antecedent	consequence	antecedent	consequence	antecedent	consequence
1 - 2 4 - 6 - -	1 2 - - 5 6 - -	1 2 - - 5 - - 8	1 2 - - 5 - 7 -	- 2 3 - 5 - 7 -	1 2 - - 5 - 7 -	1 - - 4 5 - - 8	1 - 3 - 5 - 7 -
	1 - - 4 5 - 7 -		1 2 - - 5 6 - -		1 - - 4 5 6 - -	1 - - 4 5 - 7 -	
	1 2 - - 5 - 7 -		1 - 3 - 5 6 - -		1 - - 4 5 - 7 -	1 2 - - 5 - - 8	
	1 - - 4 5 6 - -		1 - - 4 5 - 7 -		1 2 - - 5 6 - -	1 - - 4 5 6 - -	
	1 - 3 - 5 - 7 -		1 - 3 - 5 - 7 -		1 - 3 - 5 6 - -	1 - 3 - 5 6 - -	
	1 - 3 - 5 6 - -		1 - - 4 5 6 - -		1 - 3 - 5 - 7 -	1 - 3 - 5 - 7 -	
	1 2 - - 5 - - 8		1 - - 4 5 - - 8		1 - - 4 5 - - 8	1 - 3 - 5 - - 8	
	1 - 3 - 5 - - 8		1 - 3 - 5 - - 8		1 - 3 - 5 - - 8	1 2 - - 5 - 7 -	
	1 - - 4 5 - - 8		1 2 - - 5 - - 8		1 2 - - 5 - - 8	1 2 - - 5 6 - -	

Figure 50: Subject 8's responses to parts 1 and 2

Very few subjects inverted their least/most preferences choices. Subject 8 was one of the exceptions. By contrast, most subjects improved the worst without necessarily relegating the former best to lowest preference rank.

Relative ease of making the worst the best demonstrates how powerful the role of context is in the generative process and the variety and changeability of its nature. This game improves our understanding of the interrelation of context and preference. The preference test alone did not provide a sense of how to measure context more accurately, but this game does. It representations show the changing preference along side the changing context (variability in antecedent consequence). For each player there is a path through the decision space. Iterations alter the context and the preferences. These games did not, however, allow us to draw comparisons across subjects.

Unlike the Oblique Strategy games, it is not clear how to map these responses to a feature overlap. Without a clear pattern of preference to map to the similarity test, it is not possible to associate features in the newly generated patters with the similarity test.

4.4 Chain Four Segments Game

To try and gain a tighter correlation between the perception of structure and a game playing strategy, ten subjects were called back to participate in an additional game. This game connects the responses in the similarity test to the generation of patterns. Juxtaposing the patterns generated in this game gives us a new way to represent techniques for generating certain types of patterns. This expands our notion of generative strategizing by linking a preference for perceiving elemental components in a particular way to building more complicated structures.

This game used only the Nine patterns used in the similarity baseline test. The objective in this game is to create four pairs of patterns by chaining together four of the Nine basic rhythms to create one longer pattern chain, 8 seconds in duration. (Henceforth, the term *basic pattern* will be used to describe the Nine *patterns* that constitute the sonic building blocks of this game. The term *chain* will refer to the concatenation of four of these blocks together to make a new, longer pattern). Subjects are free to use particular patterns more than once. The rhythms concatenate directly to the end of the previous rhythm. These pairs of chains are to be similar to each other, but each chain with a pair must begin with a different pattern from the original nine. The first pair is to be regular, the second irregular, the third dense and the last sparse.

The interface is the same ProTools GUI. (figure 51) Subjects click and drag samples of the basic patterns into place. The interface looks the same as in the Oblique Strategies games in which icons are listed in a bin on the right of the screen. They are clicked and dragged onto tracks and shuffled into order. After composing the chains, subjects are asked to mark down how many phrases they hear in each of the eight chains (i.e. whether is still sounded like four phrases or had some other structure emerged). Subjects are also given an abridged similarity test (only eight pairs), and asked to write down on a questionnaire their criteria for similarity. It was abridged because of the amount of time it takes for subjects to respond to all thirty pairs.

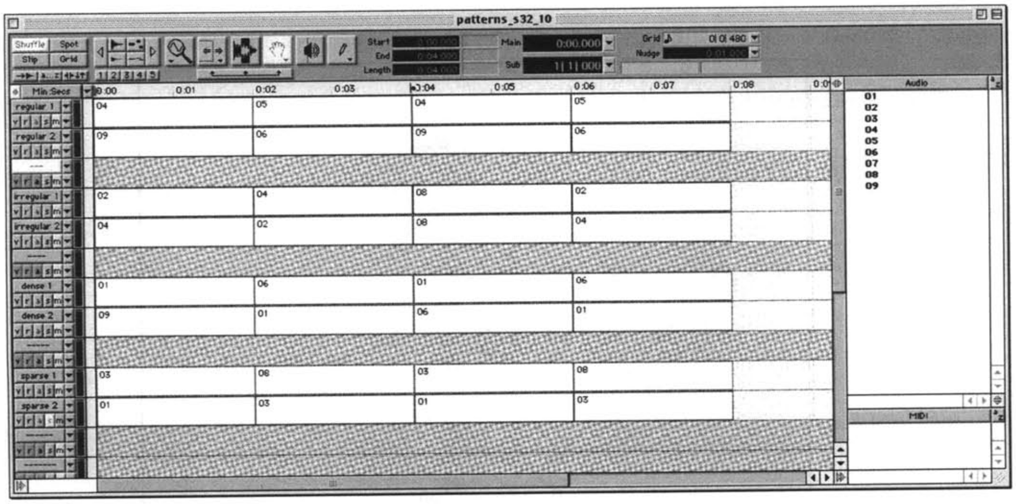


Figure 51: examples of chains

In the second similarity test subjects for the most part had similar responses. In general, the range of the result was more compressed the second time. For example, two patterns that had a similarity of rating of 9 would now have a similarity rating of 7 or 8, but over all trends were preserved. Subjects were also asked to remark on their criteria for ranking the similarity. Although these types of responses are subject to scrutiny, they were included as a means to follow up on the assumption that the position of the first two attacks, regularity and density were deciding factors.

Similarity criteria reported in the written responses were informative, but inconclusive because several subjects could not always explain their reasoning. For a great number of patterns, the position of the first two attacks was reported to be a major influence. Other criteria also appeared frequently. These included density or chunking; the number of beats in the same position; and syncopation. Some subjects used less specific criteria listing "feel" or associating the rhythms with a particular genre. Some subjects based similarity on how "well the patterns went together".

Similarity, cohesion and concepts, as we discussed previously, are responsible for the pervasive modal character in generating structure. There is a feature overlap between elements that presumes some form of similarity. How those elements are selected and sub-grouped, and the characteristics of the concepts that formulate that similarity gives each artifact its unique structure and attributes. The Oblique Strategy games demonstrated that the observer does not have direct access to an artist's concept. But because this game space is so sparse, because the constraints are spelled out, we approach observing concepts with far greater objectivity than is generally afforded in any form of artistic analysis.

4.4.1 Representing a Generative Decision across Similarity Space:

Below is the MDS plot of subject 1's responses to the original similarity test. Earlier in the chapter we grouped the subjects into three categories of perceivers. The MDS plot is an indicator of how structure is perceived by subject 1.

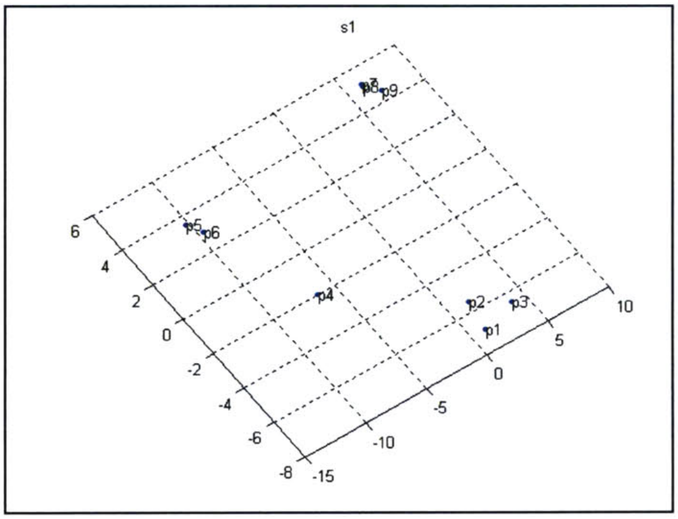


Figure 52: MDS plot of subject 1's similarity (original) test

Over this plot we can trace the patterns created across similarity space when a subject creates a chain. In this representation we see how the newly, generated chain relates to the perceived similarity of the elemental components. Figure 53 illustrates two different chains generated by subject 1.

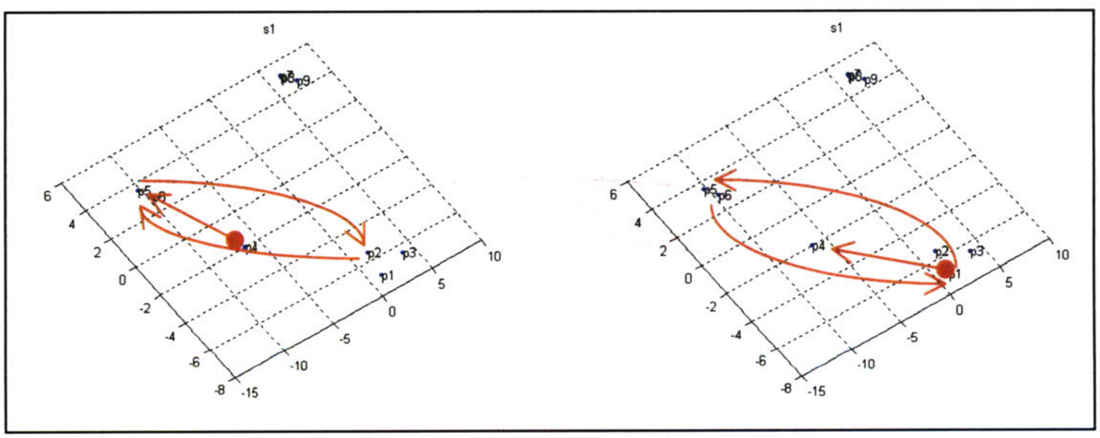


Figure 53: Decision plot. The dot indicates the position of the first pattern in the chain.

4.4.2 Categories of Chain Structures

Subjects' responses in the similarity test alone are not a good predictor of how they generate chains. However, by mapping each subject's responses to their individual perceptions of similarity, several interesting patterns emerge. Curiously, subjects with different perceptions about the structure of the Nine seemed to followed similar strategies for constructing patterns. In the proceeding discussion, the nature, distribution and perceived phrase structure of the chains will be discussed first. An analysis of how the chains relate to each subject's response to the similarity test follows afterwards.

The game requires that subjects create pairs of patterns with regular, irregular, dense and sparse characteristics. The grouping types illustrated in the following diagrams are found in all the pair categories. Ten subjects created four pairs of similar chains, two that sounded regular, two irregular, two dense and two sparse. This yielded eighty of the decision plots like the one shown in the figure above. This game produced a large variety of responses with varying criteria for similarity between chain pairs. Like any musical composition, the chains can be analyzed through varying contexts, and therefore yield different definitions of structure. As such, there are different ways to group these responses.

First, we can think of the chain as four concatenated "Nines." The subjects have all been acclimated to thinking about the Nine patterns in this way, and have been introduced to the game with the notion that they will be chaining together these Nine patterns to make new, longer chains. Three main categories of responses are result when we examine the chains in this way. These categories include (the numbers reference the Nine which make up the basic musical building blocks):

- *Circular chains* in which chains begin and end on the same pattern
  For example: xaax chained patterns 7474; xabx patterns 9179
- *Repetitive* chains in which a combination is repeated
  For example: abab patterns 9898; aaaa patterns 5555
- *Asymmetrical chains* in which there is the first and the last patterns are different such as xaab or xaxb, etc.
  For example: aaab patterns 7778; abxy patterns 5273

The following sections describe the categories and distribution of these chains. Within these each of these groups constituent patterns were selected either within the cluster groupings (in which the first two attacks are in the same position) or across cluster groupings. Circular and asymmetric groupings can potentially cross all three cluster groupings.

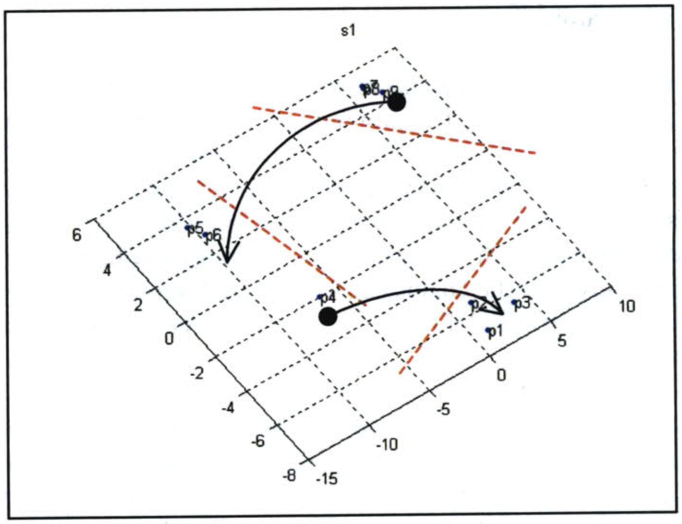


Figure 54: transitions across similarity space on an MDS plot

These categories have internal subdivisions distinguishing idiosyncratic types transitions across similarity space. At times, even where subjects' similarity plots differ, similar distances between chain components can be observed. For example, in the graph below, there are two examples of circular chains. Subject Nine falls into similarity category II and subject Five into category I. Subject Nine concatenated patterns with the first two attacks in the same position, but those patterns are perceived as being relatively dissimilar. Subject Five by contrast, grouped similar patterns in the middle of the chain.

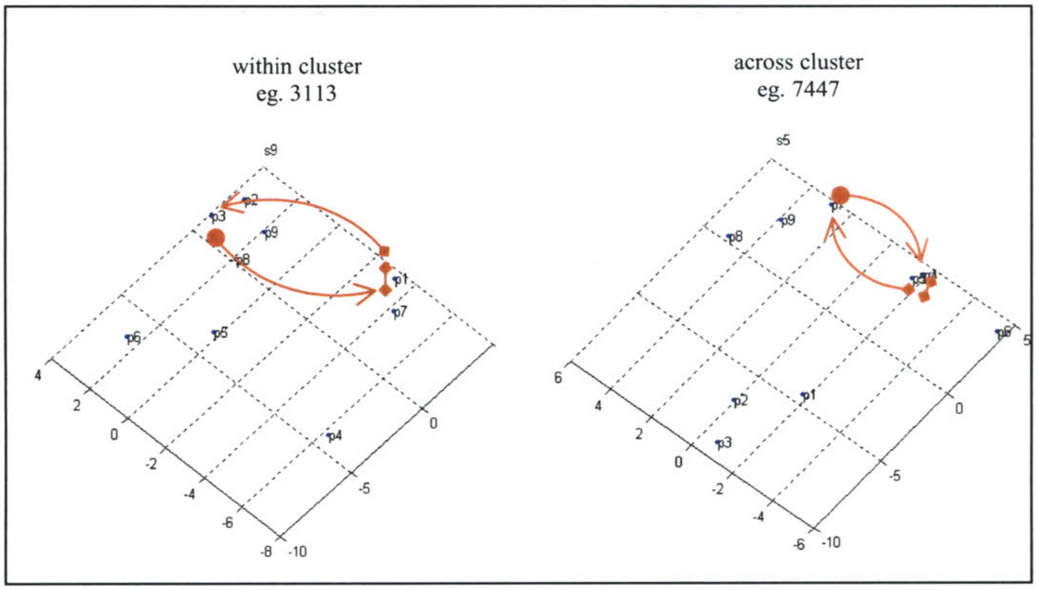


Figure 55: Circular chains xaax type. The squares indicate where the same patterns are concatenated

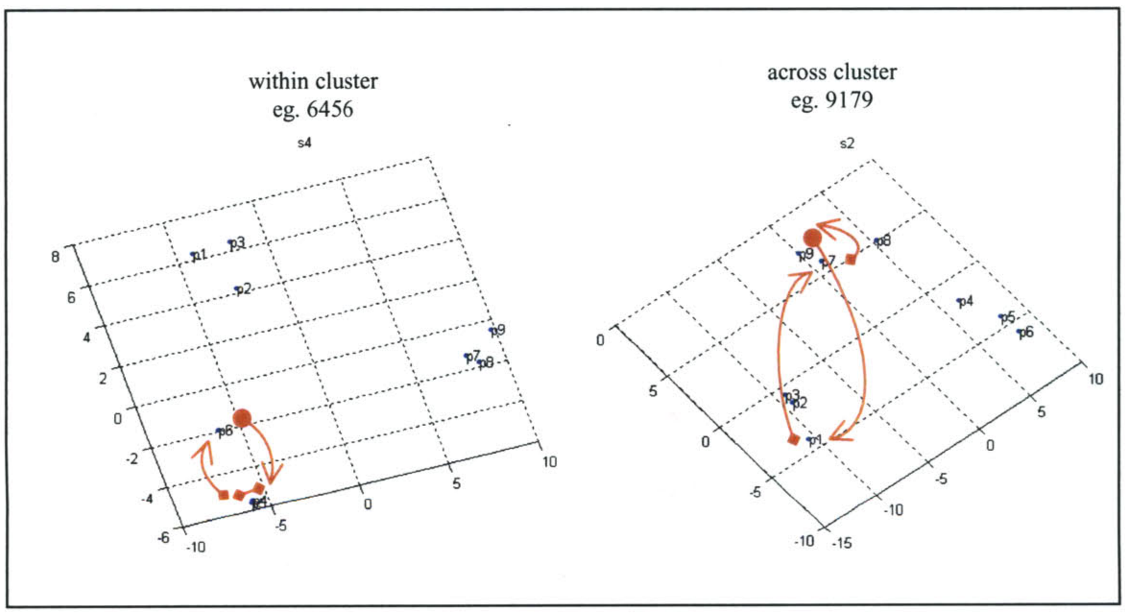


Figure 56: Circular chains xabx

Examples of each of the other types of chains are illustrated in the follow images.

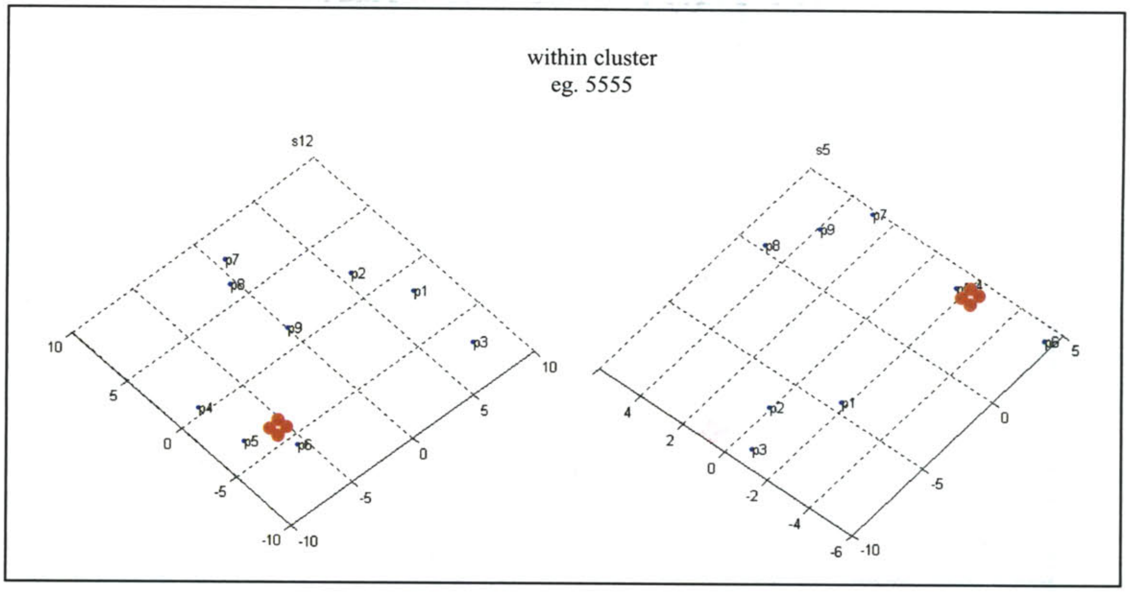


Figure 57: Repetitive chains aaaa type

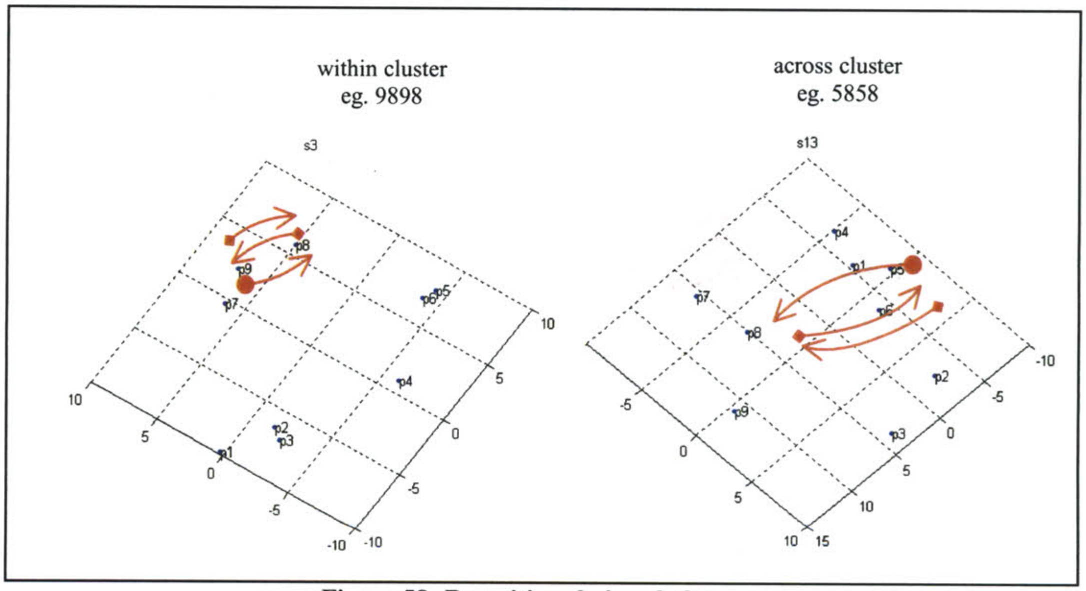


Figure 58: Repetitive chains abab type

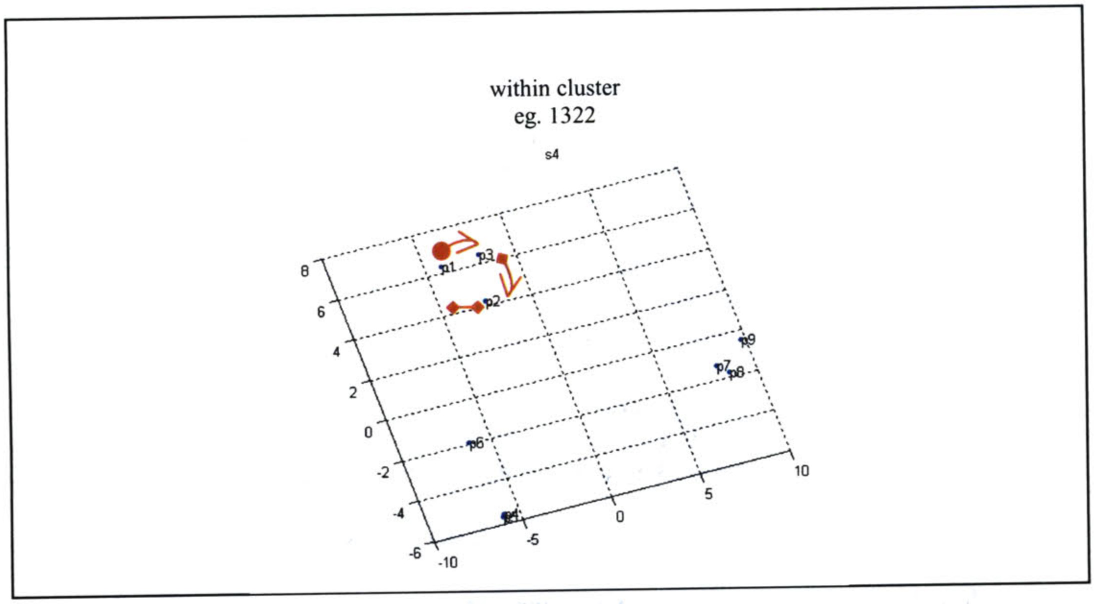


Figure 59: Asymmetrical chains

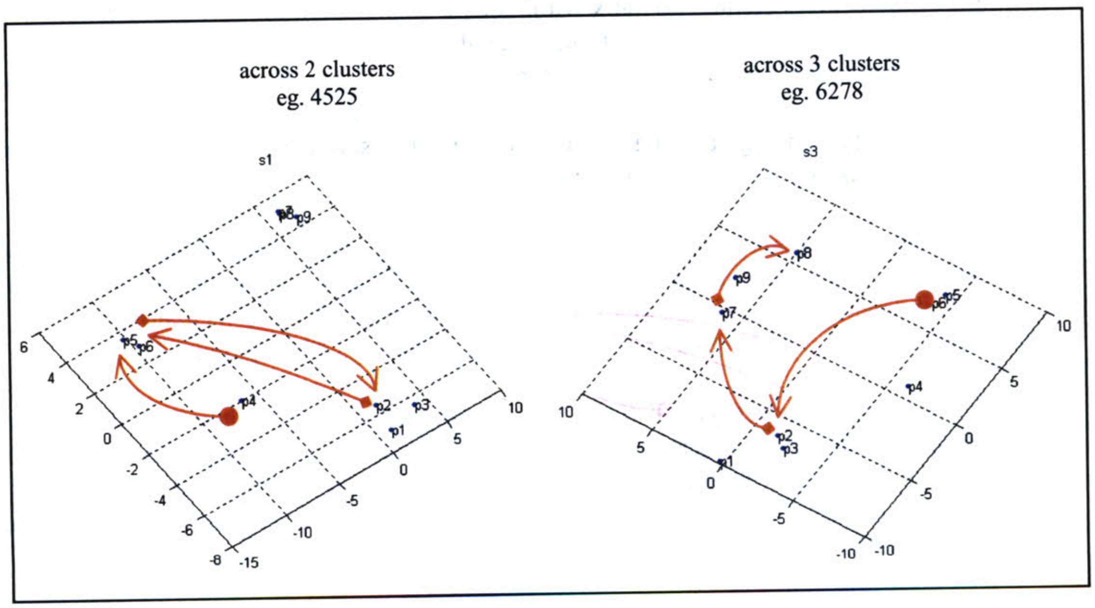


Figure 60: Asymmetrical chains

The first observation about the results is that none of these chain groups correlates to regular, irregular, dense or sparse. Within pairs, subjects frequently apply two different chaining "techniques" to two similar chains. Additionally, the similar chains are not necessarily confined to the same cluster or the same transitions between clusters. In other words, in the sparse category, subject 4 generated patterns 6456 and 4141 (i.e. chained together patterns 6,4,5, and 6). The breakdown of chain patterns is presented in figure 61. Some trends in the data set did emerge.

			Total	Regular	Irregular	Dense	Sparse
	xaax	Within cluster	**1**	1	-	-	-
	xaax	Across cluster	**1**	-	-	1	-
Circular	xabx	Within cluster	**2**	-	-	1	1
	xabx	Across-2 clusters	**5**	-	4	-	1
	xabx	Across-3 clusters	**3**	-	2	1	-
	xxxx	All same	**4**	2	-	-	2
Repetitive	abab	Within cluster	**11**	4	-	1	6
	abab	Across cluster	**12**	6	-	3	3
		Within cluster	**3**	1	-	2	-
Asymmetrical		Across-2 clusters	**19**	4	3	6	6
		Across-3 clusters	**19**	3	11	3	2

Figure 61: totals for pattern types

More than half of the total number of chains fall into an across cluster category. Subjects in the Type I perception group created no within cluster xaax chains. Type II and III perceivers created no xabx within chain clusters. All the across cluster xabx patterns created by Type I fall into the irregular pairs. For type II and III perceivers' xabx patterns are irregular, sparse or dense. Across cluster abab patterns do not include irregular patterns. Asymmetrical, across-2 clusters patterns are fairly distributed through regular, irregular, sparse and dense categories, but the majority of asymmetric, across-3 cluster patterns are irregular.

In the circular chains there are few examples of xaax, and all these chains sound dense to their creators. Ten out of eleven Repetitive patterns aaaa and abab within cluster all fall into sparse and regular categories for both type I and II pattern creators. Asymmetrical within cluster patterns are only regular or dense patterns.

Within each perceiver type, I, II and III, there are no strong correlations between the similarity test and an apparent preference or bias towards constructing chains. Even in such a small set of constructions, individual creators employ numerous strategies for chaining patterns. We see the impact of perceiving similarity and multiple levels even in such a simplistic construction.

This approach to categorizing techniques contextualizes structure only terms of concatenating of the raw musical building blocks (not unlike many techniques in formal musical analysis). In this analysis, patterns are treated in the extreme as abstractions. But in situ, the subjects listen to the chains as they create them. Patterns at the beginning impact latter groups. What the subjects hear as they concatenate these patterns may give rise to new groupings. The chains may cease to be four, concatenated rhythms, and become something altogether new. We asked subjects to review their chains and indicate how many phrases they heard in each.

4.4.3 Phrase Grouping:

When we listen to sequences of musical phrases we tend to parse them in two ways, by phrase groupings and by metric inference. As Bamberger's studies showed in chapter two, some listeners have a preference for gesturals or motivic grouping while others tend towards more formal groupings, subdividing to measures and beats.

The cross similarity space breakdown above can be refined further to indicate when particular types of circular, repetitive and asymmetrical patterns are heard in consistent phrasing groups. (Please note, subjects were asked to report how they heard the phrasing structures at the time the chains were composed. No subsequent analysis is imposed on to their interpretation.)

Again, the game constraints are set out such that the subjects are oriented towards thinking of the primary components in equal metric groupings (identical in length all with attacks in the first and fifth slot. New metric groupings arise when the patterns are concatenated into chains. Phrase divisions are not limited to two and four phrase groups. In the eighty responses, subjects predominantly reported 1,2,3,and 4 phrases emerging from each four-pattern chain. In more isolates incidents subject reported hearing 5,8,and 9 phrases.

			1	**2**	**3**	**4**	**5**	**8**	**9**
	xaax	Within cluster		1					
	xaax	Across cluster					1		
Circular	xabx	Within cluster		1	1				
	xabx	Across-2 clusters		3	1				1
	xabx	Across-3 clusters		1		3			
	xxxx	All same	1			1		2	
Repetitive	abab	Within cluster	1	8		2			
	abab	Across cluster		8	1	2			
		Within cluster	1	1	1				
Asymmetrical		Across-2 clusters	1	7	4	4	1		
		Across-3 clusters	3	9	2	4	1	1	
		totals	**7**	**39**	**10**	**15**	**3**	**3**	**1**

*s13 reported hearing 3283 with either 2 or 5 phrases
s2 could not break 7121 into phrase groupings

Figure 62: phrasing pattern types

The appendices include a complete chart of each chain categorized by phrase group. Some responses are intuitive. For example, there are no regular chains that sound like one long phrase. Less predictable is that two phrase patterns rarely begin with patterns 1, 4 or 7, or that there are no sparse patterns with three phrases. The vast majority of chains are perceived as having two phrases. It is obvious why the abab chains are perceived this way, but more interesting are the asymmetrical, across cluster categories.

The rhythms in these games are comprised of unaccented attacks equal in duration. We can only track the factors influencing phrase groupings and rhythmic inference determined by attack proximity.[4] As in all the concept design games presented, these variants exemplify techniques for creating types of patterns. In this case, these techniques produce rhythms that sound regular, irregular, dense and sparse. Figure 63 shows a pair of spares chains.

Phrase structure and similarity of primary components appear to be two criteria for similarity at play in these games. This can be seen in Subject 10's irregular pair (figure 64) in which both patterns are comprised of the same primary patterns and both have circular chains. Subject 12's similar sparse pair (figure 65) is comprised of repetitive chains, although the patterns of each chain are from different cluster groups. Subject 6's (figure 66) similarly irregular patterns are asymmetric chains, one across-2 clusters and one across-3 clusters. Both have three phrases relating perhaps to the density chunking criteria.

[4] In such a sparse domain it is difficult to "mean" anything musically. Nonetheless, we are able to distill attributes of musical structure generally obscured by the complexity of natural settings.

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0	5.25	5.5	5.75	6.0	6.25	6.5	6.75	7.0	7.25	7.5	7.75
8791 Sparse, 2 phrases Subject 1	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
1218 Sparse, 2 phrases Subject 1	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Figure 63: phrasing pattern types

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0	5.25	5.5	5.75	6.0	6.25	6.5	6.75	7.0	7.25	7.5	7.75
2482 Irregular, Phrases 4	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
4284 Irregular, Phrases 4	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-

Figure 64: Subject 10's (type III) irregular pair

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0	5.25	5.5	5.75	6.0	6.25	6.5	6.75	7.0	7.25	7.5	7.75
5555 Sparse, Phrases 1	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
9898 Sparse, Phrases 1	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-

Figure 65: Subject 12's (type I) sparse pair

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0	5.25	5.5	5.75	6.0	6.25	6.5	6.75	7.0	7.25	7.5	7.75
4996 Irregular, Phrases 3	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
8343 Irregular, Phrases 3	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•

Figure 66: Subject 6's (type III) irregular pair

The following examples show a several more interesting combinations. Both subjects 2 (figure 67) and 9 (figure 68) generated regular pairs consisting of one asymmetric chain that crosses two clusters and one asymmetric chain that crosses three clusters.

Yet, phrase grouping is not always a primary similarity criterion. Subject 4's dense pair contains an asymmetrical chain within one cluster and an asymmetrical cluster across two clusters. (figure 69) Subject 4's regular pair follows the same strategy (figure 70).

Although the constraints of the rhythms in the games prevents us from directly correlating these pattern generators to Lee's experiments on listeners' preferences in rhythmic inference (described in chapter two), Lee's studies are interesting to contrast to these results. Lee finds several points of convergence across theories. These include the importance of repetition in metric inference, and the listener's interpretive history of the sequence. [Lee 1991]. He also concludes that, in general, listeners avoid interpretations containing weak long notes or major syncopation. But again, since these games prescribed the construction of patterns of a particular character, it is difficult to compare a listener's natural perceptual tendencies with a technique intended to achieve a desired affect.

Another criterion for similarity might be quantity of coincident attacks. Since each of the Nine have attacks in the first and fifth beats, each chain will have a minimum of eight coincident attacks. Subject 2's regular chains have thirteen coincident attacks. Subject 9's regular chains have ten coincident attacks. Subject 4's dense and regular pairs have eleven and ten coincident attacks respectively. Even, if we compare these coincident patterns across one subject, no stronger trends emerge. Subject 4's 7778 dense chain and 1322 regular chain share ten attacks. The 7778 dense chain and 9472 regular chain share thirteen attacks. The 3897 dense chain and 1322 regular chain share nine attacks and the 3897 dense chain and 9472 regular chain share eight attacks.

In this section we looked at various similarity criteria including: phrasing, similarity of the component patterns based on the first two attacks, and the number of beats in the same position. Syncopation seems to be factor in some pairs, or some parts of pairs, but again, not as a consistent strategy. Varying, very localized, and often high-level strategies were used to generate each chain. Is there a correlation between the subjects' responses to the similarity test and the techniques used to generate the chains in the last game?

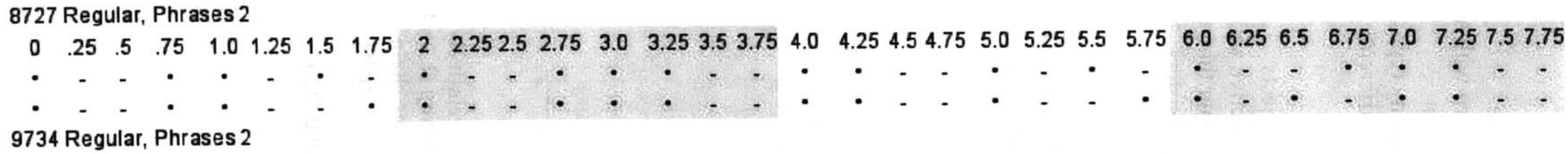


Figure 67: Subject 2's regular pair

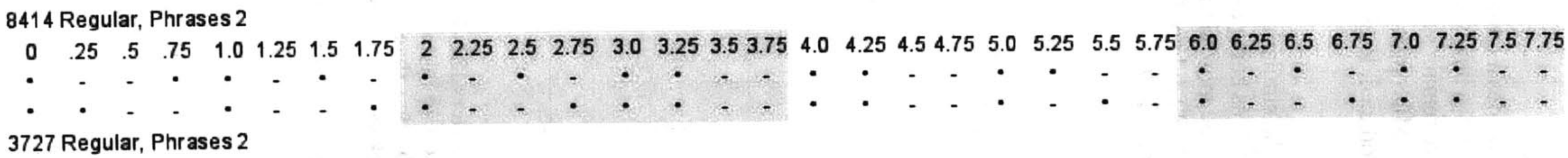


Figure 68: Subject 9's regular pair

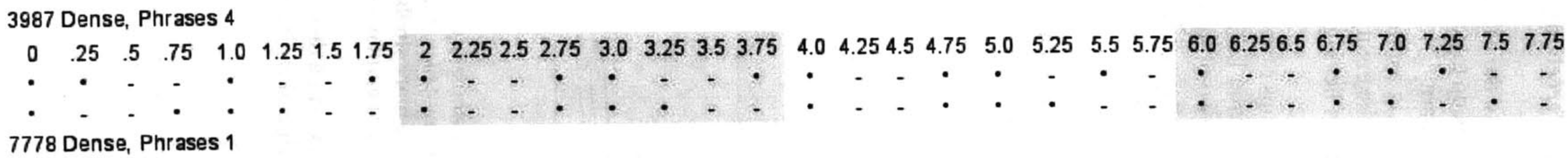


Figure 69: Subject 4's dense pair

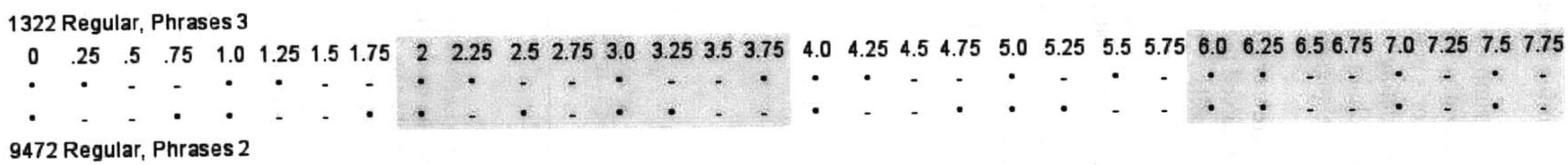


Figure 70: Subject 4's regular pair

4.4.4 Chaining Techniques and Perceiving Similarity

Superimposing the chains onto the MDS plots provides a unique look into the generative process. It enables up to compare directly a newly generated pattern with a creator's perceptions of similarity. However, there remain several problems in correlating the chain generating techniques to the MDS plots. There were many types of techniques represented in the eighty chains produced. Each subject used different techniques in producing his or her eight chains.

There were three distinct groups of responses in the similarity test. Some subjects perceived the clusters of patterns 123, 456, and 789 as being relatively distinctive and dissimilar. Others perceived two of the clusters to be more similar to each other than to the third. In the last group, patterns 123, 456, and 789 did not form distinct clusters. Without further testing we cannot with complete certainty equate transitions across similarity space.

In the chains produced we see comparable chaining techniques and ways for crossing similarity space used by different types of similarity perceivers such as in the following examples. In figure 71 both chains move between dissimilar patterns.

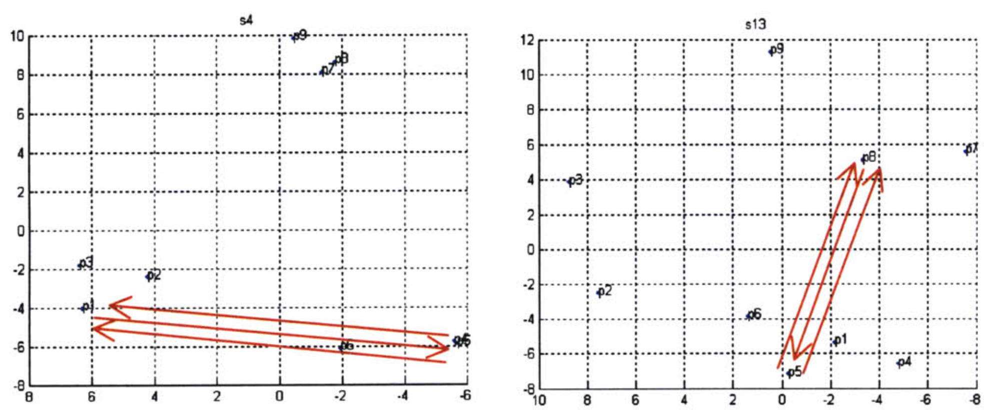


Figure 71: (Left) subject 4 falls into similarity group I. Clusters 123, 456 and 789 are relatively dissimilar. The chain combines patterns 4141. (Right) subject 13 falls into similarity group II, and perceives clusters 123 and 456 to be more similar to each other than to cluster 789. The chain combines patterns 5858. Both seem to employ similar techniques for crossing similarity space.

In figure 72, both chains move to a dissimilar pattern, that pattern repeats and then moves to a pattern in the original region of similarity space.

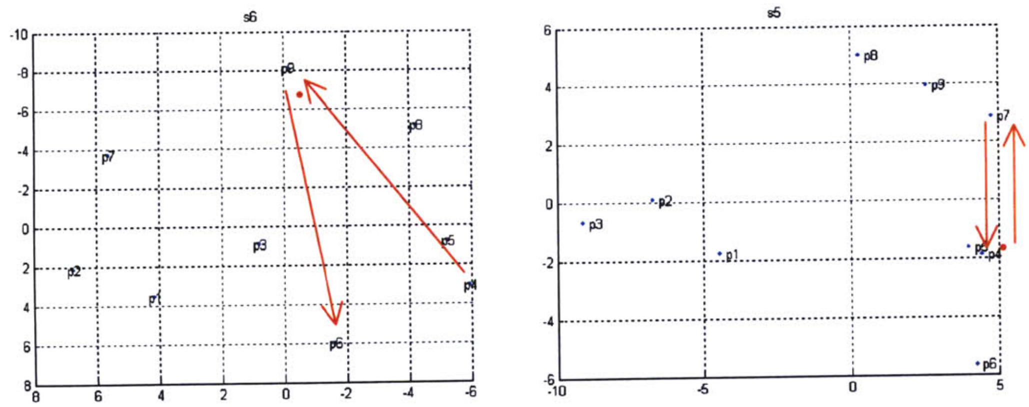


Figure 72: (Left) Subject 6 falls into group III in the similarity test. The chain combines patterns 4996. (Right) Subject 5 falls into group I. The chain combines patterns 7447.

The chains produced represent great diversity in the selection of component patterns from the Nine. Subjects used at least seven out of the Nine possible patterns to construct the eight chains. There does not seem to be a preference for the beginning pattern in the chain at the beginning of chains, and therefore, no obvious tendency towards particular metric groupings. Nevertheless, although this data set does not reveal a correlation between the preference for chaining technique and the similarity baseline, it should be maintained that such a correlation might be found with further investigation. These games offered a very simple and sparse musical space and severely limiting how subjects produced chains. If more complex patterns had been generated or more than twenty of each type of chain (regular, irregular, dense and sparse) had been produced, there may have been more evidence for connecting the choice of technique to each subject's style of perceiving similarity. These findings suggest some ways that creators with different perceptions may employ similar techniques. However, further investigation is needed to determine under what condition and at what level of musical complexity the perception of similarity plays a role in the generative process.

4.5 Similarity, Preference and Playing Games

Even in the very sparse setting of these games, there are numerous factors just in terms of inference, beat subdivision, and groupings of twos and threes impacting creators' preferences. Since the game procedures tie measurable perceptions directly to the in situ process of generating patterns, we have been able to identify styles of perceiving and plot and represent generative decisions in a novel way.

Subjects did not pay much attention to the organization of blocks on the screen in the games in chapter three. In chapter four's games, it is more apparent that a broader range of design criteria impacted the creator's generative processes. This expanded repertoire can be contrasted to Bregman's distinction between schema-driven and signal driven auditory stream segmentation. In the chaining game both signal driven and more abstract structural considerations impact the creators' decisions. The schema driven segmentation in the pattern generation games utilizes various templates such as symmetry, inversion, and so on which are all well understood musical structures. These games further develop our understanding of the relationship between context and preference. Through them we can track the iterative character of the decision making process such that it can be observed at intervals, and record under what circumstances preference changes or remain the same. We have a new kind of representation for a technique that better enables us to connect elemental structural perceptions with coherence in more complex patterns. With such findings in hand we are well equipped to both compare the strategies of individual strategists, and to compare strategies across subjects.

What does this analysis tell us about strategizing? It underscores the ways in which preference is context sensitive; moreover that with precision rather than intuition we are able to observe this relationship in situ. Yet preference alone is a poor indicator of generative strategy, for similar objects are not necessarily similarly preferred in different contexts. These findings shed new light on many aspects of generative theories we have used as a basis for this study.

We have shown throughout the game experiments that both high and low level processes shape the perception of structure for the artist. In these games we see that preference too is colored by both high and low level perceptions. Perception of structure, at least similarity, is also a choice, and a subject's biases are not completely unique. An individuals strategizing is based on how structure is perceived. Those possibilities stem from how context is constrained and what elements are selected.

Conclusions

5

5.0 Music Composition Games

The craft of art forgery illustrates one way to investigate an artist's perception of structure. Adept forgers ably intuit the perceptions of the artists they imitate. Through the game experiments, we were able to measure some of what forgers can only infer. Varied theoretical approaches from the fields of cognition, perception, aesthetics, and music theory and artistic practice provided a foundation on which to build an experimental methodology. Expanding on Habraken and Gross's work, we made the design games a tool for musical study. The game format and the sparse context proved to be powerful tools for studying the generative process, and provided a controlled, systematic way of collecting and drawing comparisons across rhythmic patterns. This approach makes both the artifact and observations of the rendering process objects for study, and thereby allows us to make closer correlations between the generative process and the features of artistic artifacts.

Comparing the generative process to a game helped us to distinguish between the various components of the generative process and enabled us to look more closely at the interrelation of these parts. Some of the processes directly engage the senses. Others operate at higher and more abstract levels. An artist imposes a deliberate strategy on constructing relationships between elements such that the emergent structure is more than the sum of its constituent elements. In the background sections, the Oblique Strategies stand out as an example of artistic practice leveraging strategy as a tool for creation.

5.1 Oblique Strategies

The Oblique Strategies were intended as a tool that fosters creative decision-making. Chapter two provides an analysis of how the Strategies work. This led to the assumption that creators define structure in terms of internal, external and frame relationships. The first game experiment tested that hypothesis. In these games, the Oblique Strategies were used as a constraint that shaped the generative task and provided consistency across creators.

The patterns produced through the games are examples of techniques. These techniques are linked to the particular constraints of the game. While the resulting patterns differed greatly, the subjects followed similar procedures. Subjects' definitions of structure related to internal, external, and frame strategies, and these finding reinforce the previous Oblique Strategies analysis. While generating patterns, subjects used as structural templates events, objects and linguistic structures. They also thought of structure in terms of spatial relationships and hierarchies.

Through these experiments, we were able to reassess the components of a generative decisions and their interrelation. Subjects' responses in this first experiment point towards a model of generative decision making in which constraints are very dynamic.[1] Figure 73 illustrates the various aspects of a generative decisions and their relationship to strategy. Strategizing is the process of balancing the requirements of the other processes. As we move from the top half to the bottom half of the illustration, we move towards processes that have greater and more direct impact over the structure of the resulting artifacts.

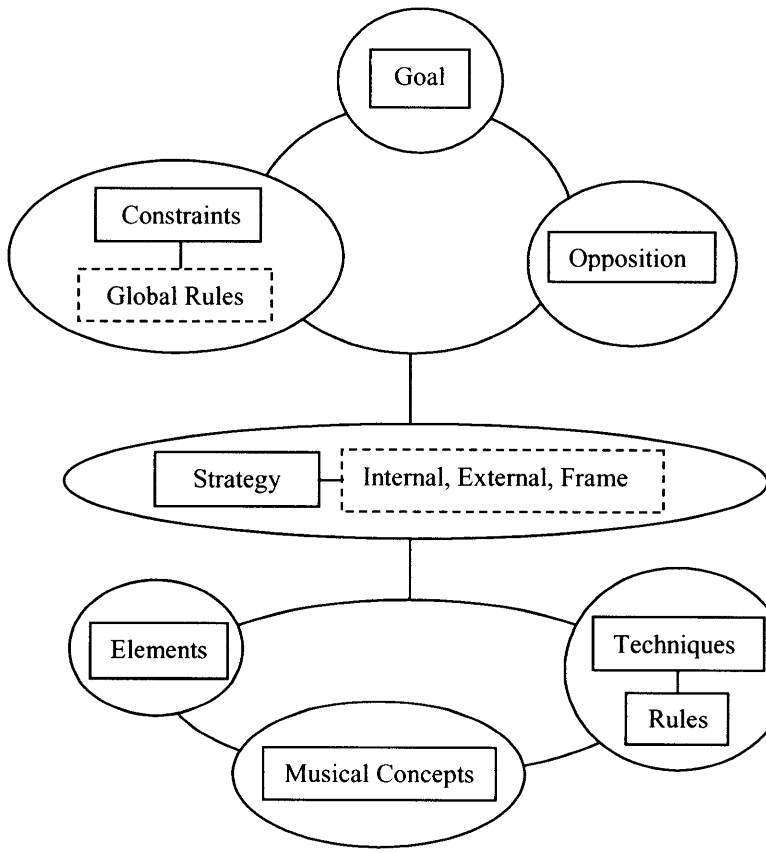


Figure 73: Generative Decision

The first experiment revealed how subjects employed techniques that utilize both top down and bottom up perceptions in structuring their patterns. Gaining better control over the isolation of these different kinds of perceptions was the motivation for the second and third experiments. The next experiments examine more closely the impact of context, preference and similarity on a generative decision. Preference is important in both setting the context and defining structure.

[1] This study focused on the production process. Processes that foster creativity or conceptualization can be thought of as removed from manipulating the musical medium are outside the scope of this study.

5.2 Preference and Similarity

Both experiments two and three use baseline similarity and preference tests. The results of these tests were contrasted against the patterns subjects generated. The antecedent-consequence configuration worked well as constraint on the context.

The results of the baseline tests were notable. The preference test indicated that subjects had highly personal and varied preferences for antecedent-consequence pairs. Nonetheless, some interesting trends appeared across the population including high preferences for particular pairings. Three examples of preferred pairings appear in figure 74. The percentages on the left indicate the number of subjects who reported these consequent patterns as most preferred against the given antecedents.

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
50%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
44%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
50%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-

Figure 74: Highly preferred antecedent consequence pairs

For some antecedents the entire population's preferences converged on just a few of the nine possible consequences. This was the case with pattern 4, for which only patterns 1,2,3 and 4 received top preference ranks. Similarly, antecedent pattern 8 prompted high preference ranks for consequence patterns 1,2,3,4,and 8 only. (figure 75)

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
19%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
31%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
6%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
44%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
25%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
25%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
12%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
25%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-

Figure 75: Antecedents with few highly preferred consequences. The percentages on the left indicate the portion of the population that found the combination most preferred.

Alternatively, for some antecedents there was little agreement about preferred consequences. Pattern 5 was an example of such an antecedent. (Figure 76).

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
19%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
<1%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
19%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
19%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
5%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Figure 76: Antecedents for which the population's preference for consequence varied significantly

High preferences for certain antecedent-consequence pairs accompanied by low preferences for others pairs marked another trend in the population's responses. Comparable responses likely indicate similarities in rhythmic inference across subjects. Some examples of this tendency are illustrated in figure 77.

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
High	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
Low	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
Low	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
High	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
Low	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
Low	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•
High	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
Low	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
Low	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Figure 77: trends across the population for most and least preferred consequences given a particular antecedent

Additionally, the similarity baseline tested the similarity between pairs of the Nine rhythms. The results characterized individual subjects' perceptions. We plotted subjects' similarity ratings for the pair-wise comparisons using multi-dimensional scaling. In these plots, we saw that the majority of subjects showed a tendency to group patterns according to the placement of the first two attacks. Most of the MDS plots showed clusters of the patterns 1, 2 and 3, the patterns 4, 5and 6, and the patterns 7, 8 and 9. However, for a few subjects the first two attacks were not a primary criterion in determining similarity. In these MDS plots, patterns 1, 2 and 3, patterns 4, 5 and 6, and patterns 7, 8 and 9 clusters overlapped. It is possible the subjects also responded to more vague characteristics such as regularity and density. The subjects' musical experience proved to be a poor indicator of grouping tendencies. The three types of similarity groups are illustrated in figure 78.

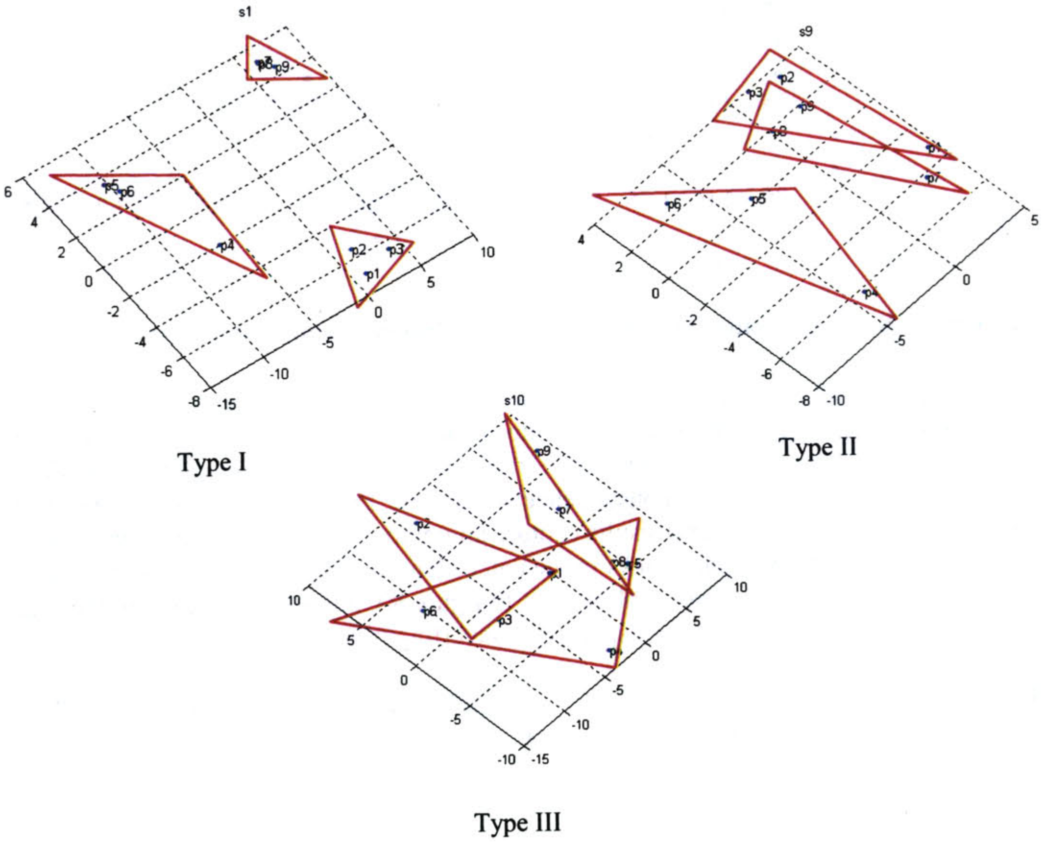


Figure 78: Similarity Grouping Categories

5.3 Make an Antecedent Games

In the "make an antecedent" game, subjects created an antecedent rhythm and ranked their preferences for the Nine as potential consequences. The results captured clearly each subject's preferences for antecedent-consequence pattern construction (given the constraints of the game). The findings also revealed what is preferred and not preferred in combination within the same context, and thereby shed some light on the connection between preference and context. Figure 79 shows three examples of newly constructed antecedents paired against most and least preferred consequences.

	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
Most	•	•	-	•	-	-	•	-	•	•	-	-	•	-	•	-
Least	•	•	-	•	-	-	•	-	•	-	•	-	•	-	•	-
	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
Most	•	-	•	-	-	-	•	•	•	•	-	-	•	-	-	•
Least	•	-	•	-	-	-	•	•	•	-	•	-	•	-	•	-
	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
Most	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
Least	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-

Figure 79: Newly generated antecedents paired against most and least preferred consequences

The make an antecedent game had a second part in which subjects constructed additional antecedents. These new antecedents were intended to make the formerly least preferred consequence the most preferable. Subject worked through three workspaces trying to make the worst consequence sound best. Each workspace utilized slightly different constraints. The results capture an iterative process in which changing the placement of particular attacks in the antecedent improves (or makes worse) the antecedent-consequence combination. In figure 80, this subject improved the original consequence in the last workspace by converting it into an antecedent.

Part	0	.25	.5	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
2	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
	•	-	-	•	•	-	•	-	•	•	•	•	-	-	-	-

Figure 80: Subject 7 Make the Worst the Best

5.4 Chain Games

In the last game, subjects chained together four of the Nine patterns to make a new, longer pattern. Although this game was the most highly constrained of the three, it led to the tightest correlations between the similarity test and the newly generated patterns. We developed an interesting representation of a generative decision by charting the transitions between each of the four provided patterns in the chain on each subject's MDS plot. In these representations, the newly generated pattern is tied directly to each creator's perception of structure. Figure 81 shows one of these plots.

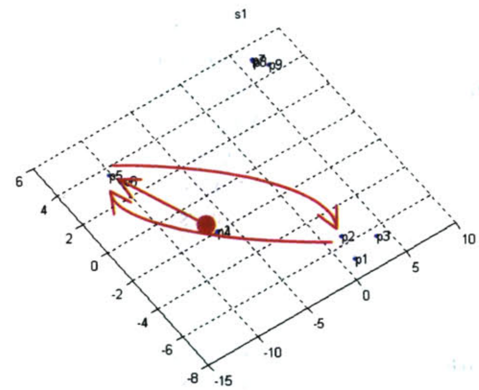


Figure 81: Representation of a four patterns chained to make a new pattern

The majority of chains produced were either repetitive or asymmetrical. In each case, about half used patterns within the same 1-2-3, 4-5-6 and 7-8-9 cluster as shown in figure 82.

Repetitive	abab	Within cluster	**11**
	abab	Across cluster	**12**
Asymmetrical		Across-2 clusters	**19**
		Across-3 clusters	**19**

Figure 82: Even distribution within and across clusters in the generated chains

Although the other two games used antecedent-consequent pairs and presented each of the Nine patterns as a phrase, after chaining these patterns together many subjects heard new phrase groupings. Most often subjects perceived two phrases in the four pattern chains, but three phrases were also common. In some instances subjects continued to hear each of the Nine rhythms as an individual phrase. The chart in figure 83 illustrates the distribution of the predominant phrase structures in the various types of chains.

		phrases	**2**	**3**	**4**
	xaax	Within cluster	1		
	xaax	Across cluster			
Circular	xabx	Within cluster	1	1	
	xabx	Across-2 clusters	3	1	
	xabx	Across-3 clusters	1		3
	xxxx	All same			1
Repetitive	abab	Within cluster	8		2
	abab	Across cluster	8	1	2
Asymmetrical		Across-2 clusters	7	4	4
		Across-3 clusters	9	2	4
		totals	**39**	**10**	**15**

Figure 83: The number of phrases heard in the various types of chains. Subjects occasionally reported hearing more than four phrases, but these responses are not represented in the chart. These unusual examples were discussed in chapter four.

Through the games, we have observed that in situ preference is a major factor but a highly context sensitive one. The ability to map generated patterns to baseline perceptions sets the groundwork for developing a new way to model individuals' generative processes. The games in chapters three and four demonstrate a method that minimizes the need to infer context and constraints from an artifact. This approach moves us towards associating particular preferences with particular contexts, degrees of freedom, and elements. It also places the artist's perceptions at the center of our generative models.

5.5 Future work

This dissertation lays out an approach for studying the generative process. The findings from these first three games show how further refinements can lead to more informative experiments on artistic strategizing. Not only are the patterns and responses themselves informative, but they also teach us a great deal about how to set constraints and control context in design games (auditory or otherwise). In particular, we can make more exacting observations of preference in context, and how preference changes with context. We can better control context in similarity tests, and probe under what contexts or changes in context an artist's perceptions alter. How localized are these perceptions? Additionally, games can be developed for other form-bearing dimensions, and we need to contrast generative strategies across these dimensions and in more complicated games. We can also do much more to capitalize on the representation of techniques developed in chapter four, by employing other ways of contrasting structure, not just similarity.

Two components of all games that were not investigated here are opposition and optimization. The generative process is quite unlike games in these two respects. For the artist, opposition can be merely the difference between the imagined and the realized, but it can also result from the specific nature of the constraints. Optimization is an extremely interesting component of the generative context. It is a driving force behind strategy, and therefore has both short and long term goals. Optimization might be rated against both self-imposed and external factors providing another possible link between the internal and external.

Applying these findings to computational models based on the sorts of similarity types, preference patterns and structures discovered in the game results can further inform. Following in the tradition of the Oblique Strategies, these findings can lend themselves to the design of new tools. With a better understanding of the generative process we can engineer more effective and more intuitive aides for creativity, but such synthetic enactments might also prove valuable as components of interactive and generative art works.

5.6 Artistic Impact

The work presented in this dissertation takes a very rigid approach towards looking at a very intuitive process, but enables us to make deeper comparisons across processes and media. Why look at the generative process in this way? Leonardo Da Vinci said, "The painter who draws merely by practice and by eye, without any reason, is like a mirror which copies every thing placed in front of it without being conscious of their existence."

Slanted towards scientific concerns though it may be, the form of analysis presented here is indicative of a change in art as much as a change in science. There is nothing unusual about a visual artist studying anatomy and biomechanics. If we are going to use machines in art making to imitate, represent, or interact with human creativity, then we must expect future generations of artists to have an understanding of human cognition and perception, as well as sufficient control over the digital media to structure representations of these things. The study of generative process is an important aspect of media arts research. It leads to new forms of media by expanding what we know about how humans communicate through artistic artifacts. It helps us maintain an increasingly sophisticated and ever-expanding tool set for established and emerging art forms.

Until relatively recently, art making dealt mostly with physical representations that the audience observed but did not alter. As the boundaries between media and performance continue to blur, the importance of machine models of human behavior permeates the artistic conscious. Our attentions turn more and more towards human-machine interactions during both artistic production and presentation. Improving the balance between artifact, artist, audience and machine challenges us to reconsider current models of human intelligence. In the short term, we move towards more compelling generative music systems and more informed approaches to automating musical activity. In the long run, however, we seek a deeper understanding of human cognition, and art is an integral and exceptional mental process.

The research presented here is thus a resource for the fields of aesthetics, computationally assisted design, composition and creativity and music cognition through which we build more musical/artistic machines, empower artists, and generate new art. At the crux of these varied endeavors - the artistic, the technical and the scientific - is a better understanding of the generative process. Dr. Francis Crick (co-discoverer of the structure of DNA) observed, "The mechanism is the important part; the rest is just playing with words." Comprehending the mechanism may spur creativity to new heights by facilitating the imaginations of artists.

Appendix 1: Chapter 3 Games, Samples and Strategies

The following charts provide detailed descriptions of the samples and oblique strategies used for the music composition games in chapter three.

Version 1

Sample ID	Length in seconds	Description
A	.5 sec	Low tom c3
B	.5 sec	Log c4
C	.5 sec	Log g3
E	.5 sec	Vibraphone c3
F	.5 sec	Vibraphone g4
H	1.5 sec	Pattern: low log – hi log – low log
J	8 sec	Digeridoo c3
K	8 sec	Rainvox c3
L	1 sec	Drmdecay c3
M	6 sec	Sweep gtr c3
Silence_500ms	.5	
Silence_1s	1	
Silence_3s	3	
Silence_4s	4	

In version 1, samples A, B, C, E, F, H, L and M can appear in a pattern six times. Samples J and K can appear three times.

Question	Oblique Strategy	Samples
Practice Screen	-	EFK
1	Cascades	BAM
2	Ghost Echos	BKC
3	Turn it Upside Down	HAB
4	Fill every beat with something	LCJ
5	Water	BAL
6	Water	FEK
7	Distorting time	CLJ
8	Distorting time	BAL

Version 2

Sample ID	Length in seconds	Description
A	.25 sec	Low tom c3
B	.25 sec	Log c4
C	.25 sec	Log g3
E	.25 sec	Vibraphone c3
F	.25 sec	Vibraphone g4
G	2 sec	Tambura
H	.75 sec	Pattern: low log – hi log – low log
J	4 sec	Digeridoo c3
K	4 sec	Rainvox c3
L	.5 sec	Drmdecay c3
M	3 sec	Sweep gtr c3
N	4 sec	Whack gtr c3
Silence_250ms	.25	
Silence_500ms	.5	
Silence_1.5s	1.5	
Silence_2s	2	

In version 2, samples A, B, C, E, F, H, L and M can appear in a pattern six times. Samples J and K can appear three times.

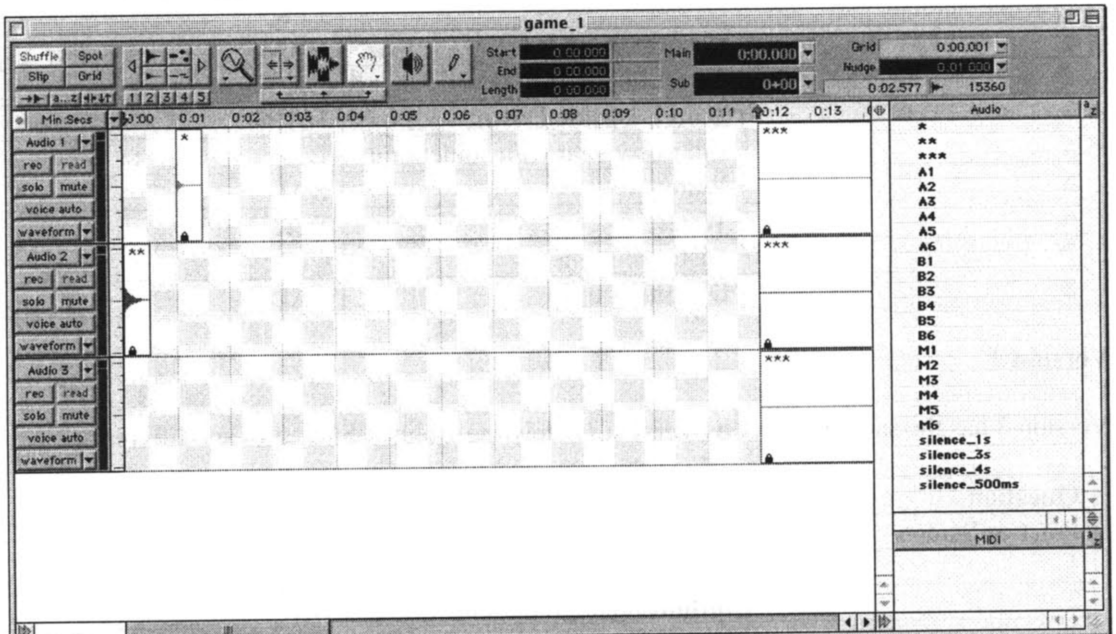
Question	Oblique Strategy	Samples
Practice Screen	-	EFK
1	Cascades	BAM
2	Ghost Echos	BKC
3	Turn it Upside Down	HAB
4	Fill every beat with something	LCJ
5	Water	BAL
6	Water	FEK
7	Distorting time	CLJ
8	Distorting time	BAL

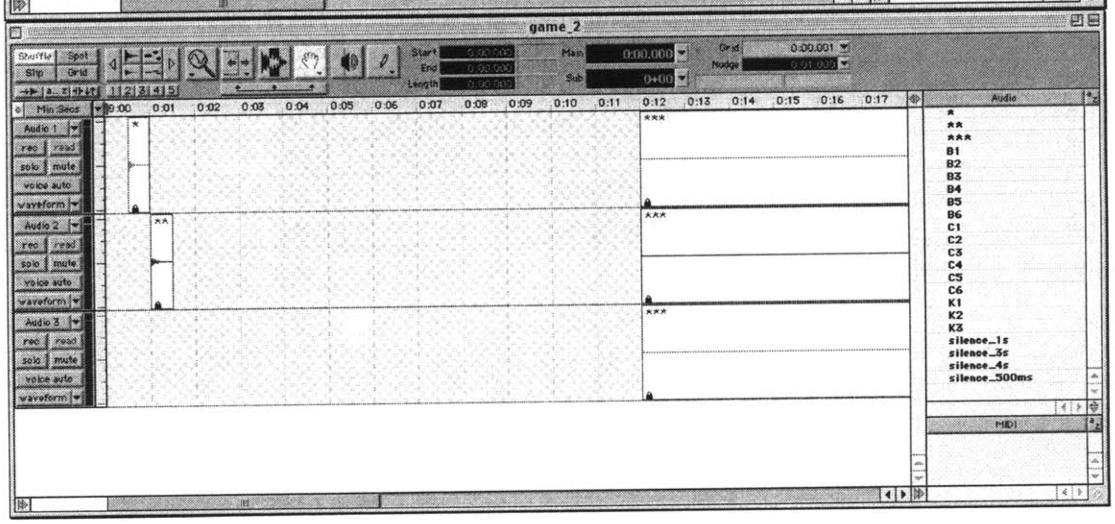
Version 3

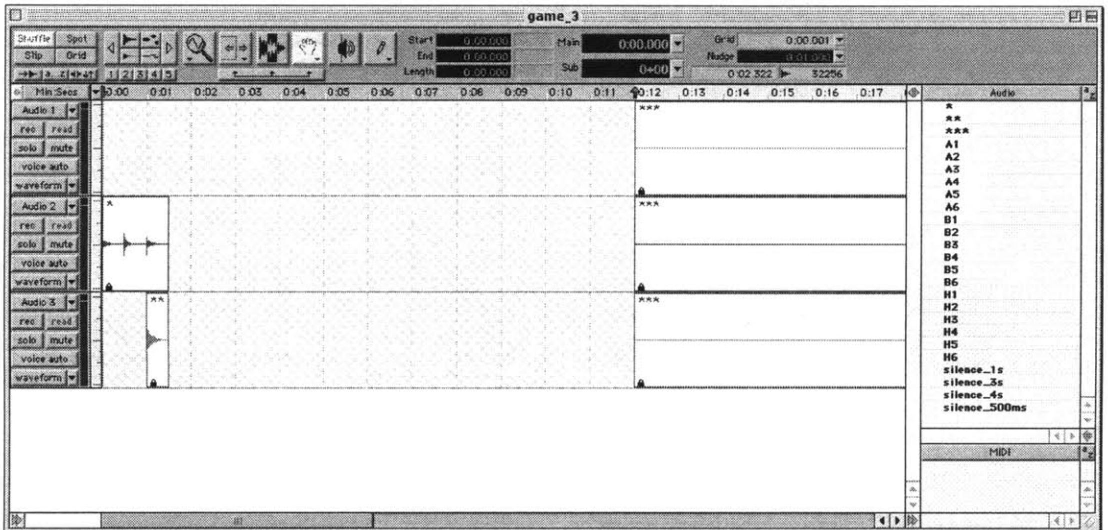
Version 3 has the same samples as Version 1. Only the Oblique Strategies are different.

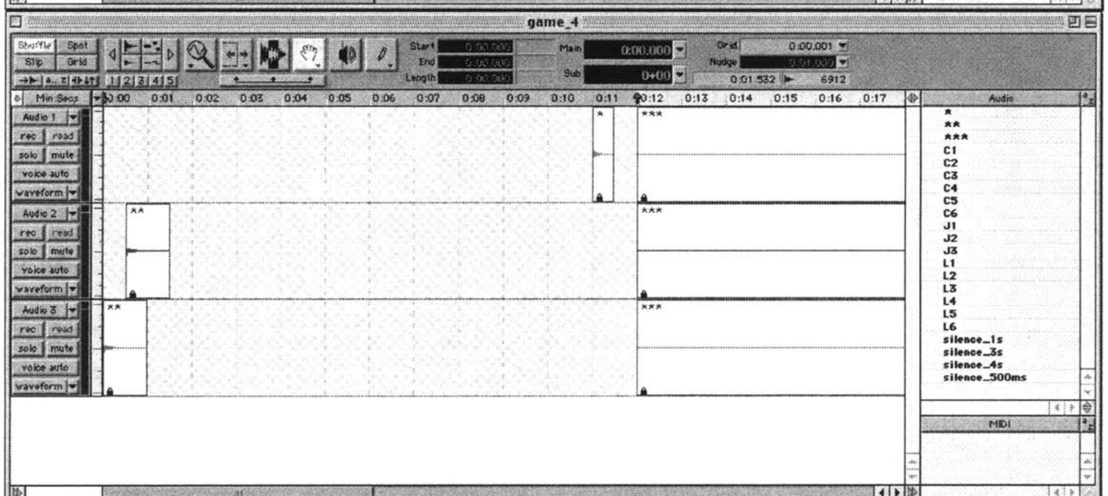
Question	Oblique Strategy	Samples
Practice Screen	-	EFK
1	(Organic) machinery	BAM
2	Infinitesimal gradations	BKC
3	Imagine the piece as a set of disconnected events	HAB
4	A line has two sides	LCJ
5	Children – Speaking - Singing	BAL
6	Children – Speaking - Singing	FEK
7	Twist the Spine	CLJ
8	Twist the Spine	BAL

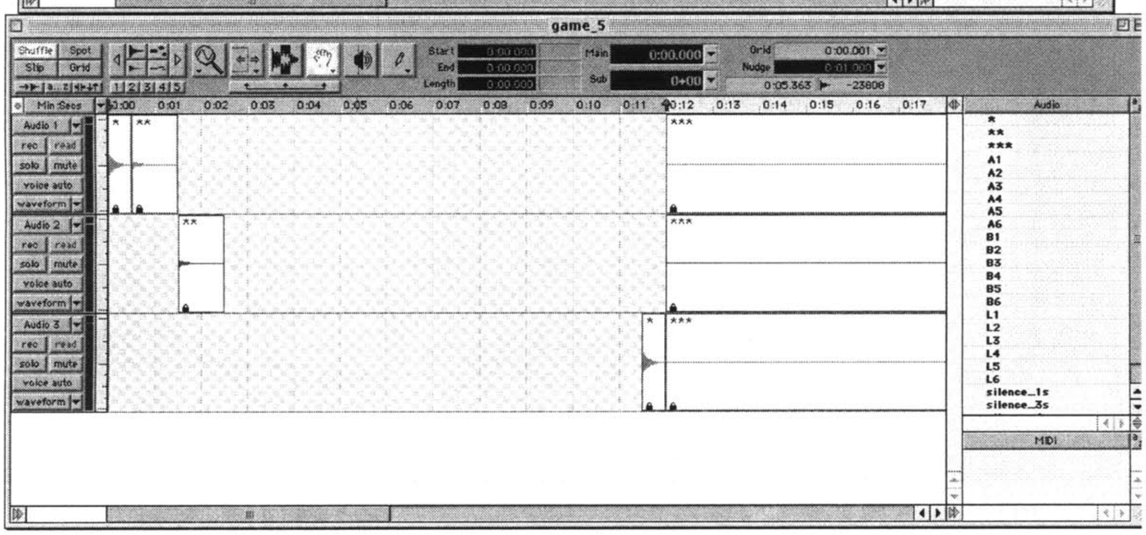
Following are screen shots of the various occlusions locked into position on each of the workspaces in version 3 of the game. Subjects had to build patterns around these fixed samples.

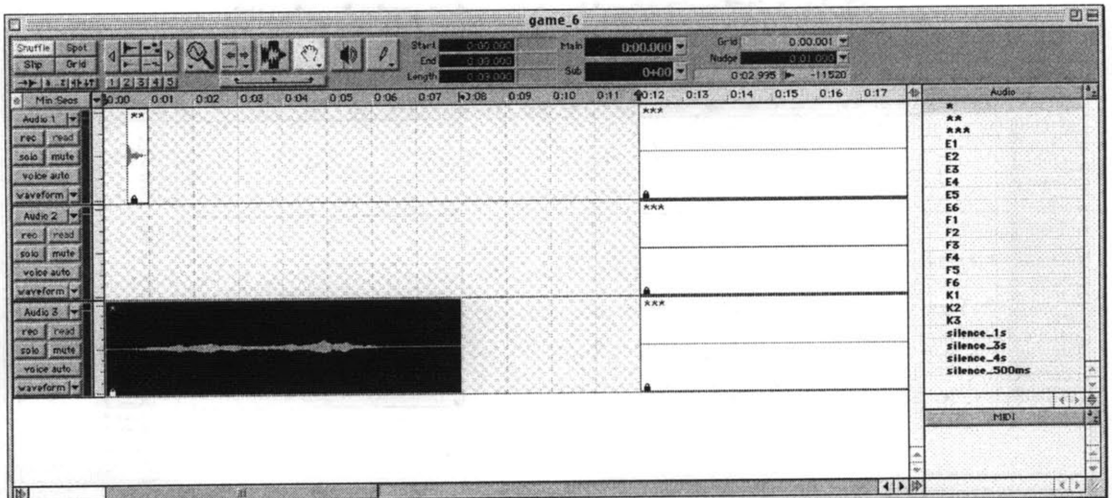


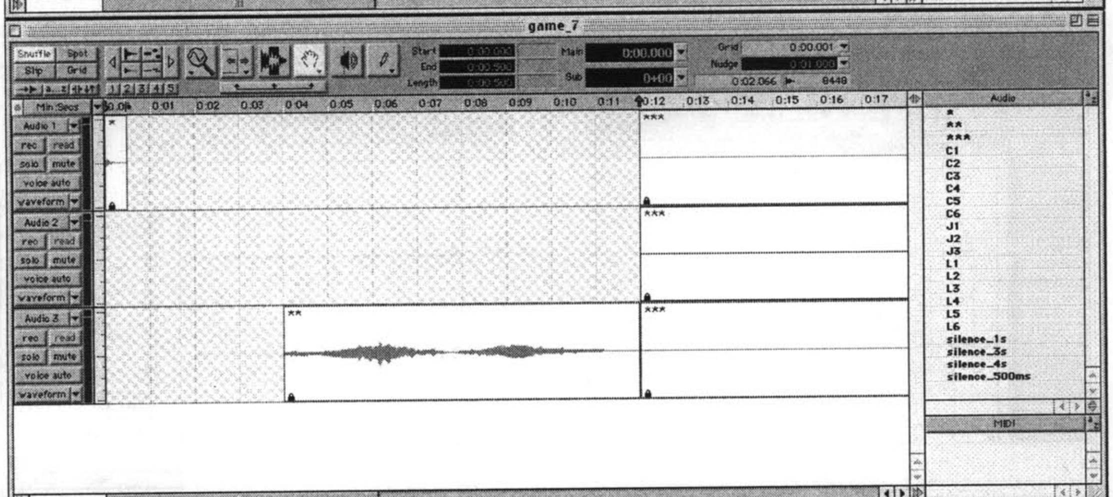


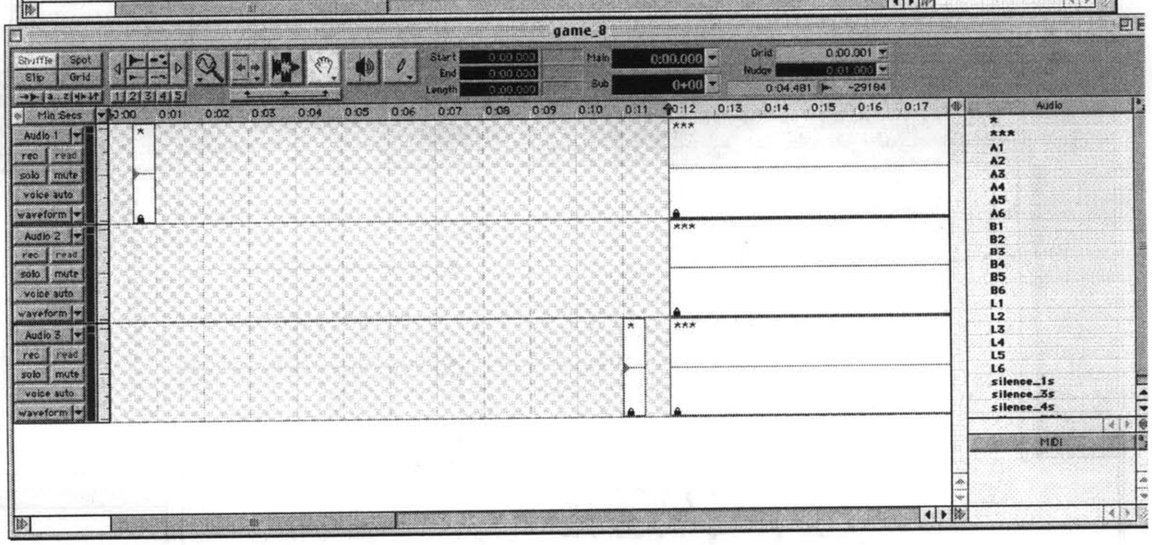

game_3
Audio 1
Audio 2
Audio 3
Audio
*
**
***
A1
A2
A3
A4
A5
A6
B1
B2
B3
B4
B5
B6
H1
H2
H3
H4
H5
H6
silence_1s
silence_3s
silence_4s
silence_500ms
MIDI


game_4
Audio 1
Audio 2
Audio 3
Audio
*
**
***
C1
C2
C3
C4
C5
C6
J1
J2
J3
L1
L2
L3
L4
L5
L6
silence_1s
silence_3s
silence_4s
silence_500ms
MIDI


game_5
Audio 1
Audio 2
Audio 3
Audio
*
**
***
A1
A2
A3
A4
A5
A6
B1
B2
B3
B4
B5
B6
L1
L2
L3
L4
L5
L6
silence_1s
silence_3s
MIDI


game_6
Audio
*
**
***
E1
E2
E3
E4
E5
E6
F1
F2
F3
F4
F5
F6
K1
K2
K3
silence_1s
silence_3s
silence_4s
silence_500ms
MIDI


game_7
Audio
*
**
***
C1
C2
C3
C4
C5
C6
J1
J2
J3
L1
L2
L3
L4
L5
L6
silence_1s
silence_3s
silence_4s
silence_500ms
MIDI


game_8
Audio
*
***
A1
A2
A3
A4
A5
A6
B1
B2
B3
B4
B5
B6
L1
L2
L3
L4
L5
L6
silence_1s
silence_3s
silence_4s
MIDI

Version 4

Sample ID	Length in seconds	Description
A	.5 sec	Low tom c3
B	.5 sec	Log c4
C	.5 sec	Log g3
E	.5 sec	Vibraphone c3
F	.5 sec	Vibraphone g4
H	1.5 sec	Pattern: low log – hi log – low log
J	8 sec	Digeridoo c3
K	8 sec	Rainvox c3
L	1 sec	Drmdecay c3
M	6 sec	Sweep gtr c3
Silence_125ms	.125	
Silence_250ms	.250	
Silence_383ms	.383	
Silence_434ms	.434	
Silence_500ms	.5	
Silence_686ms	.686	
Silence_818ms	.818	
Silence_1s	1	
Silence_1.333ms	1.333	
Silence_2.121ms	2.121	
Silence_3s	3	
Silence_4s	4	

In version 4, samples A, B, C, E, F, H, L and M can appear in a pattern six times. Samples J and K can appear three times.

Question	Oblique Strategy	Samples
Practice Screen	-	EFK
1	(Organic) machinery	BAM
2	Infinitesimal gradations	BKC
3	Imagine the piece as a set of disconnected events	HAB
4	A line has two sides	LCJ
5	Children – Speaking - Singing	BAL
6	Children – Speaking - Singing	FEK
7	Twist the Spine	CLJ
8	Twist the Spine	BAL

The occlusions locked into position on each of the workspaces in version 4 are the same as versions 3.

Version 5

Sample ID	Length in seconds	Description
A	.5 sec	Low tom c3
B	.5 sec	Log c4
C	.5 sec	Log g3
E	.5 sec	Vibraphone c3
F	.5 sec	Vibraphone g4
H	1.5 sec	Pattern: low log – hi log – low log
J	8 sec	Digeridoo c3
K	8 sec	Rainvox c3
L	1 sec	Drmdecay c3
M	6 sec	Sweep gtr c3
Silence_500ms	.5	
Silence_1s	1	
Silence_3s	3	
Silence_4s	4	

In version 5, samples A, B, C, E, F, H, L and M can appear in a pattern six times. Samples J and K can appear three times.

Question	Oblique Strategy	Samples
Practice Screen	-	EFK
1	(Organic) machinery	BAM
2	Infinitesimal gradations	BKC
3	Imagine the piece as a set of disconnected events	HAB
4	A line has two sides	LCJ
5	Children – Speaking - Singing	BAL
6	Children – Speaking - Singing	FEK
7	Twist the Spine	CLJ
8	Twist the Spine	BAL

The occlusions locked into position on each of the workspaces in version 5 are the same as versions 3 and 4.

Version 6

Sample ID	Length in seconds	Description
A	.5 sec	Low tom c3
B	.5 sec	Log c4
C	.5 sec	Log g3
D	.250 sec	Maraca c4
E	.5 sec	Vibraphone c3
F	.5 sec	Vibraphone g4
G	4 sec	Tambura
H	1.5 sec	Pattern: low log – hi log – low log
I	1 sec	Pattern: low vib – hi vib
J	8 sec	Digeridoo c3
K	8 sec	Rainvox c3
L	1 sec	Drmdecay c3
M	6 sec	Sweep gtr c3
N	8 sec	Whack gtr c3
Silence_125ms	.125	
Silence_250ms	.250	
Silence_383ms	.383	
Silence_434ms	.434	
Silence_500ms	.5	
Silence_686ms	.686	
Silence_818ms	.818	
Silence_1s	1	
Silence_1.333ms	1.333	
Silence_2.121ms	2.121	
Silence_3s	3	
Silence_4s	4	

In version 6, samples A, B, C, E, F, H, L and M can appear in a pattern six times. Samples J and K can appear three times.

Question	Oblique Strategy	Samples
Practice Screen	-	EFK
1	Cascades	BAM
2	Ghost Echos	BKC
3	Turn it Upside Down	HAB
4	Fill every beat with something	LCJ
5	Water	BAL
6	Water	FEK
7	Distorting time	CLJ
8	Distorting time	BAL

Appendix 2:
Preference Pairs

The following charts detail the results from the preference test described in chapter 4. All of the Nine, basic rhythmic patterns are shown as antecedents paired against each of the Nine as consequences. The column on the far left identifies the number of the consequence pattern. The second column shows the percentage of subjects who chose that consequence for the preference rank specified in the title of each chart.

Antecedent pattern 1

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	31%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	50%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	<1%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	<1%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	25%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 1

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	19%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	31%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	19%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	<1%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	<1%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	6%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	44%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	<1%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	25%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	25%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 1

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	19%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	19%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	25%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	13%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	<1%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	31%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	•	-
3	25%	•	•	-	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	•	-	-	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	•	-
9	19%	•	•	-	-	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 2

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	38%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	<1%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	25%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 2

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	19%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	6%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	38%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	13%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	19%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	25%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	25%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	19%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	19%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	19%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	<1%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	<1%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	13%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	19%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	19%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 2

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	<1%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	13%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	25%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	6%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	19%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	19%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	25%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	6%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	6%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	<1%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	31%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	25%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	25%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	44%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	<1%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	<1%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	<1%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	•	-	-	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	•	-
3	19%	•	•	-	-	•	-	•	-	•	•	-	-	•	-	-	•
4	<1%	•	•	-	-	•	-	•	-	•	-	•	-	•	•	-	-
5	31%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	-	•	-	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	•	-	-
8	6%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	•	-
9	19%	•	•	-	-	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 3

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	31%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	19%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	<1%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	19%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	<1%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	25%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	6%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	38%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	<1%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	6%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	6%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	31%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	13%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	<1%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	13%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	19%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	13%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	19%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 3

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	25%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	19%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	<1%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	13%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	25%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	<1%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	25%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	<1%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	38%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	25%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	<1%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	13%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	13%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	25%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	6%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	19%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	31%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 3

Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	•	-	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	•	-	-	•	-	-	•	•	-	•	-	•	•	-	-
5	19%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	•	-
6	19%	•	•	-	-	•	-	-	•	•	-	•	-	•	-	-	•
7	19%	•	•	-	-	•	-	-	•	•	-	-	•	•	•	-	-
8	<1%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	•	-
9	25%	•	•	-	-	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 4

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	31%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	44%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	<1%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	<1%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	31%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	<1%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	19%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	<1%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	<1%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	38%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	19%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	19%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	19%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	<1%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	19%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 4

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	25%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	25%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	13%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	<1%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	25%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	25%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	<1%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	25%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	25%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	19%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	19%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	31%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 4

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	19%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	25%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	25%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	•	-	•	•	-	-	•	•	-	-	•	•	-	-
2	<1%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	•	-
3	31%	•	-	•	-	•	•	-	-	•	•	-	-	•	-	-	•
4	<1%	•	-	•	-	•	•	-	-	•	-	•	-	•	•	-	-
5	31%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	-	•	-	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	•	-	-	•	-	-	•	•	•	-	-
8	13%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	•	-
9	19%	•	-	•	-	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 5

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	<1%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	19%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	19%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	25%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	19%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	<1%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	19%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 5

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	25%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	<1%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	13%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	19%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	19%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	13%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	<1%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	19%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	38%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	<1%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	<1%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	31%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	19%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	13%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	13%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 5

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	19%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	13%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	19%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	19%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	<1%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	19%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	19%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	13%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	6%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	13%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	•	-	•	-	•	-	•	•	-	-	•	•	-	-
2	<1%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	•	-	•	•	-	-	•	-	-	•
4	13%	•	-	•	-	•	-	•	-	•	-	•	-	•	•	-	-
5	19%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	•	-
6	31%	•	-	•	-	•	-	•	-	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	-	•	-	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	•	-
9	19%	•	-	•	-	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 6

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	31%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	19%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	19%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	<1%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	13%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 6

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	38%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	<1%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	<1%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	13%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	19%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	31%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	19%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	31%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	<1%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	19%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	<1%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	<1%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	25%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	13%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 6

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	19%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	25%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	<1%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	25%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	13%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	6%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	25%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	•	-	-
2	6%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	•	-	•	-	-	•	•	•	-	-	•	-	-	•
4	<1%	•	-	•	-	•	-	-	•	•	-	•	-	•	•	-	-
5	<1%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	•	-
6	31%	•	-	•	-	•	-	-	•	•	-	•	-	•	-	-	•
7	<1%	•	-	•	-	•	-	-	•	•	-	-	•	•	•	-	-
8	13%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	•	-
9	31%	•	-	•	-	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 7

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	<1%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	50%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	19%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	<1%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	25%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	13%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	31%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	6%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	6%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	25%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	<1%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	25%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	13%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 7

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	38%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	<1%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	6%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	13%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	19%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	13%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	25%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	<1%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	25%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	<1%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	25%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	25%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 7

Nine preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	-	•	•	•	-	-	•	•	-	-	•	•	-	-
2	6%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	•	-
3	38%	•	-	-	•	•	•	-	-	•	•	-	-	•	-	-	•
4	<1%	•	-	-	•	•	•	-	-	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	•	-	-	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	•	-	-	•	-	-	•	•	•	-	-
8	<1%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	•	-
9	25%	•	-	-	•	•	•	-	-	•	-	-	•	•	-	-	•

Antecedent pattern 8

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	25%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	25%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	<1%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	25%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	6%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	31%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	6%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	19%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	<1%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	19%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	19%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	<1%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	19%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 8

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	<1%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	6%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	19%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	19%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	25%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	19%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	<1%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	38%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	25%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	6%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	6%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	25%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	19%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	6%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	6%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	38%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	6%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	6%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	<1%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	19%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	13%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 8

Eighth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	<1%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	31%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	19%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	-	•	-	•	•	-	-	•	•	-	-
2	6%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	-	•	-	•	•	-	-	•	-	-	•
4	<1%	•	-	-	•	•	-	•	-	•	-	•	-	•	•	-	-
5	19%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	-	•	-	•	-	•	-	•	-	-	•
7	13%	•	-	-	•	•	-	•	-	•	-	-	•	•	•	-	-
8	13%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	•	-
9	19%	•	-	-	•	•	-	•	-	•	-	-	•	•	-	-	•

Antecedent pattern 9

First preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	19%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	25%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	<1%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	19%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	<1%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	13%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Second preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	25%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	<1%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	13%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	6%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 9

Third preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	19%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	25%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	6%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Fourth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	19%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	<1%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	13%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	19%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Fifth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	25%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	6%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	6%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	19%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	<1%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	19%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	13%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Sixth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	25%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	13%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	19%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	6%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Antecedent pattern 9

Seventh preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	19%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	19%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	13%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	<1%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	25%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	<1%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

Eighth preference

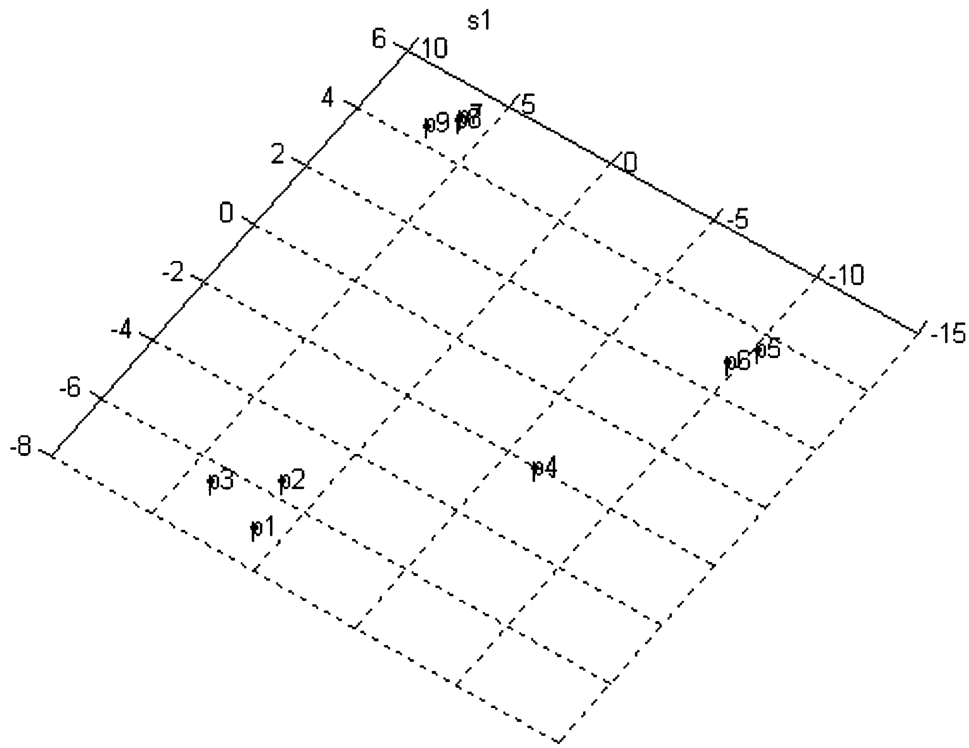
		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	<1%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	6%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	19%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	13%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	19%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	25%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

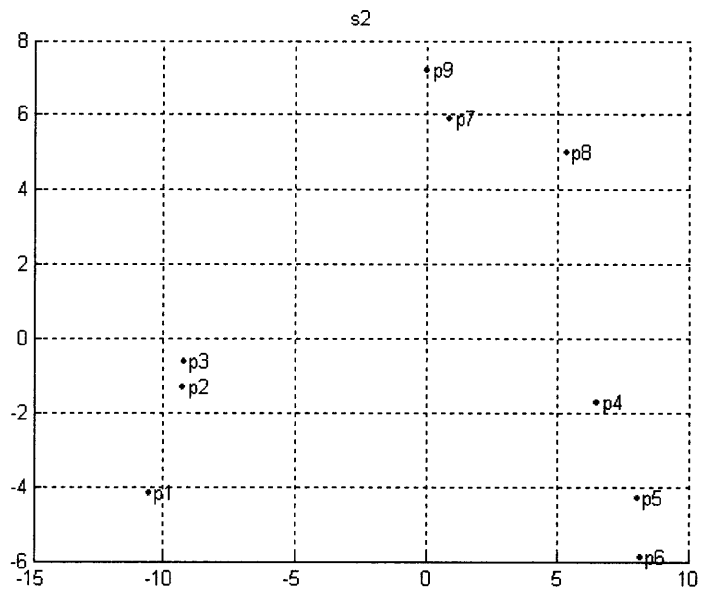
Ninth preference

		0	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
1	6%	•	-	-	•	•	-	-	•	•	•	-	-	•	•	-	-
2	<1%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	•	-
3	13%	•	-	-	•	•	-	-	•	•	•	-	-	•	-	-	•
4	<1%	•	-	-	•	•	-	-	•	•	-	•	-	•	•	-	-
5	31%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	•	-
6	13%	•	-	-	•	•	-	-	•	•	-	•	-	•	-	-	•
7	6%	•	-	-	•	•	-	-	•	•	-	-	•	•	•	-	-
8	<1%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	•	-
9	31%	•	-	-	•	•	-	-	•	•	-	-	•	•	-	-	•

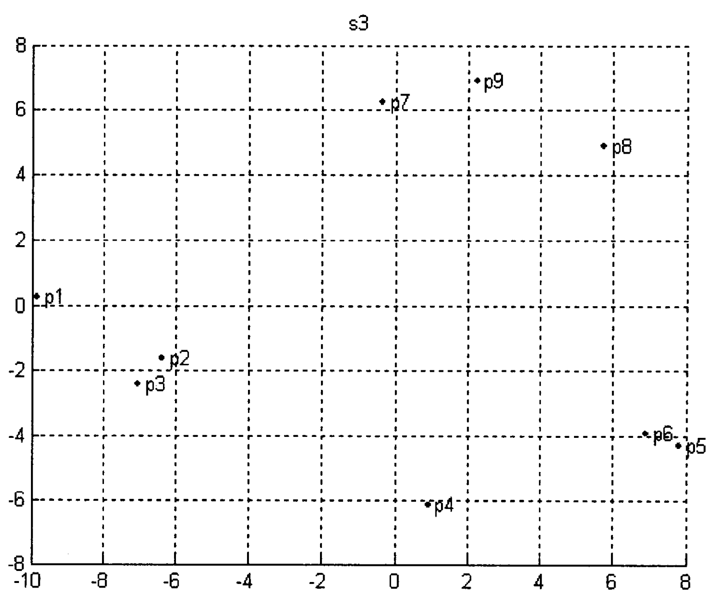
Appendix 3:
MDS Similarity Plots

Cluster Type I: Subjects 1, 2, 3, 4, 5, 7, 11 and 14





s2
8
6
4
2
0
-2
-4
-6
-15
-10
-5
0
5
10
p9
p7
p8
p3
p2
p4
p1
p5
p6



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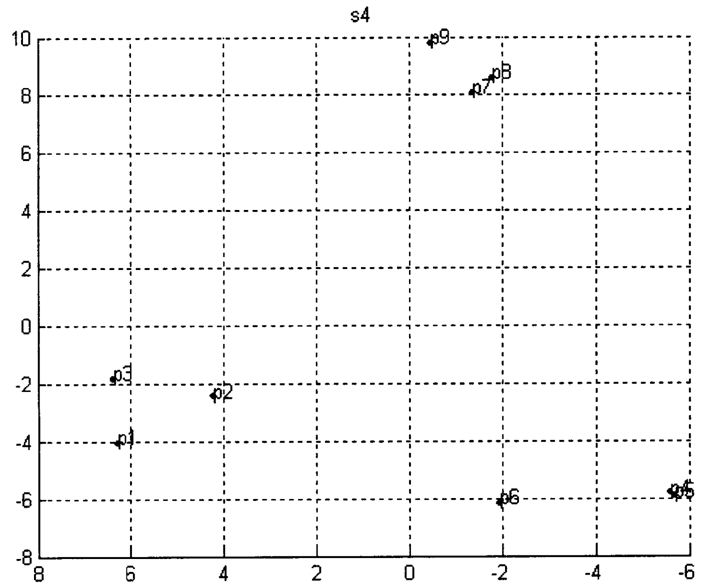
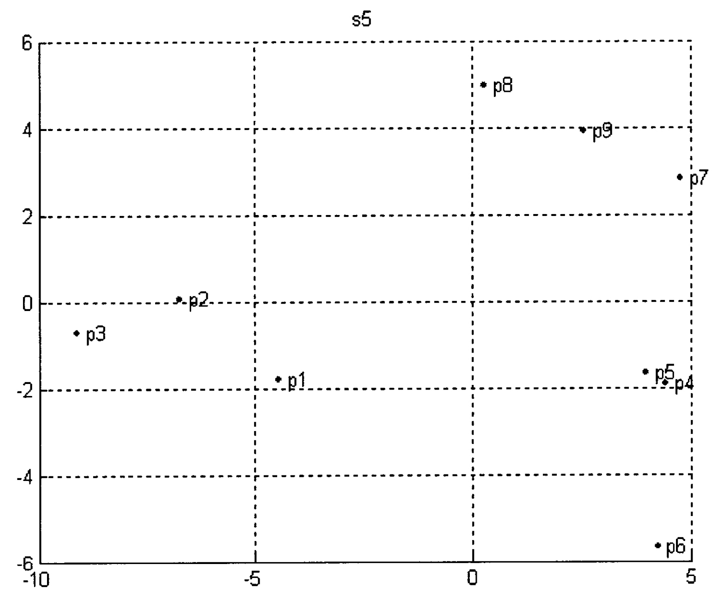
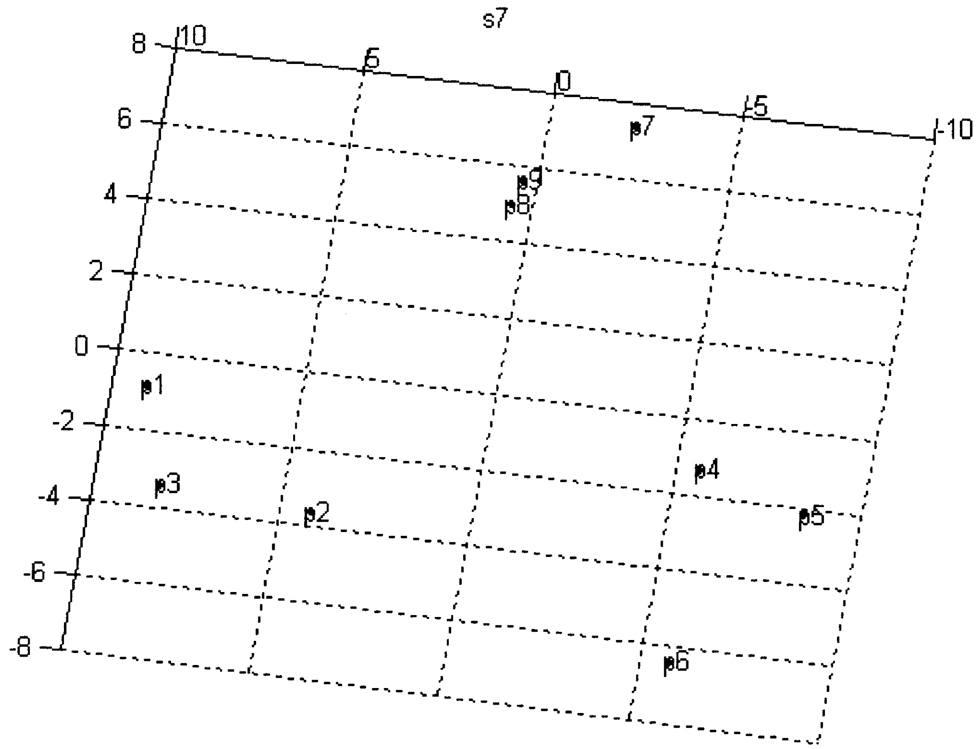
8
6
4
2
0
-2
-4
-6
-8
-10
-8
-6
-4
-2
0
2
4
6
8
p9
p7
p8
p1
p2
p3
p6
p5
p4


s4
p9
p8
p7
p3
p2
p1
p6
p4
p5


s5
p8
p9
p7
p2
p3
p1
p5
p4
p6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2
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-2
-4
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p1
p2
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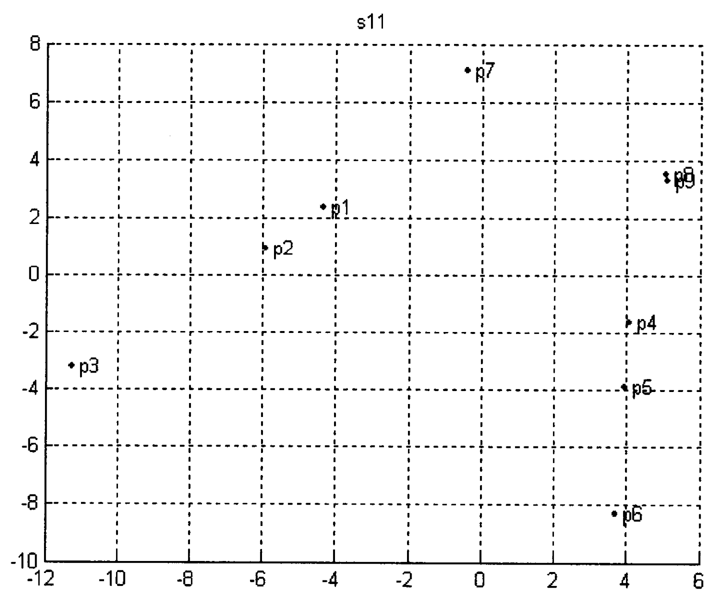
p4
p5
p6
p7
p8
p9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4
2
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-2
-4
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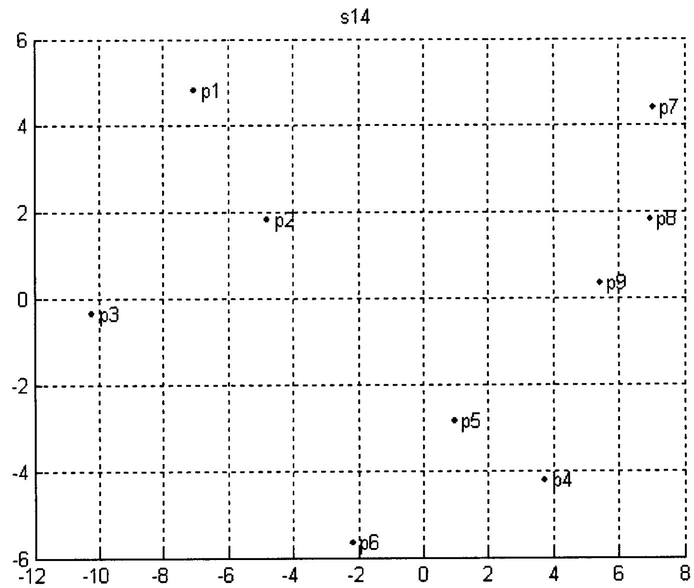
-8
-10
-12
-10
-8
-6
-4
-2
0
2
4
6
p1
p2
p3
p4
p5
p6
p7
p8
p9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p2
p3
p4
p5
p6
p7
p8
p9
6
4
2
0
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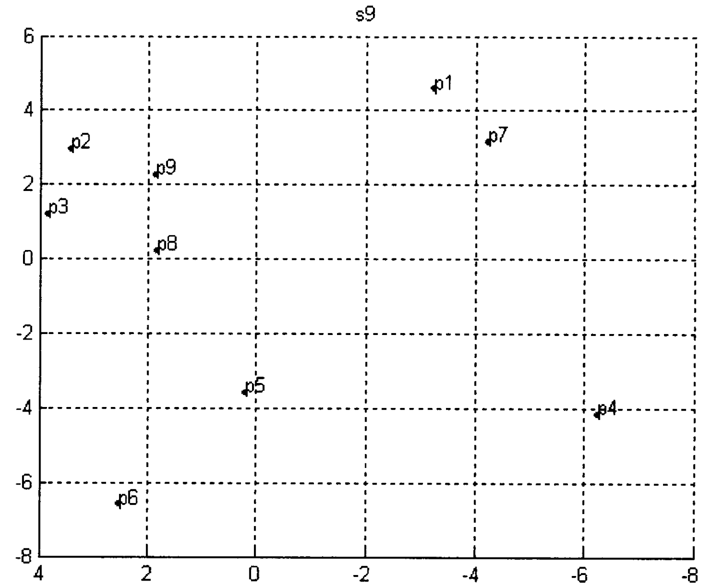
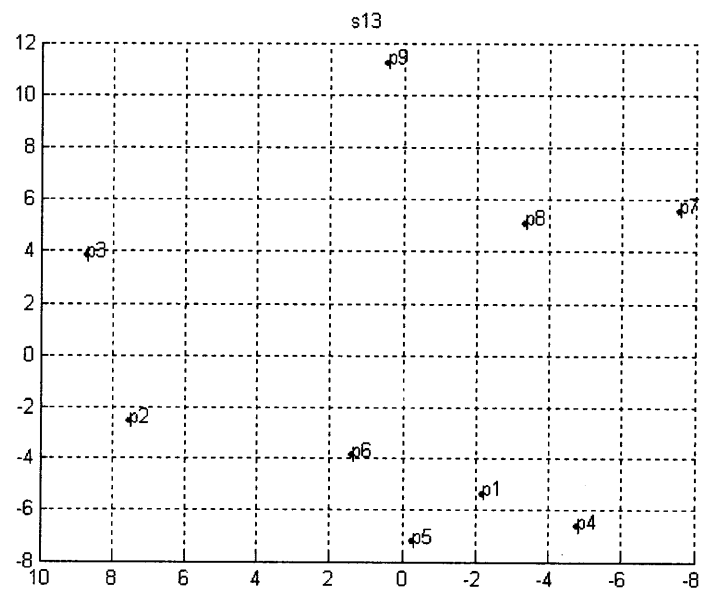
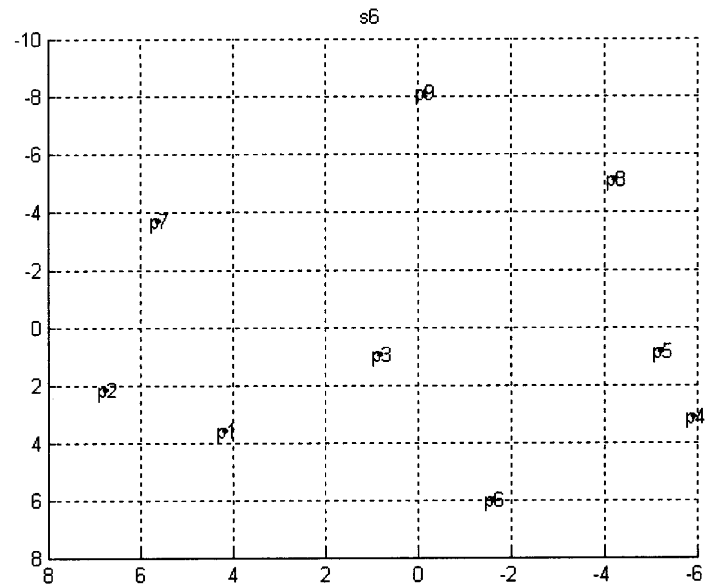
-4
-6
-12
-10
-8
-6
-4
-2
0
2
4
6
8

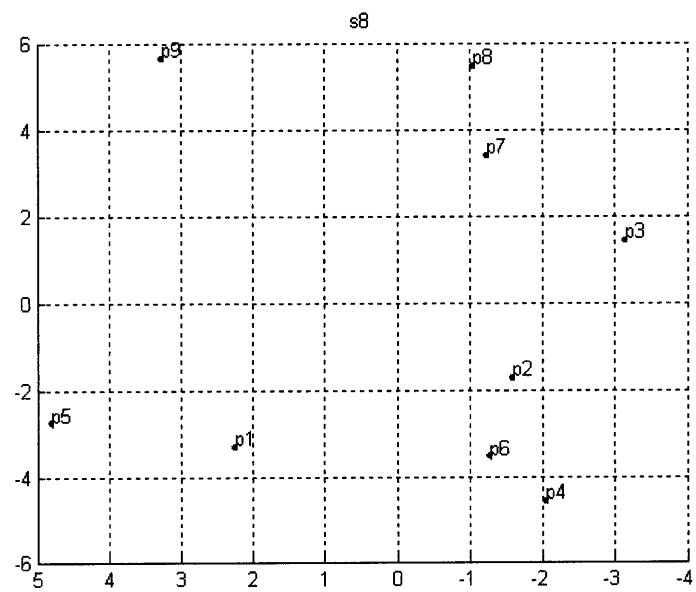
Custer Type II: Subjects 9 and 13

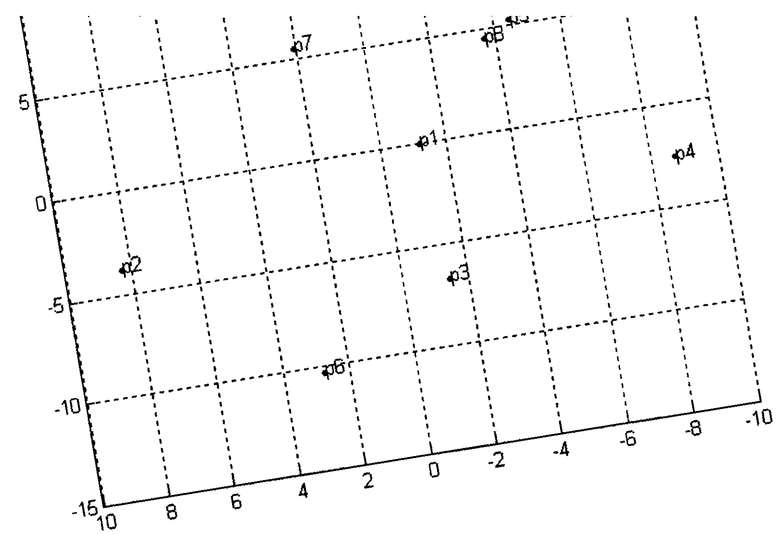




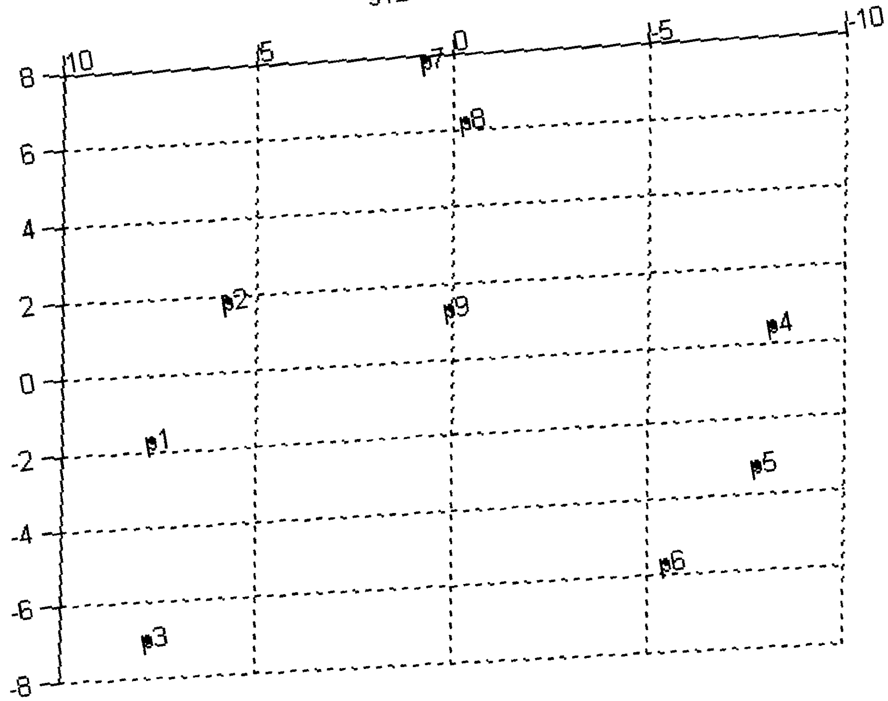
Cluster type III: Subjects 6, 8, 10 and 12






p7
p8
p1
p4
p2
p3
p6
5
0
-5
-10
-15
10
8
6
4
2
0
-2
-4
-6
-8
-10

s12


10
5
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-5
-10
8
6
4
2
0
-2
-4
-6
-8
p7
p8
p2
p9
p4
p1
p5
p6
p3

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