PERCEPTUAL AND SEMANTIC DIMENSIONS OF SOUND MASS

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In memory of Eleanor Stubley, Clifford Crawley, and James Bradley,
for whose guidance and inspiration I am eternally grateful

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Abstract

Sound mass, a musical aesthetic predicated on the grouping of many sound sources or events into a single auditory percept, has been an important feature of late-20th- and early-21st-century music. The compositional practices and (poietic) aims of composers associated with sound mass, especially Witold Lutosławski (1913-1994), Iannis Xenakis (1922-2001), György Ligeti (1923-2006), and Krzysztof Penderecki (b. 1933), have been well-documented, but sound mass has been relatively little studied from the listener's (esthesic) point of view.

There is almost no extant empirical literature on sound mass as a perceptual phenomenon: most of the published scholarship seems to rely on the intuitions of composers or theorists to determine what constitutes a mass, with little empirical examination of the sonic and musical parameters that lead to sound mass fusion. The term also lacks a broadly accepted definition: the many accounts in the literature all invoke perceptual fusion of some kind, but they differ considerably in their emphases.

Sound mass seems to invite a different kind of listening than music based on tonal or combinatorial properties, shifting the emphasis away from discrete structures of pitch and rhythm and onto massed totalities that may be perceptually simple in spite of great acoustical complexity. In this way, sound mass brings music closer to many familiar "natural" and quotidian auditory experiences. Perhaps because of this, sound mass composers and scholars describe this music in many evocative metaphorical terms, some of which may have a basis in acoustical similarity, such as '*water*' and '*crowds*,' others that seem to be based on cross-modal or conceptual homologies, such as '*atmospheres*' and '*kaleidoscopes*.' While such associations are often evocative and intuitive, the extent to which listeners experience such associations in response to this music remains unstudied and unclear.

This dissertation begins to address the many questions surrounding perceptual and semantic dimensions of sound mass through a combination of theoretical, empirical, and compositional approaches.

Chapter 1, "Perceptual Dimensions of Sound Mass," considers the problems of defining the term "sound mass," reviews extant definitions, and proposes a new one. It proceeds to review some common features of sound mass in light of perceptual principles by which they promote

integration or fusion, with reference to many examples from the sound mass repertoire. A summary list of attributes to be considered in sound mass analysis is provided.

Chapter 2, "Empirical Research on Sound Mass Perception," reports the findings of experiments conducted at the Music Perception and Cognition Lab at McGill university under the supervision of Dr. Stephen McAdams. The first experiment, conducted with Chelsea Douglas, evaluates listeners' dynamic perceptions of sound mass in Ligeti's *Continuum*, as measured with continuous response data. The second experiment isolates excerpts from *Continuum* and modifies selected parameters such as register, instrumental timbre, and attack rate (tempo), in order to evaluate the extent to which these parameters influence sound mass perception. The third experiment isolates harmonic structures from *Continuum* to evaluate the relation between pitch density and sound mass perception when the rhythmic context is neutralized. A supplementary pilot study, conducted with Eddy Kazazis, evaluates listeners' ratings of complex harmonies (including many of the same ones from *Continuum* used in experiment 3) along three categories: Bright-Dark, Pitched-Noisy, and Density.

Chapter 3, "Semantic Dimensions of Sound Mass," addresses some of the general problems of musical meaning, as well as cultural attitudes towards musical meaning that prevailed in the 1950s and 1960s, the period during which the canonical sound mass repertoire emerged. Drawing on multidisciplinary research in music perception and cognition, semiotics, cognitive semiotics, metaphor theory, and embodied cognition, this chapter offers a dynamical model of extramusical meaning based on homology between selected musical attributes and corresponding attributes of extramusical domains. It concludes with a compilation of many metaphorical associations of sound mass, drawn from the discourse of composers and theorists of this music.

Chapter 4, "Empirical Research on Sound Mass Semantics," reports on further experiments conducted at McGill's Music Perception and Cognition Lab under Dr. McAdams. In experiment 4, participants heard 40 musical excerpts featuring sound mass and related fusion-based aesthetics. They rated each excerpt on three batteries of semantic scales, drawn from the metaphorical associations of composers and theorists detailed in chapter 3. In experiment 5, participants performed the same task but with the grammatical forms of the ratings categories reversed: if a category appeared in nominal form (e.g. "a crystal") in experiment 4, it appeared in adjectival form (e.g. "crystalline") in experiment 5.

Chapter 5, “Compositional Application of Sound Mass: *biome* (2017),” describes my composition for solo trombone and wind orchestra, in which many aspects of sound mass perception and semantics discussed in chapters 1-4 are applied artistically. A recording is available at https://soundcloud.com/jasonnoble-1/biome.

Résumé

La masse sonore, esthétique musicale fondée sur le groupement de nombreuses sources sonores ou événements en un seul percept auditif, a été une caractéristique importante de la musique de la fin du XXème et du début du XXIème siècle. Les pratiques de composition et les objectifs (poïétiques) des compositeurs associés à la masse sonore, en particulier Witold Lutosławski (1913-1994), Iannis Xenakis (1922-2001), György Ligeti (1923-2006) et Krzysztof Penderecki (né en 1933), ont été bien documentés mais la masse sonore reste relativement peu étudiée du point de vue de l'auditeur (esthétique).

Il n'existe quasiment pas de littérature empirique sur la masse sonore en tant que phénomène perceptif : la plupart des études publiées semblent s'appuyer sur les intuitions des compositeurs ou des théoriciens afin de déterminer ce qui constitue une masse, avec peu d'examen empirique des paramètres sonores et musicaux qui fusionnent pour créer une masse sonore. La terminologie manque également d'une définition largement acceptée : les nombreux écrits de la littérature invoquent tous une fusion perceptive d'une certaine manière, mais diffèrent tous considérablement dans les aspects sur lesquels ils mettent l'accent.

La masse sonore amène à un type d'écoute différent de la musique basée sur des propriétés tonales ou combinatoires, déplaçant l'accentuation faites sur les structures discrètes de la hauteur et du rythme vers des totalités massives qui peuvent être perceptivement simples malgré une grande complexité acoustique. De cette manière, la masse sonore rapproche la musique de nombreuses expériences auditives « naturelles » et quotidiennes familières. Peut-être à cause de cela, les compositeurs s'appuyant sur la masse sonore et les érudits ont décrit cette musique avec de nombreux termes métaphoriques très évocateurs dont certains peuvent trouver leur fondement dans leur similitude acoustique, comme « eau » et « foules », d'autres qui semblent être basés sur ou des homologies conceptuelles, comme les « atmosphères » et les « kaléidoscopes ». Bien que de telles associations soient souvent évocatrices et intuitives, la possibilité dont les auditeurs font l'expérience de telles associations en réponse à cette musique reste encore inexpliquée et mal comprise.

Cette dissertation aborde ainsi les nombreuses questions entourant les dimensions perceptives et sémantiques de la masse sonore à travers une combinaison d'approches théoriques, empiriques et compositionnelles.

Le chapitre 1, intitulé « Dimensions perceptives de la masse sonore », examine les problèmes de définition du terme « masse sonore », passe en revue les définitions existantes et en propose une nouvelle. Il passe en revue certaines caractéristiques communes de la masse sonore à la lumière des principes perceptifs grâce auxquels ils favorisent l'intégration ou la fusion, en se référant à de nombreux exemples du répertoire musical sur la masse sonore. Une liste récapitulative des attributs à prendre en compte dans l'analyse de la masse sonore est proposée.

Le chapitre 2, intitulé « Recherche empirique sur la perception de la masse sonore », présente les résultats d'expériences menées au Laboratoire de Perception et Cognition de la Musique de l'Université McGill (Music Perception and Cognition Lab de l'Université McGill) sous la supervision du Dr Stephen McAdams. La première expérience, menée en collaboration avec Chelsea Douglas, évalue la perception dynamique de la masse sonore dans *Continuum* de Ligeti en utilisant un procédé de mesure de réponse continue chez des auditeurs. La deuxième expérience isole des extraits de *Continuum* et modifie des paramètres sélectionnés tels que le registre, le timbre instrumental et le taux d'attaque (tempo), afin d'évaluer dans quelle mesure ces paramètres influencent la perception de la masse sonore. La troisième expérience isole les structures harmoniques de *Continuum* pour évaluer la relation entre la densité de hauteur et la perception de la masse sonore lorsque le contexte rythmique est neutralisé. Une étude pilote supplémentaire, menée avec Eddy Kazazis, évalue les jugements d'auditeurs concernant la complexité des harmonies (incluant plusieurs de celles issues de *Continuum* utilisées dans l'expérience 3) selon trois categories : Brillant – Sombre (Bright-Dark), Tonal – Bruité (Pitched-Noisy) et Densité (Density).

Le chapitre 3, intitulé « Dimensions sémantiques de la masse sonore », aborde certains des problèmes généraux de la signification musicale ainsi que les attitudes culturelles concernant le sens musical qui prévalaient dans les années 1950 et 1960, période durant laquelle le répertoire canonique de la masse sonore a émergé. En s'inspirant de recherches pluridisciplinaires sur la perception et la cognition musicale, la sémiotique, la sémiotique cognitive, la théorie métaphorique et la cognition incarnée, ce chapitre propose un modèle dynamique du sens extramusical basé sur l'homologie entre attributs musicaux sélectionnés et les attributs correspondants à des domaines extramusicaux. Il se termine par une compilation de nombreuses associations métaphoriques de masse sonore issues du discours des compositeurs et des théoriciens de cette musique.

Le chapitre 4, intitulé « Recherche empirique sur la sémantique des masses sonores », fait état d'autres expériences menées au laboratoire de Perception et Cognition de la Musique de McGill (McGill Perception Music et Cognition Lab) sous la direction du Dr. McAdams. Dans l'expérience 4, les participants ont entendu 40 extraits musicaux mettant en évidence la masse sonore et l'esthétique liée à la fusion. Ils ont évalué chaque extrait sur trois types d'échelles sémantiques issues des associations métaphoriques de compositeurs et de théoriciens détaillées au chapitre 3. Dans l'expérience 5, les participants ont effectué la même tâche mais avec les formes grammaticales des catégories de notation inversées : forme nominale (e.g. "un cristal") dans l'expérience 4, il apparaissait sous la forme d'un adjectif (e.g. "cristallin") dans l'expérience 5.

Le chapitre 5, intitulé « Application de la masse sonore à la composition : biome (2017) », décrit ma composition pour trombone solo et orchestre d'instruments à vent, dans laquelle de nombreux aspects de la perception et de la sémantique des masses sonores abordés dans les chapitres 1 à 4 sont appliqués artistiquement. Enregistrement disponible à https://soundcloud.com/jasonnoble-1/biome.

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"It takes a village to raise a child," so the saying goes. I think it is also true that it takes a society to produce a work of art: no composition or research project is ever the work of any one person alone. I have relied on the support of a mass of people throughout my artistic and academic life, especially over the last few years as I have worked towards this dissertation. I cannot thank them enough.

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Thank you to the many wonderful, supportive current and former faculty members at the McGill Schulich School of Music for teaching and guiding me during my graduate studies here: in particular, Eleanor Stubley, Robert Hasegawa, Peter Schubert, Philippe Leroux, Christoph Neidhöfer, Denys Bouliane, Brian Cherney, and Jean Lesage. Special thanks to the members of my dissertation panel: John Rea, Guillaume Bourgogne, Lena Weman, and Barry Truax. Very special thanks to Hélène Drouin for her tremendous administrative support leading up to the defense and throughout my time at McGill.

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Contributions of Authors

Chapter 2 of this dissertation, "Empirical Research on Sound Mass Perception," is based in part on an article that has already been published:

Douglas, Chelsea, Jason Noble, and Stephen McAdams. "Auditory Scene Analysis and the Perception of Sound Mass in Ligeti's *Continuum*." *Music Perception* 33 no. 3, February 2016, 287-305.

Chelsea Douglas designed the experimental interface and conducted the statistical analysis for Experiments 1 and 2.

Chapter 2 also incorporates unpublished research from a Supplementary Pilot Study, conducted in collaboration with Eddy Kazazis, who programmed the patch for the experiment and analyzed the statistics.

Lab assistants Channey Phung and Lena Heng recruited, instructed, and supervised participants for Experiments 1 – 5.

Stephen McAdams supervised this dissertation and directs the laboratory in which the research was conducted, the Music Perception and Cognition Lab at McGill University. In addition to providing intellectual guidance and research facilities, he generously funded the experiments reported in Chapters 2 and 4, as well as the dissemination of this research at various conferences.

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Introduction

The disappearance of the individual into the mass—in the era of overpopulation, big data, and the social media "hive mind," this theme may seem even more pertinent than in the past. However, it has long been familiar both from our scientific knowledge of the physical and biological world and from our everyday experience. Water molecules amass to form droplets, which coalesce into rivulets, tributaries, rivers, lakes, and oceans, freeze into crystals, evaporate into clouds, and from a great distance appear as a blue planet. Amassed biomolecules form cells, organs, organisms, ecosystems, and biomes. In auditory perception, voices amalgamate into the massive roar of a crowd, but each voice, taken as an individual, is itself a conglomeration of many sound components, analyzed as partials and resynthesized into timbre by the auditory system; and again, each of those partials is a perceptual fusion of many sequential oscillations, each so brief as to be undetectable to conscious perception.

The identity of a thing—whether it is taken to be a mass of smaller entities, a single entity, or a component of a larger massed entity—depends on the spatiotemporal scales within which it is posited, and may coexist with multiple other identities at different scales. The perspective upon which we choose to focus our attention, therefore, profoundly affects the way we interpret and interact with the world by defining or delimiting the identities of the things that populate it. As Iannis Xenakis said, "if we observe galactic masses, we must decide whether it is to be the movement of the whole mass, the movement of a single star, or the molecular constitution of a minute region on a star that interests us."[1]

However, human perception being limited by certain psychological and physiological scales and constraints, we are normally able to attend to only a finite range of perspectives: we cannot choose to hear each vibration of a piano string as an individual sound, or to see each flash from a rapid stroboscope as a discrete burst of light; we cannot fuse a succession of footsteps into a pitch, or see a flashing traffic light as a continuous illumination. Our perceptual and cognitive systems have adapted to certain scales of spatial and temporal awareness, of sensory resolution, and of information processing which, while they admit of considerable intersubjective variation,

[1] Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition* (Bloomington: Indiana University Press, 1971), 49.

provide a vague but meaningful sense of a "human perspective" on the world (as opposed, for example, to the spatial scale of subatomic particles, or the temporal scale of continental drift).

In spite of limitations on the perspectives we may be able to adopt in perception, we have developed instruments of research that open up to our fields of inquiry spatiotemporal zones that are inaccessible to our immediate awareness. Our computers, telescopes, microscopes, radiation dating, and high-speed motion capture technologies offer us access to scales of time and space that would otherwise be beyond our reach, capturing our imaginations with levels of order completely alien to those that define our unmediated experience: they allow us to dissolve a mass on one scale into a concatenation of entities on another, or to comprehend that what we think of in daily life as individual things or persons are, at other levels, negligible components of massed totalities. At its furthest polar extremes, fascination with ontological amassment leads us to follow the rabbit-hole of levels all the way down to the simplest, and all the way up to the most complex, concatenations that can be called "one": from the Higgs Boson particle to the deterministic universe, from the simplest single-celled metabolisms to Gaia theory, from the most primitive preattentive sensations to the so-called "body of human knowledge." We are fortunate to live in a time in which all of these fascinating antipodes are being actively explored, but for which none have been fully accounted: the problem of "the one and the many" continues to reverberate throughout philosophy, science, and contemporary life in general. In art, and specifically in music, stimuli that exceed or subvert human perceptual scales implicitly point beyond them, challenging our concepts of one and many, drawing our attention, perhaps uncomfortably, to the liminal space between things we can apprehend and things we cannot.

Make no wonder that the tension between singularity and totality has found such a prominent place in the music of recent decades, especially in the aesthetic that has come to be known as "sound mass." While the term had been a French locution in various discourses since the mid-19th century,[2] the contemporary usage of the term is largely attributable to the composer Edgard Varèse who coined it in a lecture in 1936, later published as a manifesto called "The Liberation of Sound":

> When new instruments will allow me to write music as I conceive it, taking the place of the linear counterpoint, the movement of sound-masses, of shifting planes, will be clearly perceived. When these sound-masses collide the phenomena of penetration or repulsion will seem to occur. Certain transmutations taking place on certain planes will seem to be projected onto other planes, moving at different speeds and at different angles. There

[2] Thanks to John Rea for drawing my attention to this fact.

> will no longer be the old conception of melody or interplay of melodies. The entire work will be a melodic totality. The entire work will flow as a river flows.[3]

In his compositions, Varèse "consistently invented vertical sound structures that were so highly individualized that ordinary terminology—chord, voicing, doubling—no longer has explanatory value."[4] Be that as it may, sound mass in musical practice is now most associated with Witold Lutosławski (1913-1994), Iannis Xenakis (1922-2001), György Ligeti (1923-2006), Krzysztof Penderecki (b. 1933), and later composers influenced by them. The premise of the sound mass aesthetic is that many component parts group into a single auditory percept, but the fusion need not, and indeed cannot, be complete: if it were as complete as the fusion of partials into a human voice or the sound of a musical instrument, then the sense of multiplicity would be lost and instead of a mass one would perceive a single sound source. It is therefore too reductive to say that listeners cannot hear the individual parts of a sound mass: that depends on how they direct their attention, and they can often hear out individual parts if they try, just as one can strain to focus on an individual voice amid the din of the crowd. But there is a sense that to do this is to miss the point of the music, whose organization emphasizes totality and minimizes the individual identities of constituent parts.

This dissertation addresses perceptual and semantic dimensions of sound mass. Chapter 1, "Perceptual Dimensions of Sound Mass," considers the problems of defining the term "sound mass," reviews extant definitions, and proposes a new one. It proceeds to review some common features of sound mass in light of perceptual principles by which they promote integration or fusion, with reference to examples from the sound mass repertoire. A summary list of attributes to be considered in sound mass analysis is provided.

Chapter 2, "Empirical Research on Sound Mass Perception," reports the findings of experiments conducted at the Music Perception and Cognition Lab at McGill university under the supervision of Dr. Stephen McAdams. The first experiment, conducted with Chelsea Douglas, evaluates listeners' dynamic perceptions of sound mass in Ligeti's *Continuum* (1968), as measured with continuous response data. The second experiment uses isolated excerpts from *Continuum* as

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[3] Edgard Varèse and Chou Wen-chung, "The Liberation of Sound," *Perspectives of New Music* 5, no. 1 (Autumn-Winter, 1966): 11. This lecture recalls Varèse's affinity with Futurist poetics; see Dragana Stojanović, "Work of Edgard Varèse and 'Futurist Music': Affinities (and Differences)," *New Sound: International Magazine for Music* 34, no. 1 (2009): 50-61.
[4] Robert Erickson, *Sound Structure in Music* (Los Angeles: University of California Press, 1975), 20-1.

stimuli, with selected parameters such as register, instrumental timbre, and attack rate (tempo) modified to evaluate the extent to which these parameters influence listeners' perceptions of sound mass. The third experiment isolates harmonic structures from *Continuum* to evaluate the relation between pitch density and sound mass perception when the rhythmic context is neutralized. A supplementary pilot study, conducted with Eddy Kazazis, evaluates listeners' ratings of complex harmonies, including many of the same structures from *Continuum* used in Experiment 3, along three categories: Bright-Dark, Pitched-Noisy, and Density.

Chapter 3, "Semantic Dimensions of Sound Mass," addresses some general problems of extramusical meaning, as well as cultural attitudes towards extramusical meaning that prevailed in the 1950s and 1960s, the period during which the canonical sound mass repertoire emerged. Drawing on multidisciplinary research in music perception and cognition, semiotics, cognitive semiotics, metaphor theory, and embodied cognition, this chapter offers a dynamical model of extramusical meaning based on homology between selected musical attributes and corresponding attributes of extramusical domains. It concludes with a compilation of many metaphorical associations with sound mass, drawn from the published discourse of composers and theorists of this music.

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Chapter 5, "Compositional Application of Sound Mass: *biome* (2017)," describes my composition for solo trombone and wind orchestra, composed uner the supervision of Dr. Chris Paul Harman, in which many of the theoretical aspects of sound mass perception and semantics discussed in Chapters 1-4 are applied artistically.

Chapter 1: Perceptual Dimensions of Sound Mass

1.1 Introduction: Defining 'Sound Mass'

Just what counts as a sound mass? I first encountered the term in an undergraduate textbook:

> The term *sound-mass* is sometimes used for a chord in which the pitch content is irrelevant compared to the psychological and physical impact of the sound. The most characteristic examples of sound-mass (this term seems never to be used in its plural form) are large clusters…But sound-mass can be created by other means as well …[e.g. polychords played fortissimo]…Yet another kind of sound-mass can be created by extreme activity in a large ensemble.[5]

The ambiguity of this account fascinated me: how can pitch content become "irrelevant," and how can it be "compared" with "psychological and physical impact"? How can such apparently different phenomena—chords, polychords, clusters, extreme activity—be considered the same thing? Why had the author opted to provide contrasting examples instead of a proper definition?

A review of the scholarly literature does little to allay this ambiguity. The many published definitions of sound mass are all predicated on on perceptual fusion of some kind, but differ considerably in their emphases.[6] Jonathan Bernard defines "*masses* of sound" as "aggregations that in one way or another deemphasized pitch as a sound quality, or at least as a *privileged* sound quality,"[7] whereas Kari Besharse proposes using the term "*soundmass*" to denote "textures in which many individual notes contribute to a more static block of sound that is essentially chordal in nature."[8] Bernard emphasizes a *diminished role of pitch*, while Besharse emphasizes *pitch* (notes, chords) *as the defining parameter* of sound mass. The former view seems to be the more broadly accepted of the two. J. Michele Edwards states that "[s]ound mass minimizes the

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[5] Stefan Kostka, *Materials and Techniques of Twentieth-Century Music*, (Upper Saddle River, NJ: Prentice Hall, 1999), 237.

[6] In *Traité des objets musicaux*, Pierre Schaeffer uses the term *masse sonore* somewhat elusively, appearing to denote the perception of spectrally-based timbre which functionally resists transposition and filtering (by classical studio techniques). I consider this sense to be distinct from the concept of sound mass studied in this dissertation, and as such have not addressed Schaeffer's use of the term. Thanks to Barry Truax for drawing my attention to this terminological incongruity.

[7] Jonathan Bernard, "Ligeti's Restoration of Interval and Its Significance for His Later Works." *Music Theory Spectrum* 21, no. 1 (Spring, 1999): 2.

[8] Kari Besharse, "The Role of Texture in French Spectral Music" (PhD dissertation, University of Illinois at Urbana-Champaign, 2009), 55.

importance of individual pitches in preference for texture, timbre, and dynamics as primary shapers of gesture and impact…sound mass obscures the boundary between sound and noise,"[9] while according to Danuta Mirka, sonoristic composition takes "sound masses (rather than single tones)" as primary syntactical units, for which timbre is "the most decisive category of any given sound value."[10] Edwards interprets the diminished role of pitch as an *assimilation with noise*, while Mirka interprets it as an *emancipation of timbre*. David Metzer, on the other hand, emphasizes the *evolution of sonority* through non-pitch parameters of massed sonorities in the music of Ligeti and Lachenmann: "the sonority evolves through changes in density, tone color, size, dynamics, internal agitation, and register."[11] Jennifer Joy Iverson says that the defining characteristic of Ligeti's sound-mass style is its foregrounding of "homogeneous, colorful orchestral clusters" that "minimize the impact of the more discrete parameters of pitch, rhythm, harmony and melody"[12]; Gwyneth Roberts uses the term "sound mass" to refer to "a block of sound of such complexity that its individual components are subordinate to the total aural effect"[13]; Denis Smalley defines "sound knots or masses (as in clusters, for example)" as "[d]ensities that approach noise."[14] Iverson suggests that the *homogeneity* of the sound components leads to their perceptual integration, while Roberts emphasizes the *complexity* of their arrangement, and Smalley considers *density* to be the essential factor. For practitioners of stochastic procedures and granular synthesis, *aggregation* is the defining feature: Iannis Xenakis speaks of "mass events" which are "made out of thousands of isolated sounds; this multitude of sounds, seen as a totality, is a new sonic event."[15] Barry Truax speaks of "fused masses of great internal complexity" that result from the accumulation of "the most 'trivial' grains of sound."[16]

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[9] J. Michele Edwards, "North America since 1920," in *Women & Music: A History,* ed. Karin Pendle (Bloomington: Indiana UP, 2001): 326.
[10] Danuta Mirka, *The Sonoristic Structuralism of Krzysztof Penderecki* (Katowice, Poland: Music Academy in Katowice, 1997), 8. Mirka also acknowledges that sound value "depends on several other factors that determine the internal structure of sound masses, such as density, mobility, homogeneity and diversity."
[11] David Joel Metzer, *Musical Modernism at the Turn of the Twenty-First Century* (Cambridge: Cambridge University Press, 2009), 214.
[12] Jennifer Joy Iverson, "Historical Memory and György Ligeti's Sound-Mass Music 1958-1968" (PhD dissertation, The University of Texas at Austin, 2009), 2.
[13] Gwyneth Roberts, "Procedures for Analysis of Sound Masses" (PhD dissertation, Indiana University, 1978), 5.
[14] Denis Smalley, "Klang, Morphologien, Spektren: Spektromorphologie in der Instrumentalimusik" (original English version, provided by the author), in *Klang Perspektiven*, ed. Lukas Haselböck, (Frankfurt: Wolke Verlag Hofheim, 2011): 15.
[15] Xenakis, *Formalized Music*, 9.
[16] Barry Truax, "Composing with Real-Time Granular Synthesis," *Perspectives of New Music* 28, no. 2 (Summer, 1990), 123-4.

Douglas, Noble, and McAdams (2016) offer the following description:

> *Sound mass* exists when the individual identities of multiple sound events or components are attenuated and subsumed into a perceptual whole, which nevertheless retains an impression of multiplicity. Typically this involves one or more parameters of sound—for example, rhythmic activity, pitch organization, or spectral content—attaining a degree of density, complexity, and/or homogeneity that is perceived as saturation.[17]

We considered retaining the "impression of multiplicity" (in spite of subsuming the component parts into a perceptual whole) to be an essential feature: if the category "sound mass" included auditory units so completely fused that the impression of multiplicity is lost, then all complex sounds would be sound masses, and the concept would provide no basis for differentiating between a single note on a violin and the opening sonority of Ligeti's *Atmosphères* (1961) or the "tonal masses" described by Robert Erickson.[18] This is to say that without the requirement of perceptual multiplicity, the concept of sound mass would be so general as to be nearly meaningless and of little value for music theory and analysis. Our emphasis on density, complexity, and homogeneity reflects various definitions in the literature as well as the researchers' intuitions; however, as we have learned, it is important not to confuse *perceived* density, complexity, and homogeneity with *acoustical* density, complexity, and homogeneity. Subsequent experimental findings (see Chapter 4) have shown that perceived density and homogeneity correlate positively with sound mass fusion, but perceived complexity correlates *negatively* with sound mass fusion. This may seem counter-intuitive, but it follows logically from the limits of our auditory information processing capabilities: after a certain point we are no longer able to parse incoming information into meaningful units, and increasing acoustical complexity results in *decreasing* perceived complexity as superimposed acoustical details cancel each other out and meld together in perceptual representation.[19] Karlheiz Stockhausen made this point in observing that at a certain point of complexity, sound events lose their rhythmic character and instead contribute to the timbre of the mass.[20] Our term "saturation" implied maximum capacity, in the sense that the listener's capacity to

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[17] Chelsea Douglas, Jason Noble, and Stephen McAdams, "Auditory Scene Analysis and the Perception of Sound Mass in Ligeti's *Continuum*," *Music Perception* 33 no. 3 (February 2016): 287.
[18] Erickson, 22; 28; 36.
[19] Lasse Thoresen describes this situation as "a category in which the very complex and the very simple meet in a paradoxical, ambivalent union. We shall call this form-element *paradoxical complexity*—a specific case of the classical *coincidentia oppositorum*, the unity of opposites. It applies to objects with myriad details, but with a perceptually simple overall character. A homogenous accumulation with elements in flutter time may often qualify for this category." *Emergent Musical Forms: Aural Explorations* (London, ON: University of Western Ontario, 2015), 456.
[20] Karlheinz Stockhausen, paraphrased in Iverson, 129.

discriminate within a given parameter is overwhelmed. Again, subsequent experimental findings have prompted further reflection: factors such as register (especially the very low register), gestural integration ("common fate" motion in Gestalt terminology), and harmonic complexity (the sheer number of different pitch classes, irrespective of their spacing) have been shown to influence sound mass perception in ways not convincingly conveyed by the term "saturation." The aforementioned definition also encompasses auditory units not usually considered sound masses: for example, the notes of a tonal chord are subsumed into a perceptual whole via the emergent property of harmony, which yet retains an impression of multiplicity (we can still hear the individual notes, for instance by mentally arpeggiating the chord). To account for these observations, our proposed definition may be amended thus:

> *Sound mass*: A perceptually dense and homogeneous auditory unit integrating multiple sound events or components while retaining an impression of multiplicity. Although their acoustical correlates may be highly complex, sound masses are perceptually simple because they resist perceptual segmentation in one or more parameters (e.g., pitch, rhythm, timbre).

Sound mass can be achieved through many different compositional techniques, which exploit many features of auditory perception (often in tandem with one another). In what follows, some of those techniques will be reviewed with reference to supporting examples from the repertoire. It must be said at the outset that composers associated with sound mass, including Ligeti, Lutosławski, Penderecki, and Xenakis, each developed their own aesthetic agendas, compositional practices, and musical discourses: they do not constitute a "school" in any traditional sense. They, and the many later composers who were influenced by their work, are referred to here as "sound mass composers" in order to highlight certain intellectual and artistic commonalities between them, but this is not to minimize the significant differences between them and their respective œuvres.

1.2 Sound Mass and Perceptual Principles

In his 2001 paper "Tone and Voice: A Derivation of the Rules of Voice-Leading from Perceptual Principles" and his 2006 book *Sweet Anticipation: Music and the Psychology of Expectation*, David Huron explains many of the normative practices of tonal counterpoint in terms of auditory scene analysis and other aspects of auditory perception. He states that "the principal purpose of voice-leading is to create perceptually independent musical lines,"[21] and he "derives" traditional voice leading rules from perceptual principles. The traditional voice leading rules listed by Huron are:

(1) *Registral Compass Rule*. Write in the region between F_2 and G_5.
(2) *Textural Density Rule*. Write for three or more concurrent parts.
(3) *Chord Spacing Rule*. Separate upper voices by no more than an octave. The lowest two voices (e.g., bass and tenor) may be separated by wider intervals.
(4) *Avoid Unisons Rule*. Two voices should not share the same concurrent pitch.
(5) *Common Tone Rule*. Pitches common to consecutive chords should be retained in the same part.
(6) *Nearest Chordal Tone Rule*. If a part cannot retain the same pitch in the next sonority, it should move to the nearest available pitch.
(7) *Conjunct Motion Rule*. When a part must change pitch, favour diatonic stepwise motion.
(8) *Avoid Leaps Rule*. Large melodic intervals should be avoided.
(9) *Part-Crossing Rule*. Parts should not cross with respect to pitch.
(10) *Part Overlap Rule*. No part should move to a pitch higher than the immediately preceding pitch in an ostensibly higher part. Similarly, no part should move to a pitch lower than the immediately preceding pitch in an ostensibly lower part.
(11) *Parallel Unisons, Fifths, and Octaves Rule*. No two voices should move in parallel unisons, fifths, or octaves.
(12) *Consecutive Unisons, Fifths, and Octaves Rule*. No two voices should form consecutive unisons, octaves, fifteenths (or any combination thereof). Also, no two voices should form consecutive fifths, twelfths, nineteenths (or any combination thereof).
(13) *Exposed (or Hidden or Direct) Octaves (and Fifths) Rule*. Unisons, perfect fifths, octaves, twelfths, and so on should not be approached by similar motion unless at least one of the parts moves by diatonic step.[22]

Huron also names the following nontraditional voice leading rule, which is not prescribed in traditional counterpoint pedagogy but is nevertheless observed as a normative practice:

(14) [D23]. *Asynchronous Preparation of Tonal Fusion Rule*. When approaching unisons, octaves, or fifths, avoid synchronous note onsets.

I list these rules here without detailed discussion for the sake of comparison with the practices of sound mass composition. I would like to suggest that the same perceptual principles that ground these voice leading rules and normative practices are also operative in sound mass, but with exactly the opposite aesthetic goal: whereas tonal counterpoint seeks to *preserve* the independence of

[21] David Huron, "Tone and Voice: A Derivation of the Rules of Voice-Leading from Perceptual Principles," *Music Perception* 19 no. 1 (Fall 2001): 2.
[22] Huron, "Tone and Voice," 5-6.

musical lines, sound mass seeks to *attenuate* their perceptual independence and assimilate them into a perceptual totality. As such, while there is no single normative practice for sound mass composition that parallels the rules of voice leading for tonal counterpoint, generally speaking sound mass represents a set of compositional practices running directly contrary to the rules of tonal counterpoint but relying on the same perceptual principles. The principles listed by Huron (and corresponding techniques of sound mass composition) will be discussed one at a time below for clarity's sake, but they are by no means mutually exclusive and frequently operate together.

1.2.1 TONENESS PRINCIPLE.

> *Strong auditory images are evoked when tones exhibit a high degree of toneness. A useful measure of toneness is provided by virtual pitch weight. Tones having the highest virtual pitch weights are harmonic complex tones centered in the region between F2 and G5. Tones having inharmonic partials produce competing virtual pitch perceptions, and so evoke more diffuse auditory images.*[23]

The toneness principle provides the perceptual foundation for pitch-centrism in traditional Western music, taking sounds with spectral content and fundamental frequencies best-suited to salient pitch perception as the basic building-blocks of music. This principle specifically favours "harmonic complex tones" (spectra with multiple partials related by simple integer ratios), as distinct from inharmonic sounds (irrationally related partials) or noise-based sounds (no clearly defined partials; distribution of energy over some or all of the frequency range). The boundaries between these categories are not sharply defined: many harmonic sounds, such as those produced by wind and string instruments played with traditional technique, contain noise components (e.g., the sound of air rushing through a flute or the bow scraping along a string). Inharmonic sounds, such as those produced by metallic idiophones like bells or gongs, often have some partials related by simple integer ratios and others related irrationally. In general, the greater the degree of acoustical harmonicity, the stronger the perception of pitch, such that pure harmonic spectra yield unambiguous pitch, inharmonic spectra yield more diffuse and multiphonic percepts, and noise-based spectra have no sense of pitch (though, as stated above, these categories are continuous rather than discrete). Another major factor in pitch perception is register. Although human hearing extends roughly from 20 Hz to 20 kHz, pitch perception is not uniform throughout this range: towards the bottom end we hear indistinct "rumbling," and towards the top we hear indistinct "sizzling," with

[23] Huron, "Tone and Voice," 10.

clear pitch perception residing in the range from about 30 Hz to about 4000-5000 Hz.[24] As Huron observes, we are maximally sensitive to pitch between F_2 and G_5, roughly the range covered by the grand staff and roughly coterminous with the combined ranges of adult male and female voices. We have evolved to be acutely sensitive to the strong auditory images invoked by harmonic sounds in this range, probably because the voice (a harmonic sound source) is a singularly important source of auditory information for humans. As such, harmonic spectra with fundamentals between F_2 and G_5 are likely to stand out as distinct auditory streams, thereby weakening or destroying sound mass integration, unless their pitch salience is attenuated in some way.

Sound mass composers have responded to this perceptual challenge by embracing extreme registers and non-harmonic sounds in their musical vocabularies. Undoubtedly the most famous example of a high-register mass in Penderecki's œuvre is the opening of *Threnody for the Victims of Hiroshima* (1960), in which the string instruments are instructed to play the highest (indeterminate) pitch available on their instrument fortissimo. Penderecki exploits the extreme low register in the opening section of *Polymorphia* (1961), which features a microtonal cluster of the lowest notes in the celli and double basses. In mm. 164-173 of Penderecki's *Dimensions of Time and Silence* (1959-60), not only are non-pitched percussion instruments given a very prominent role in the texture, but the choral voices, whose production normally prioritizes pitched vowels, instead articulate consonants only, and the string players are instructed to strike the strings with the palm of the hand for a percussive effect.

[24] Christopher Plack, *The Sense of Hearing, 2nd Edition* (New York: Taylor & Francis, 2014), 118-19.

Figure 1: Krzysztof Penderecki, *Threnody for the Victims of Hiroshima*, beginning.[25]

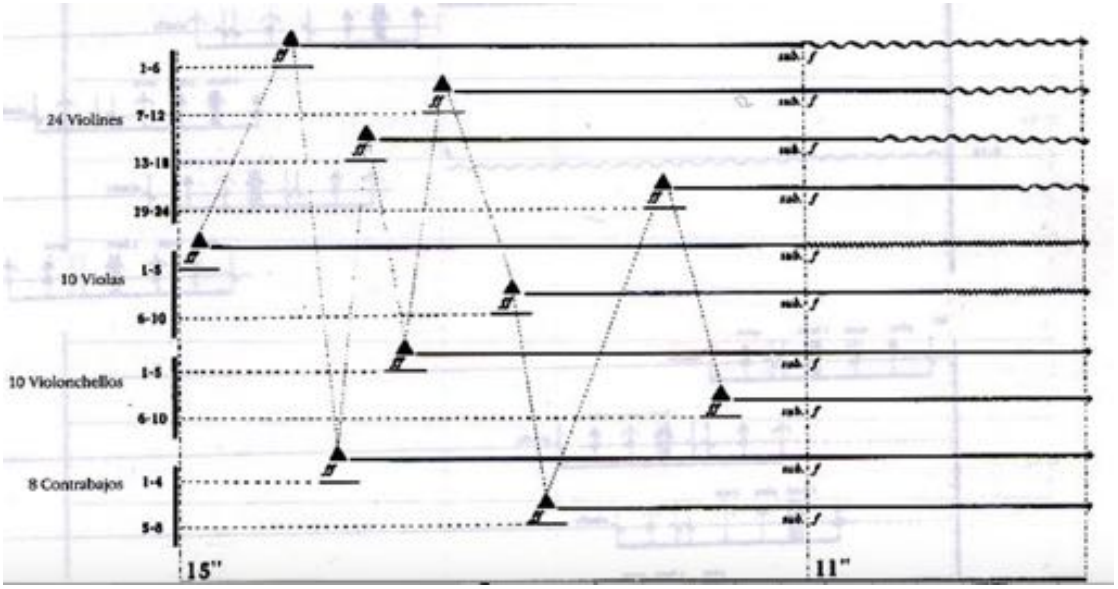

Figure 2: Krzysztof Penderecki, *Polymorphia*, rehearsals 6-9.[26]

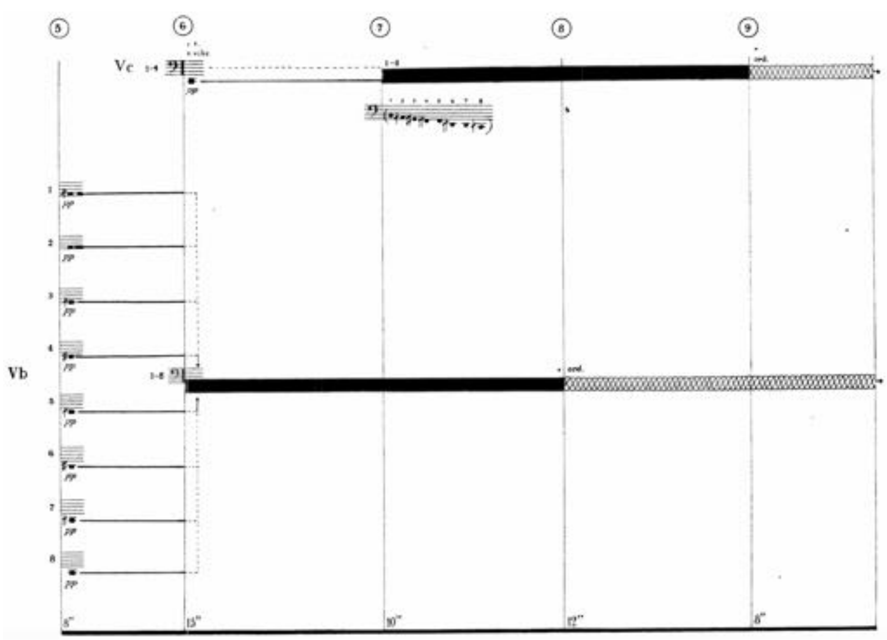

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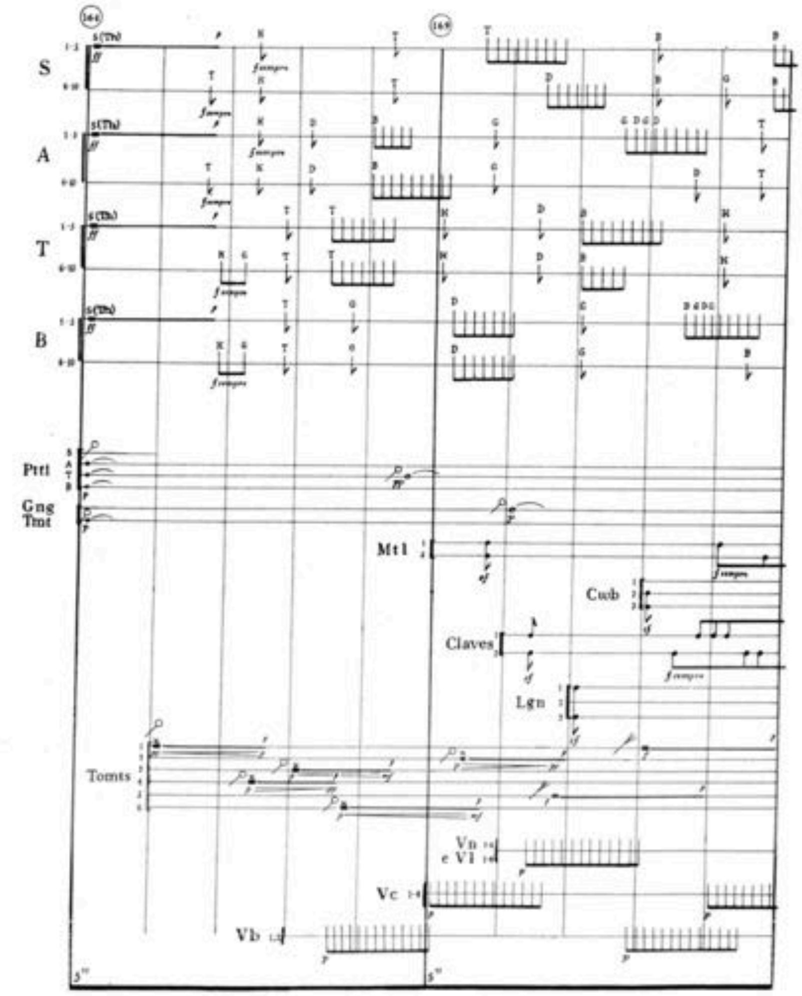
Figure 3: Krzysztof Penderecki, *Dimensions of Time and Silence*, mm. 164-169.[27]



1.2.2 PRINCIPLE OF TEMPORAL CONTINUITY.

> *In order to evoke strong auditory streams, use continuous or recurring rather than brief or intermittent sound sources. Intermittent sounds should be separated by no more than roughly 800 ms of silence in order to ensure the perception of continuity.*[28]

Temporal continuity is frequently (though not always) a property of a sound mass as a whole, but discontinuity in individual parts sometimes helps prevent their constituent sound events from segregating from the mass by integrating into separate auditory streams. Events can be

[28] Huron, "Tone and Voice," 12.

separated with rests, as in section 43 of Lutosławski's Symphony No. 2 (1965-67), in which progressively elongated rests inhibit internal stream integration *within* parts, favouring instead global integration *between* parts:

Figure 4: Witold Lutosławski, Symphony No. 2, section 43.[29]

Rhythmic qualities are also closely related to sounds' spectromorphological profiles. Attack-heavy and sustain-light sounds, such as string pizzicato, may not require notated rests in order

[29] SYMPHONY NO. 2 Music by Witold Lutosławski © Copyright 1968 Chester Music Limited for the World except Poland, Albania, Bulgaria, the territories of former Czechoslovakia, Rumania, Hungary, the whole territory of the former USSR, Cuba, China, North Vietnam and North Korea where the Copyright, 1967, is held by Polskie Wydasnictwo Muzyczne, Kraków, Poland. All Rights Reserved. International Copyright Secured. Reprinted by permission.

to inhibit stream formation, especially in densely overlapping textures such as mm. 52-60 of Xenakis's *Pithoprakta* (1955-6), in which each pizzicato is executed as a glissando. The sustain (gliss) portion of each sound, which is fairly weak and prone to dissipation due to the absence of further energy input after the initial pluck, can be overwhelmed by the attacks of subsequent notes in other instruments:

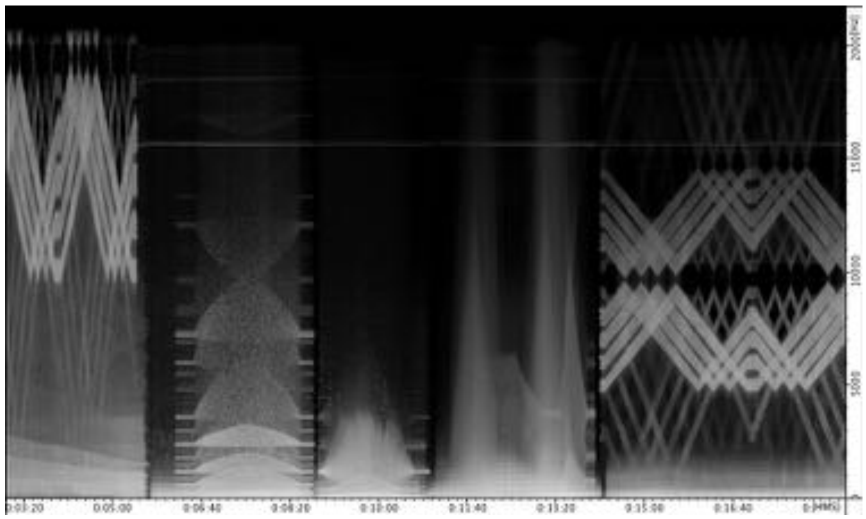
Figure 5: Iannis Xenakis, *Pithoprakta*, mm. 49-56.[30]

In the electronic technique of granular synthesis, which was heavily influenced by Xenakis's ideas, there are often no "parts" as such but only brief, discontinuous events, distributed stochastically. For example, Barry Truax's *Riverrun* (1986) is produced entirely with very brief

[30] *Pithoprakta* by Iannis Xenakis. © Copyright 1967 by Boosey & Hawkes Music Publishers Ltd. Reprinted by Permission of Boosey & Hawkes, Inc.

sine tones or frequency-modulated sine tones (sometimes as short as 1ms) distributed over defined temporal and frequency ranges. These are readily visible in a spectrograph of the piece:

Figure 6: Barry Truax, *Riverrun*, spectrograph. Produced with permission.



Another important aspect of temporal continuity is the duration of sound events. As Huron remarks, the vast majority of notes in Western tonal music are between 150 ms and 1s in duration,[31] and Justin London affirms that "[r]hythm involves our perception of durations within a fairly narrow range—from 1/10 of a second (that is, 100 milliseconds or 'ms') to about two seconds."[32] Sound mass, on the other hand, frequently employs notes or other sounds of vastly elongated durations: the opening chord of Ligeti's *Atmosphères*, at the notated tempo of 40 beats per minute, lasts 24 seconds before the first notated change (the *morendo* exit of the flutes, followed by similar exits from the bassoons, clarinets, horns, and violins) and over three times that long before the first "chord change" in m. 13. At the opposite end of the temporal spectrum, sound mass can be created from very large numbers of very short sound events. As noted above, the shortest event that we can produce or perceive as a rhythmic element is 100 ms, which, if repeated periodically, produce a frequency of 10 events per second (Hz). Frequencies above roughly 20 Hz are perceived as pitch (the frequency of the lowest note on the piano is 27.5 Hz), though the region of maximal pitch salience begins at about 87 Hz (F_2). This leaves a region that Edward Large has called a "no-

[31] Huron, "Tone and Voice," 27.
[32] Justin London, "Temporal Complexity in Modern and Post-Modern Music: A Critique from Cognitive Aesthetics," in *Unfolding Time: Studies in Temporality in Twentieth Century Music* (Ghent, Belgium: Leuven University Press, 2009): 48.

man's-land"[33] between roughly 10 and 20 Hz: too slow to be resolved as pitch and too fast to be resolved as rhythm. Auditory experience in this range can be ambiguous, characterized by roughness and a kind of pseudo-continuity in which events are neither clearly integrated nor clearly segregated. Perhaps because of perceptual ambiguity and difficulty of production, this no-man's-land traditionally played little role in music (with the exception of ornamental figures like trills and drumrolls[34]). More recently, however, this liminal region has been of great interest to sound mass composers. As Mirka notes, "trills and vibrati oscillate so rapidly that for the listener they fuse into one narrow band of simultaneously sounding pitches [and] turn into a real band of sound when performed at the same time by several instruments," a perceptual feature that Penderecki exploited in his sonoristic style."[35] Ligeti exploited the liminal region between rhythm and pitch at length in his organ étude *Coulée* and harpsichord piece *Continuum* (see Chapter 2).

1.2.3 MINIMUM MASKING PRINCIPLE.

> *In order to minimize auditory masking within some vertical sonority, approximately equivalent amounts of spectral energy should fall in each critical band. For typical complex harmonic tones, this generally means that simultaneously sounding notes should be more widely spaced as the register descends*.[36]

What Huron refers to as "masking"[37] is interference between vibrations on the basilar membrane (the part of the cochlea that transduces incoming sound signals into neural impulses). The basilar membrane is organized tonotopically, such that each frequency in the range of human hearing corresponds to a physical location on the membrane that vibrates most strongly in response to that frequency. The term *critical band* refers to any region approximately one-millimeter long on the basilar membrane: simultaneous frequencies that fall within a critical band are close enough to physically interfere with one another. Although they are the same physical length, not all critical bands encompass the same range of frequencies: because the tonotopic mapping of the basilar membrane is approximately logarithmic, the range of frequencies covered by one millimeter varies

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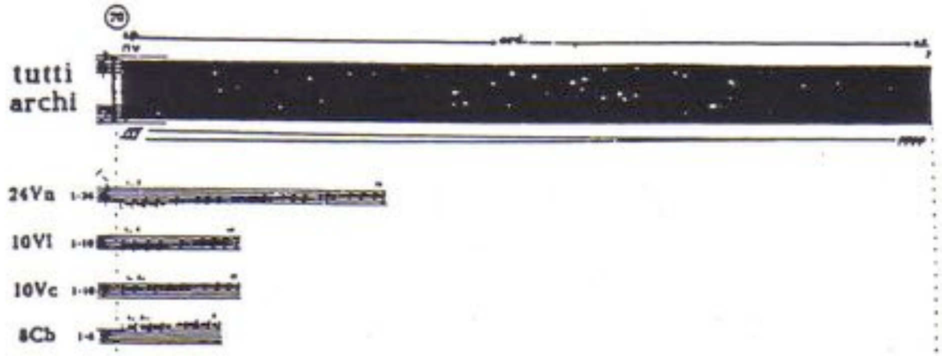
[33] Edward Large, "President's Address" (presentation, *Conference of the Society for Music Perception and Cognition*, Vanderbilt University, Nashville TN, 03 August 2015).
[34] Justin London ("Temporal Complexity") identifies the "trill threshold," which he describes as the "point where individual notes begin to blur," at around 10 notes per second. (48)
[35] Mirka, 103.
[36] Huron, "Tone and Voice," 18.
[37] Huron's conception of "masking" differs somewhat from the way the term is used by other authors in the fields of auditory science and music perception and cognition. For example, according to Christopher Plack, "[m]asking occurs whenever the activity produced on the basilar membrane by one sound (the *masker*) obscures the activity produced by the sound you are trying to hear (the *signal*). (91)

widely depending on the location (one millimeter near the apex, where low frequencies are transduced, covers a much smaller frequency range than a millimeter near the base, where high frequencies are transduced). In terms of perceived pitch, the range covered per critical band is much greater in the low register (near the apex of the basilar membrane) than in the high register (near its base): as a result, two tones separated by, for example, a third in the low register will fall within the same critical band and will interfere with one another, resulting in beating, sensory dissonance, and diminished pitch resolution (in Huron's terminology, "masking"). In the middle and upper registers, however, two tones separated by the same interval will fall in different critical bands and will not interfere with one another. As Huron explains, this is why chords in tonal music tend to be voiced with wider intervals at the bottom and narrower intervals at the top: chords that are voiced this way minimize sensory dissonance and maximize pitch resolution. In sound mass, on the other hand, pitch resolution detracts from the aesthetic goal of global integration or fusion, and so the mutual interference of frequencies in the same critical band may often be desirable. This is a characteristic feature of perhaps the most familiar type of sound mass—the large cluster chord—which harnesses interference to addresses the challenge of using sounds with high toneness (e.g., most sounds of conventional musical instruments) without disintegrating the mass into separate auditory streams.

The proximity of pitches in a cluster depends to some extent on the sonic medium and tuning system. Keyboard instruments such as the piano and organ are restricted to chromatic clusters unless retuned outside of 12-tone equal temperament. Examples of such chromatic clusters are found in Edgard Varèse's *Ionisation* (1929-31) at rehearsal 13, and throughout Ligeti's *Volumina* (1961/62; 1966). Orchestral wind and string instruments are capable of producing microtonal pitches, expanding the potential for cluster density: a famous example is the final chord in Penderecki's *Threnody for the Victims of Hiroshima* (1960), in which every quarter-tone within a compass of over two octaves is played simultaneously (Figure 7). Electronic resources, such as the UPIC system developed by Xenakis, expand the potential for density even further, allowing complete saturation of all frequencies within a defined range. Xenakis exploited this potential in compositions such as *Mycenae Alpha* (1978; see Figure 50, Chapter 3).

Figure 7. Krzysztof Penderecki, *Threnody for the Victims of Hiroshima*, final chord.[38]



1.2.4 Tonal Fusion Principle.

> *The perceptual independence of concurrent tones is weakened when their pitch relations promote tonal fusion. Intervals that promote tonal fusion include (in decreasing order): unisons, octaves, perfect fifths, ... Where the goal is the perceptual independence of concurrent sounds, intervals ought to be shunned in direct proportion to the degree to which they promote tonal fusion.*[39]

Some types of sound mass—notably the "spectral soundmass" described by Kari Besharse—exploit harmonic fusion, the auditory system's strong tendency to group harmonically related partials together in auditory streaming. Spectral soundmasses not only use intervals that promote tonal fusion, as described in Huron's passage above, but recreate the complex structure of a real or ideal harmonic spectrum in order to maximize perceptual fusion. As Lasse Thoresen observes, spectral chords may be distinguished from tonal chords based on their relative degrees of perceptual fusion: "A spectral chord is ideally fused to the extent it approaches a sound-object with a timbre; in a normal chord, however, the ideal is often that one should be able to discern the individual notes of the chord since the chord itself may be only a meeting point of melodic lines in a polyphonic web."[40] Fusion of this kind, which, as Jonathan Harvey remarks, demonstrates that "harmony can be subsumed by timbre,"[41] can be achieved synthetically, as in Harvey's piece *Mortuos Plango, Vivos Voco* (1980), or it can be achieved with instrumental synthesis, the classic example being Grisey's *Partiels* (1976) in which the low E of the trombone and double bass is orchestrated by assigning the frequencies of their spectra to other instruments:

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[39] Huron, "Tone and Voice," 19.

[40] Thoresen, 343.

[41] Jonathan Harvey, "Spectralism," *Contemporary Music Review* 19 no. 3 (2001): 14.

Figure 8: Gérard Grisey, *Partiels,* beginning.[42]

As Robert Hasegawa points out, "[t]he goal of instrumental synthesis is not a precise reproduction of the trombone sound—which would in any case be impossible given the complex spectra of acoustic instruments—but rather a hybrid sonority permitting us to hear both the individual instruments and their fusion into a unified timbre."[43] This effect can also be achieved with human voices: Stockhausen's *Stimmung* (1968), which is based entirely on a spectral voicing of a B-flat dominant 9th chord, adopts a spectral-fusion-based aesthetic (though it predates the movement known as "Spectralism"). Spectralist sonorities need not always be harmonic: spectral composers including Grisey, Tristan Murail, Philippe Hurel, and Kaija Saariaho make frequent use of inharmonic spectra. However, the degree to which a sonority exhibits *harmonic* fusion is a function of the harmonicity of that sonority's interval structure.

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[43] Robert Hasegawa, "Gérard Grisey and the 'Nature' of Harmony," *Music Analysis* 28 no. 2-3 (2009): 349-350.

1.2.5 Pitch Proximity Principle.

> *The coherence of an auditory stream is maintained by close pitch proximity in successive tones within the stream. Pitch-based streaming is assured when pitch movement is within van Noorden's "fission boundary" (normally 2 semitones or less for tones less than 700 ms in duration). When pitch distances are large, it may be possible to maintain the perception of a single stream by reducing the tempo.*[44]

The pitch proximity principle refers to successive rather than simultaneous tones: melodic continuity is promoted by small intervals (steps) and diminished by larger intervals (leaps). It is therefore possible to weaken the continuity (stream integration) of individual musical lines by populating them with large leaps. When such lines are multiply superposed, the weakness or absence of stream integration within each line makes it more likely that the notes will integrate into a composite whole (mass) with little or no melodic identity. This may be what Xenakis was responding to in his famous critique of serialism, whose enormous complexity, he said, causes one to hear "nothing but a mass of notes in various registers."[45] When the melodic continuity afforded by conjunct motion (along with other factors such as registral separation) is stripped away from counterpoint, as in the serial context which Xenakis was critiquing, the musical lines lose their identities as lines and become an integrated mass. Xenakis and other sound mass composers responded by working with the mass directly, taking it to be an aesthetic end in itself rather than a by-product of combinatorial construction. An example of this is rehearsal 10 in Penderecki's *Dimensions of Time and Silence*, in which the wide leaps and overlapping ranges of the harp, keyboards, and percussion instruments obliterate any sense of melodic continuity in favour of a massed texture (Figure 9).

Pitch proximity can also be a strong factor in situations where most notes assimilate into a mass but a few "outliers" are marked to segregate into a separate auditory stream. For example, in section 5 of Lutosławski's Symphony No. 2, the three flutes play at independent tempi in an overlapping middle register at a relatively low dynamic level, promoting strong integration. After this texture has been established, the flutes occasionally interject high B-flats and A-naturals played staccato and forte (beginning in the second system of Figure 10), which split off distinctly into a separate stream.

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[44] Huron, "Tone and Voice," 24.
[45] Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition* (Bloomington: Indiana University Press, 1971), 8.

Figure 9: Krzysztof Penderecki, *Dimensions of Time and Silence*, rehearsal 10.[46]

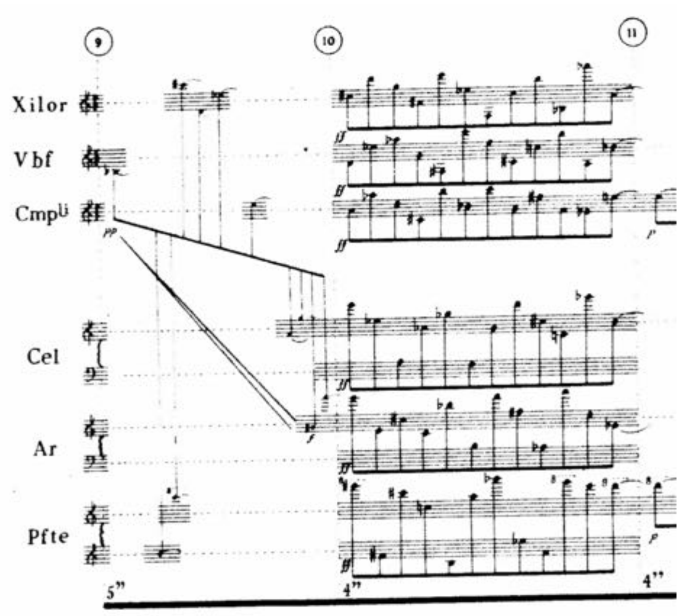
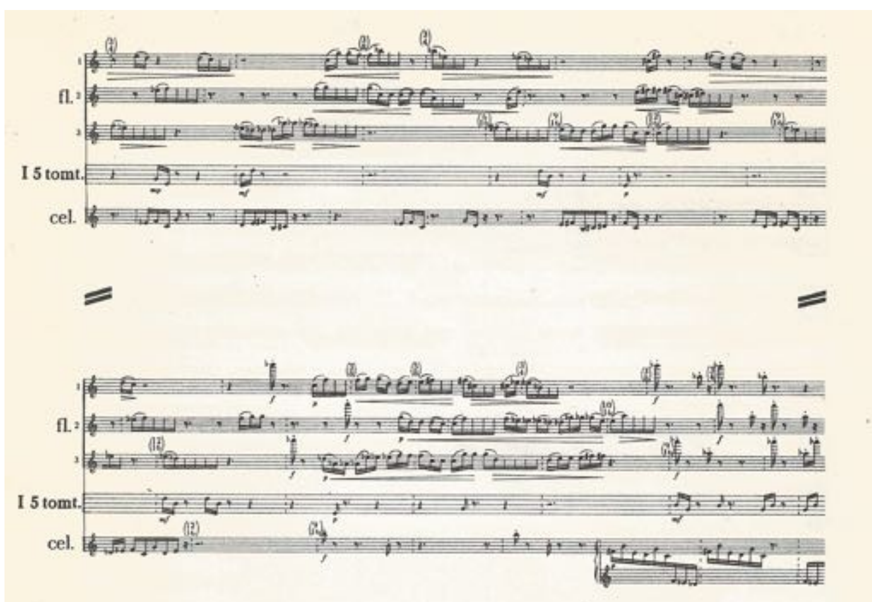


Figure 10. Witold Lutosławski, Symphony No. 2, section 5.[47]



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1.2.6 PITCH CO-MODULATION PRINCIPLE.

> *The perceptual union of concurrent tones is encouraged when pitch motions are positively correlated. Perceptual fusion is most enhanced when the correlation is precise with respect to log frequency.*[48]

This principle, along with the tonal fusion principle, provides the basis for that most famous of voice-leading rules: the ban on parallel fifths and octaves. Huron, drawing on an extensive series of experiments by Stephen McAdams,[49] states that synchronous, similar motion between parts causes them to group or fuse perceptually (the tendency is stronger when the motion is parallel, preserving not only contour but exact pitch intervals). Harmonic parallelism has been used in some music that would not normally be considered sound mass but that nevertheless exploits similar fusion-based aesthetic goals, such as Maurice Ravel's *Boléro* (1928) and Veljo Tormis's *Jaanilalud* (1967). It is an auditory adaptation of the Gestalt "law of common fate" which Emilios Cambouropoulos and Costas Tsougras describe thus: "objects that move together tend to be connected to each other and grouped together."[50] Semblant motion between lines is a musical example of common fate, but not the only one: other types of coherent motion can cause parts to group perceptually as well. An overarching global gesture that unites parts in their eventual trajectory, even if their paths vary with respect to one another along the way, promotes fusion as well. For example, in Xenakis's *Metastaseis* (1953-4), the final section (which is a retrograde of the opening section) begins with a wide "chord" consisting of 46 distinct pitches, one for each string instrument in the orchestra, organized in chromatic and whole-tone groupings. The instruments then gradually and asymmetrically converge via independent glissandi to a unison pitch. The glissandi are coordinated in groups of instruments with distinct, overlapping contours (Figure 11). More complex or idiosyncratic types of gestural similarity can promote grouping as well, especially when similar gestures overlap in multiple parts. This is the basis for microcanon (a subspecies of Ligeti's micropolyphony), for some of Lutosławski's aleatoric practices, and for the phased, EKG-like patterns in Penderecki's *Polymorphia* (see Figure 44, Chapter 3).

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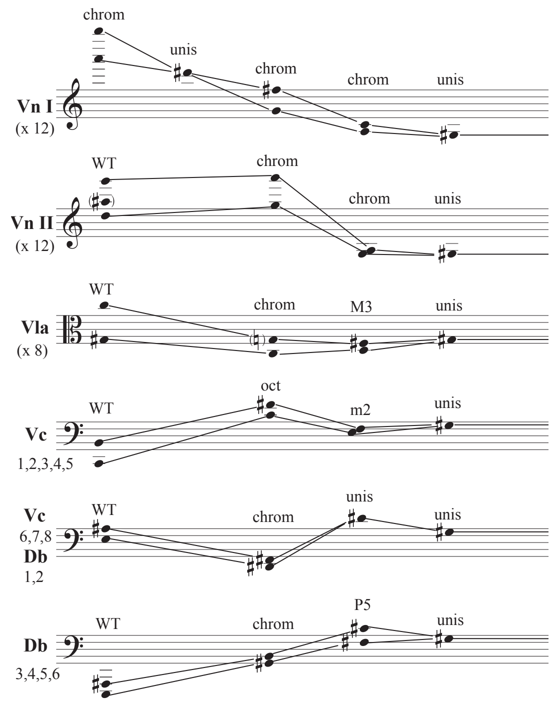
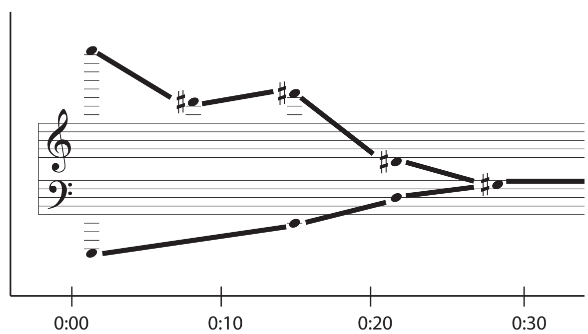
[48] Huron, "Tone and Voice," 21.
[49] Stephen McAdams, "Spectral Fusion and the Creation of Auditory Images," in *Music, Mind, and Brain: The Neuropsychology of Music*, ed. M. Clynes, 279-298 (New York: Plenum Press, 1982); Stephen McAdams, "Segregation of Concurrent Sounds. I: Effects of Frequency Modulation Coherence," *Journal of the Acoustical Society of America* 86 (1984a): 2148-2159; Stephen McAdams, *Spectral Fusion, Spectral Parsing and the Formation of Auditory Images* (PhD Dissertation, Stanford University, 1984b).
[50] Emilios Cambouropoulos and Costas Tsougras, "Auditory Streams in Ligeti's *Continuum*: A Theoretical and Perceptual Approach," *Journal of Interdisciplinary Music Studies* 3 nos. 1 & 2 (spring/fall 2009): 123-4.

Figure 11: (a) Sectional contours of Iannis Xenakis, *Metastaseis*, concluding section.

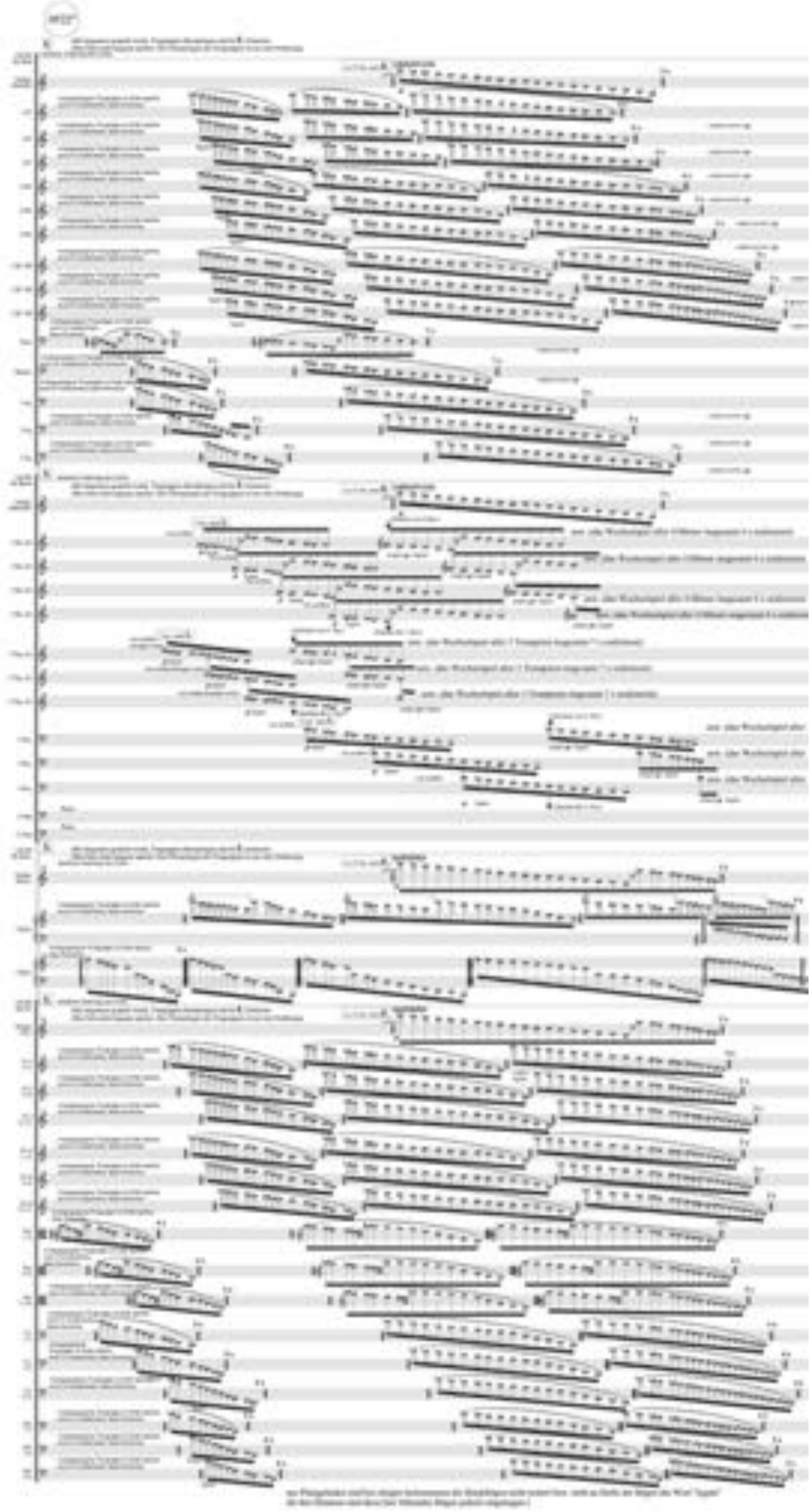


(b) Global contour of Iannis Xenakis, *Metastaseis*, concluding section.



Another example of common fate motion is the familiar "Shepard Tone" which creates an illusion of perpetual descent through its deployment of partials or pitches, with new sounds appearing at the top to replace those that disappear off the bottom in a kind of musical barber shop pole. Although an idealized synthetic Shepard Tone will preserve frequency ratios exactly, there are many musical examples in which a similar effect is achieved with only approximate correspondence between the trajectories of the parts, as in rehearsal L in Georg Friedrich Haas's *Hyperion* (2005; Figure 12).

Figure 12: Georg Friedrich Haas, *Hyperion*, rehearsal L.[51]



[51] Georg Friedrich Haas, "Hyperion" © 2006 by Universal Edition A.G., Wien/UE33400 www.universale-dition.com. Reproduced by permission.

1.2.7 ONSET SYNCHRONY PRINCIPLE.

> *If a composer intends to write music in which the parts have a high degree of perceptual independence, then synchronous note onsets ought to be avoided. Onsets of nominally distinct sounds should be separated by 100 ms or more.*[52]

A great amount of information that helps us identify the source of a sound is delivered in the attack phase; also, clearly defined onsets of sounds tend to draw our attention to the new sound event in the auditory scene. Therefore, if maintaining a massed totality is an aesthetic goal, it is expedient to attenuate the onsets of any new sounds entering the sonic texture, as Ligeti often did in his orchestral pieces with instructions such as "attack imperceptibly" (e.g. *Lontano*, 1967; Chamber Concerto, 1969-70; Double Concerto, 1972). If entries of new sounds are not attenuated, there is a strong tendency for those events to segregate into a separate stream. However, if other factors promote perceptual grouping between the new sounds and the extant mass, the new sounds may gradually assimilate into it. This occurs throughout Ligeti's organ étude *Harmonies* (1969), which consists almost entirely of a series of complex ten-note chords, with one new note replacing an old one in each measure at a free tempo. As new notes enter, they momentarily capture the listener's attention and segregate into a separate stream, but are soon re-submerged into the mass in the ever-changing, dense harmonic context:

Figure 13: György Ligeti, *Étude No. 1 "Harmonies,"* beginning.[53]

Onset synchrony is also an important factor in the perception of pulse and meter, as the coincidence of accented events at regular intervals provides clear markers to which the listener can entrain. Since clear meter promotes segmental listening—breaking up the music's temporal continuity into strong and weak beats, bars, and so forth—its aesthetic function runs contrary to the

[52] Huron, "Tone and Voice," 40.
[53] Ligeti TWO ETUDES FOR ORGAN, *No. 1: Harmonies*. Copyright © 1969 by Schott Music GmbH & Co. KG, Mainz, Germany. Copyright © renewed, All Rights Reserved. Used by permission of European American Music Distrinbutors Company, sole U.S. and Canadian agent for Schott Music GmbH & Co. KG, Mainz, Germany.

fusion-based aesthetic of sound mass, and many sound mass composers have avoided it accordingly. One way this has been done is through the avoidance of synchronous onsets between parts: even if there may be some implication of pulse or meter within parts individually, asynchrony of multiple superposed layers will tend to override any cues for metrical entrainment provided by any given part, resulting in what Jadwiga Paja has described as “diffusional aggregations” and “polymorphic polyphony” that create an “intermediate dimension” between the horizontal and the vertical.[54] This type of organization is particularly characteristic of Lutosławski’s “repeat cell” sections, quasi-indeterminate constructions that typically assign each musician a cell of musical material traditionally notated to specify both rhythms and pitches, which they may repeat freely at their own individual tempi without coordinating with the rest of the ensemble. The contents of Lutosławski’s repeat cells usually feature rhythmic groupings of different lengths and accent patterns between the players, as is the case in the example below from *Mi-Parti* (1976; Figure 14).

However, as Huron notes, synchronous onsets between parts can also *promote* sound mass fusion, as sounds that begin together tend to group together. This effect is especially salient in what Stephen McAdams and Moe Touizrar refer to as “punctuation blend,”[55] the kind of perceptual fusion that occurs when several instruments articulate notes with simultaneous onsets, short duration, and often a high dynamic for accentuation. Punctuation blend is well-illustrated at rehearsal 34 of Lutosławski’s Double Concerto for Oboe, Harp, and Chamber Orchestra (1980; Figure 15).

[54] Jadwiga Paja, “The Polyphonic Aspect of Lutosławski’s Music” (*Acta Musicologica* 62, no. 2/3, May-Dec, 1990), 186-189.
[55] Stephen McAdams, & Moe Touizrar, “Timbre and auditory grouping in relation to orchestration decisions in *The Angel of Death*,” (presentation, Symposium on "The interaction of scientific and artistic imagination: Perceptual studies and the making of music," Roger Reynolds' 80th Birthday Celebration, UC San Diego, February 2015)**.**

Figure 14: Witold Lutosławski, *Mi Parti* rehearsal 17.[56]

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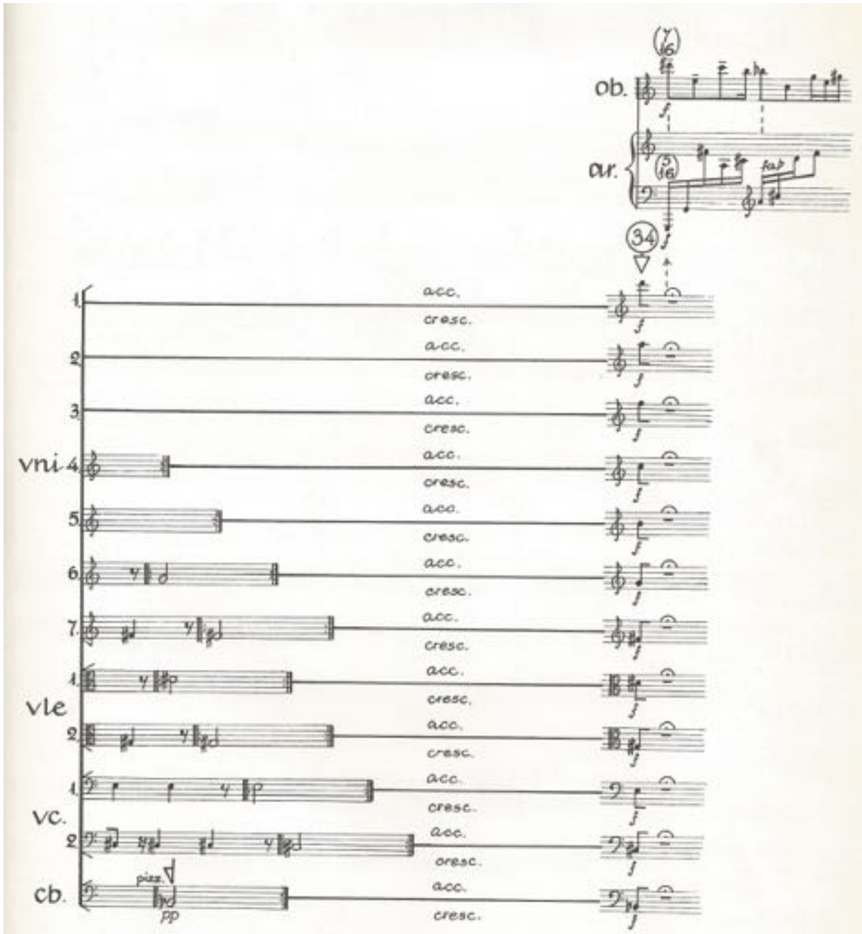
[56] MI-PARTI Music by Witold Lutosławski © Copyright 1976 by Polskie Wydawnictwo Muzycszne SA, Kraków, Poland. Transferred to Chester Music Ltd. © Copyright by Chester Music Ltd for the World except Albania, Bosnia and Herzegovina, Bulgaria, China, Croatia, Cuba, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, North Korea, Poland, Romania, Serbia and Montenegro, Slovakia, Slovenia, Ukraine, Vietnam and the Commonwealth of Independent States (CIS). All Rights Reserved. International Copyright Secured. Reprinted by permission.

Figure 15. Witold Lutosławski, Double Concerto for Oboe, Harp, and Chamber Orchestra, rehearsal 34.[57]



1.2.8 Principle of Limited Density.

If a composer intends to write music in which independent parts are easily distinguished, then the number of concurrent voices or parts ought to be kept to three or fewer.[58]

Huron explains that our ability to follow independent musical lines follows an "*un, deux, trois, beaucoup*"[59] pattern: once the number of concurrent parts exceeds three, our ability to follow them (or even to have a sense of how many there are) decreases dramatically. Therefore, if attenuating the perceptual salience of individual lines is an aesthetic goal, a simple (and much-

[57] DOUBLE CONCERTO FOR OBOE, HARP AND CHAMBER ORCHESTRA Music by Witold Lutosławski © Copyright 1981 Chester Music Limited for the World except Poland, Albania, Bulgaria, the Czech Republic and Slovakia, Romania, Hungary, the whole territory of the former USSE, Cuba, China, North Vietnam and North Korea where the Copyright is held by Polskie Wydawnictwo Muzyczne – PWM Edition, Krakow, Poland. All Rights Reserved. International Copyright Secured. Reprinted by permission.
[58] Huron, "Tone and Voice," 46.
[59] Huron, "Tone and Voice," 46.

exploited) technique is to have a large number of parts active at the same time. A quintessential example is Xenakis's pioneering treatment of each string instrument as an individual part in *Metastaseis* (1953-4) and *Pithoprakta* (1955-6), a practice which was soon adopted by Penderecki and Ligeti. Subversion of the principle of limited density is also at play in Ligeti's practice of micropolyphony, in which, according to the composer, "each single part, though imperceptible by itself, contributes to the character of the polyphonic network as a whole."[60]

It is important to note that the sheer number of parts does not in itself guarantee sound mass integration: if musical organization emphasizes collective properties such as metrical synchronization and tonal harmonic structure, then even for music with a large number of parts, impressions of density and unity by which sound mass has been characterized in this chapter may be evaded. Arnie Cox illustrates this point with reference to Thomas Tallis's 40-voice motet *Spem in Alium* (1570):

> The more complex the auditory scene, the greater the challenge for mimetic comprehension. For example, in the case of Tallis's forty-voice motet 'Spem in alium,' when most or all of the voices are singing at once, mimetic participation with particular voices becomes largely impossible. And yet there is still a straightforward mimetic invitation in connection with the composite vocal exertions. The meter, rhythms, and tempo emerge from a recurring general pattern of vocal exertions and these combine with a shared strength (acoustic intensity) and manner of articulation. At this level, mimetic participation in effect is with the composite emergent musical entity.[61]

In this example, despite the large number of parts, the emergent properties of the music *in toto* facilitate the kind of segmental analytical listening (and, in the language of embodied music cognition, "mimetic participation") that sound mass negates.

1.2.9 Timbral Differentiation Principle.

> *If a composer intends to write music in which the parts have a high degree of perceptual independence, then each part should maintain a unique timbral character.*[62]

Timbral homogeneity is a decisive factor in sound mass fusion (as has been supported by experimental evidence; see Chapter 4). Sound mass composers have intuitively understood this, frequently either writing for timbrally homogeneous ensembles (e.g. string orchestra) or deploying

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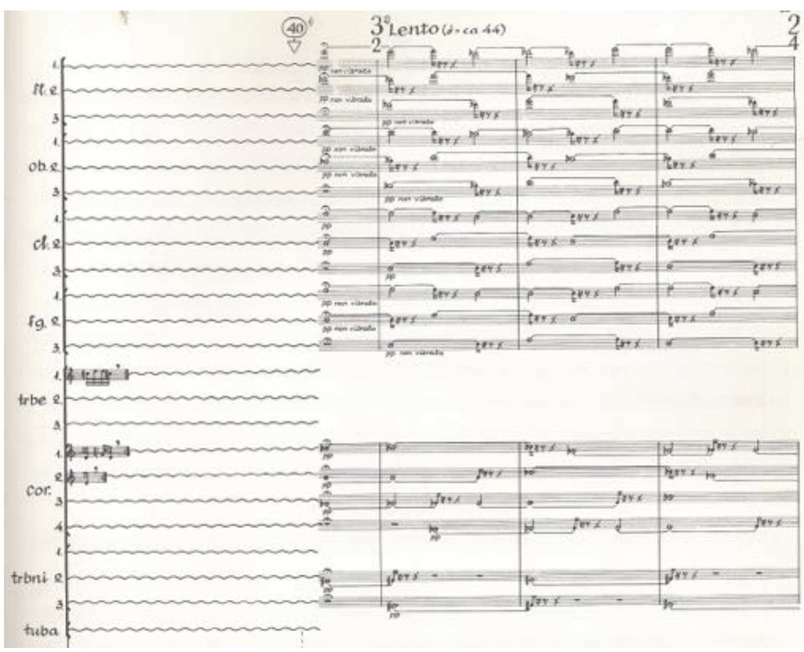
[60] Ligeti, "Ligeti in Conversation," 136.
[61] Arnie Cox, *Music & Embodied Cognition: Listening, Moving, Feeling & Thinking* (Bloomington: Indiana University Press, 2016), 49-50.
[62] Huron, "Tone and Voice," 49.

timbres in homogeneous subsets of mixed ensembles, as, for example, Lutosławski does in his Symphony No. 2 and Cello Concerto (1970). When attempting to achieve sound mass fusion with heterogeneous ensembles, dynamics, articulations, and other playing techniques serve important roles. For example, sounds played very softly and without vibrato lose some of the spectral cues that mark their timbral salience and therefore allow them to blend more easily, as in rehearsal 40 of Lutosławski's *Mi-Parti* (Figure 16).

Alternately, the heterogeneity of ensemble timbres can be overwhelmed with fortissimo dynamics and noise, as in the tutti climax at rehearsal F of Toru Takemitsu's *Asterism* (1969). The interaction between timbre and dynamics can be also used to nuanced aesthetic effect, allowing for a kind of timbral counterpoint in a heterogeneous massed ensemble texture. Ligeti exploits this throughout *Lontano* (1967), with timbral layers coming into the foreground through crescendi before submerging back into a pianissimo large ensemble massed texture: two striking moments of this kind are the emergent foregrounding of the violins in m. 11 which are then displaced by the flutes and oboes a measure later, and, the dramatic overturning from a string-dominated to a brass-dominated timbral mass in mm. 93-98.

Figure 16: Witold Lutosławski, *Mi-Parti*, rehearsal 40.[63]



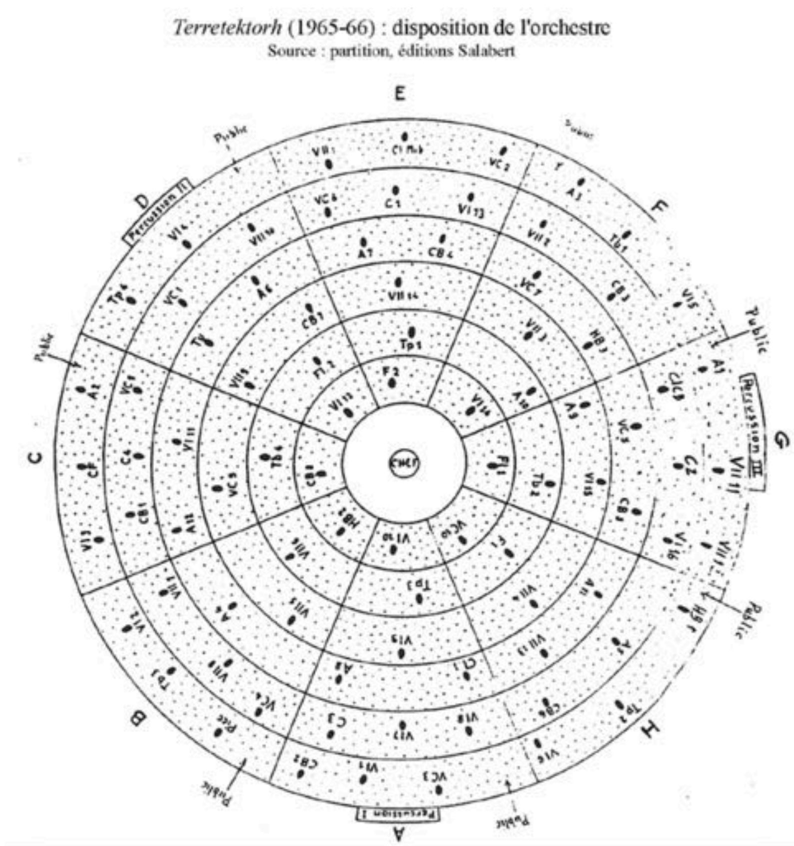
[63] MI-PARTI Music by Witold Lutosławski © Copyright 1976 by Polskie Wydawnictwo Muzycszne SA, Kraków, Poland. Transferred to Chester Music Ltd. © Copyright by Chester Music Ltd for the World except Albania, Bosnia and Herzegovina, Bulgaria, China, Croatia, Cuba, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, North Korea, Poland, Romania, Serbia and Montenegro, Slovakia, Slovenia, Ukraine, Vietnam and the Commonwealth of Independent States (CIS). All Rights Reserved. International Copyright Secured. Reprinted by permission.

1.2.10 Source Location Principle.

> *If a composer intends to write music in which the parts have a high degree of perceptual independence, then it is helpful to separate in space the various sound sources for each part.*[64]

As will be discussed at length in Chapter 3, spatial imagery and metaphors are intimately linked with sound mass. But beyond metaphorical association, literal spatial positioning of sound sources occasionally figures as an artistic parameter in sound mass compositions. For example, in Xenakis's *Terretektorh* (1965-66), the musicians of the orchestra are interspersed among the audience, such that, according to Maria Anna Harley, "[t]he proximity of the sound creates a new aural experience strengthened by the movement of sound masses in space."[65]

Figure 17: Iannis Xenakis, *Terretektorh*, seating plan.[66]



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[64] Huron, "Tone and Voice," 51.
[65] Maria Anna Harley, "Spatial Sound Movement in the Instrumental Music of Iannis Xenakis," *Journal of New Music Research* 23 no. 3 (1994): 300.
[66] *Terretektorh* by Iannis Xenakis. © Copyright 1967 by Boosey & Hawkes Music Publishers Ltd. Reprinted by Permission of Boosey & Hawkes, Inc.

1.3 SOURCE BONDING

In addition to the various sound mass techniques discussed so far, electronic technology makes it possible to introduce recorded samples of "real-world" sound masses, such as the sounds of herds of animals, crowds of people, wind, water, and various other environmental sources, into a musical context. This has been an important feature of electracoustic compositional practices such as *musique concrète* and soundscape composition. For example, in Trevor Wishart's electroacoustic piece *Vox 5*, a human voice phonating on a voiced alveolar fricative [z] transforms into the sound of a swarm of bees, and then back into a human voice.

1.4 SOUND MASS PARAMETERS

As the above discussion demonstrates, sound mass integration can be achieved in many different ways. Developing a rigorous analytical method that could account for all such procedures would be a monumental task, and is not the focus of this dissertation. Nevertheless, a number of relevant parameters may be identified for consideration in sound mass analysis:

Table 1: Sound mass parameters.

A. Timbre
Spectral quality of sound components (harmonic/inharmonic/noise-based) Attack quality of sound components (articulation) Uniformity of sound components (homogeneous/heterogeneous) Orchestration (instrumental identities) Consistency (stable/transforming)
B. Rhythm
Relative durations of sound events Relative degree of activity Periodicity (pulsed/non-pulsed, metrical/ametrical) Coordination (synchronous/asynchronous)
C. Pitch
Stability (discrete pitches/glissandi) Tessitura (above, within, or below range of maximal pitch salience) Compass (wide range/narrow range) Distribution (global density, local densities) Harmonic structure (e.g. spectral, diatonic, chromatic, microtonal)
D. Dynamics
Loudness Variability (static/dynamic)
E. Gesture
Coherence (presence or absence of global trajectory) Stratification (one perceptible layer/multiple perceptible layers) Similarity of local gestures between parts Overlap of gestures between parts

1.5 SUMMARY

In this chapter, I have reviewed various definitions and conceptualizations of sound mass in the extant literature, including one from a paper in which I was a co-author. I critiqued those existing definitions, and offered a new one in light of ensuing observations and reflections, including recent experimental findings (see Chapters 2 and 4). I surveyed a representative sample of works to demonstrate various ways that sound mass integration may be achieved, focusing on four composers associated with the aesthetic and conceptual development of sound mass: Iannis Xenakis, Krzysztof Penderecki, György Ligeti, and Witold Lutosławski. I have not attempted to compile an exhaustive list of sound mass compositions, nor to provide an historical or biographical account of the development of sound mass. Instead, I have focused on identifying shared sonic and musical features across the repertoire that contribute to sound mass perception. I structured this discussion around ten principles identified by David Huron as providing the perceptual foundation for tonal voice leading, because I believe the same principles also provide the basis for sound mass perception, albeit via practices and aesthetic aims that run directly contrary to the practices of tonal counterpoint. Having thus theoretically identified some of the perceptual principles operative in sound mass perception, I turn now to experiments conducted in order to corroborate their validity with empirical evidence.

Chapter 2: Empirical Research on Sound Mass Perception

2.1 INTRODUCTION

Sound mass has been an important and influential concept in music in the decades since its inception in the 1950s and 1960s, and yet many questions about its perception remain unanswered. To what extent do listeners agree on whether or not a particular combination of sounds constitutes a sound mass? Is it possible to identify specific musical parameters and values that define the threshold(s) of sound mass perception?

It follows from the discussion in the previous chapter that sound mass is not simply the whole of the auditory scene, an unqualified assimilation into which all heard sounds and sound components are subsumed. Sound mass involves perceptual grouping, but it is not necessary that *all* perceived sounds at any given time be grouped into the mass. It may be possible, for example, to perceive multiple sound masses simultaneously: a roaring fire and a flock of seagulls, or the rustling of leaves and the rush of a river. Also, sound mass may coexist in the perceptual field with other, segregated streams, as when we perceive the ambient noise of a crowd as a sound mass but nevertheless distinguish the voice of the person next to us in conversation. With respect to music, sound mass may be considered a matter of degree: masses may be tightly fused or more loosely integrated; all of the sound events in a given texture may be fused or some may segregate into separate auditory streams; different grouping factors may cause multiple simultaneous musical sound masses, for example, one based on sustained pitch density in a low register, and another based on rapid common fate motion in a higher register. As a piece of sound mass music unfolds over time, the type/extent of fusion it employs is not necessarily fixed but may be variable, and may provide a source of musical dialectic: a polar but continuous opposition of *segregation-integration* that evolves over musical time.

This idea is intuitive enough, but evaluating the extent to which listeners experience music in this way can be challenging. Some relevant factors are intersubjectively variable, such as familiarity and attentiveness. With regards to the stimuli, some of the factors that affect sound mass fusion are covariant (e.g. timbre, register, pitch, and dynamics), making it difficult to determine which factor(s) cause segregation or integration at any given point in time. Depending on the compositional method, sound mass may be achieved in many different ways that may vary widely from piece to piece or within a single piece. Such diversity makes it impossible to provide a general account of sound mass perception on the basis of any one piece, composer, or method, and it is difficult to isolate variables experimentally using real music because there are few pieces in the sound mass repertoire in which any variables are held constant. Fortunately, such pieces do exist.

2.2 LIGETI'S *CONTINUUM*

One example is Ligeti's *Continuum* (1968, published 1970), in which the attack rate is constant from beginning to end. There are no tempo changes in the piece and the notated rhythm appears as a steady stream of eighth notes instructed to be played "as fast as possible, so that the individual tones can hardly be perceived, but rather merge into a continuum."[67] Ligeti exploits a perceptual phenomenon that has been common currency among composers for centuries in devices such as trills, tremoli, and drumrolls. As Danuta Mirka describes it, "the peculiarity of tremoli was exactly that successive, repeated impulses...merged into a phenomenon whose component sounds were only barely discernible by a listener ... [standing] at the border between temporal continuity and temporal discontinuity."[68] In *Continuum*, this perceptual phenomenon is foundational rather than ornamental. Speaking about this piece, Ligeti said:

> I thought to myself, what about composing a piece that would be a paradoxically continuous sound, something like *Atmosphères*, but that would have to consist of innumerable thin slices of salami? A harpsichord has an easy touch; it can be played very fast, almost fast enough to reach the level of continuum, but not quite (it takes about eighteen separate sounds per second to reach the threshold where you can no longer make out individual notes and the limit set by the mechanism of the harpsichord is about fifteen to sixteen notes a second). As the string is plucked by the plectrum, apart from the tone you also hear quite a loud noise. The entire process is a series of sound impulses in rapid succession which create the impression of continuous sound.[69]

Ligeti identifies the maximum speed of articulation on the harpsichord at 15-16 Hz, right in the middle of the "no-man's-land" between rhythm and pitch (see Chapter 1).

[67] Ligeti, *Continuum* (Mainz: B. Schott's Söhne, 1970), 1.
[68] Mirka, 287.
[69] György Ligeti et al., *Ligeti in Conversation with Péter Várnai, Josef Häusler, Claude Samuel, and himself* (London: Eulenburg, 1983), 22-3.

Ligeti is not the only author to specify a frequency limit for sound mass fusion ("the level of continuum"); Barry Truax[70] and Curtis Roads[71] both define the slightly faster value of 20 attacks/s as the threshold of continuum in granular synthesis, while Gérard Grisey[72] specifies 20 Hz as the threshold separating the perception of pulsation from timbral fusion. The value of 20 events/s is known to be perceptually significant, having been used as the number of frames per second in some early films to exploit the visual phenomenon of apparent motion,[73] and defining the fuzzy boundary between pitch and infrapitch perception in audition.[74] John MacKay states that the possibility of rhythmic structure disappears from granular sequences at rates of succession of 15 tones per second or higher,[75] and Justin London identifies the longer value of ca. 100 ms (i.e., 10 attacks/s) as "the shortest interval that we can hear or perform as an element of rhythmic figure,"[76] implying that faster values are sub-rhythmic, beyond our ability to resolve temporally. However, it is questionable whether attack rate alone is a sufficient predictor of sound mass perception. If Ligeti's claim that the threshold of continuum is 18 sounds/s is universally true, then all music that achieved that attack rate should be perceived as sound mass. Furthermore, there should be no variation in the perception of sound mass over the course of a piece such as *Continuum* in which the attack rate is constant.

But as is acknowledged by all who have written about *Continuum*, including Ligeti himself, the rhythm perceived by the listener is not reducible to this attack rate but rather arises from patterns in the notes. This piece has received considerable scholarly attention, with much interest aroused by the apparent contradiction between the music as notated and its perceptual reality. Several authors have gone as far as to describe *Continuum* as a perceptual experiment,[77] and

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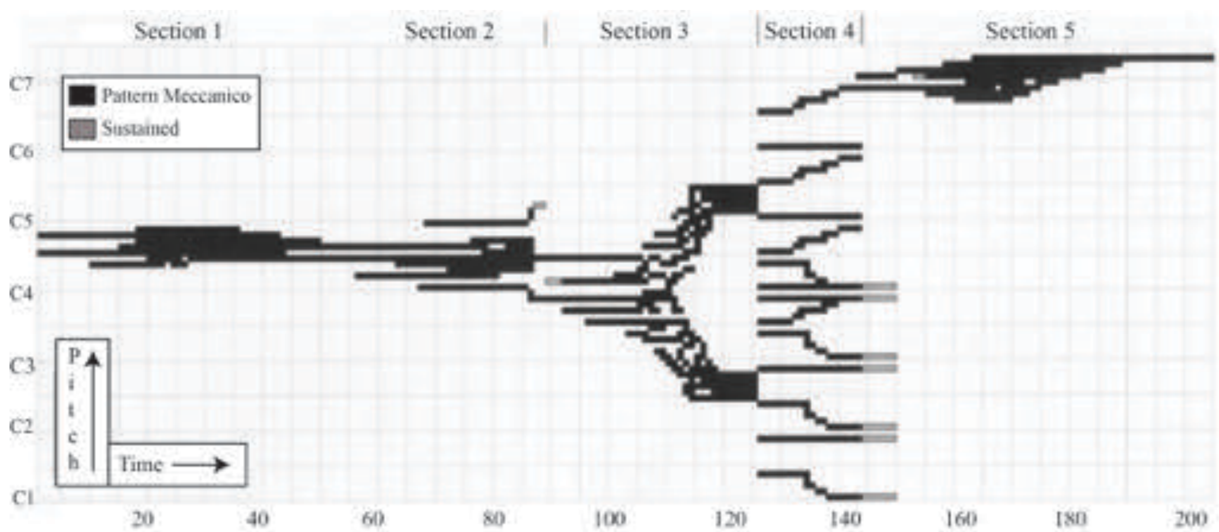
70 Barry Truax, "Real-Time Granular Synthesis with a Digital Signal Processor," *Computer Music Journal* 12, no. 2 (1988): 18.
71 Curtis Roads, "The Perception of Microsound and its Musical Implications," *Annals of the New York Academy of Sciences* 999, no. 1 (2003): 274-5.
72 Gérard Grisey, "La musique : Le devenir des sons" (written in 1982), in *Écrits ou l'invention de la musique spectrale*, ed. Guy Lelong & Anne-Marie Réby (Paris: Musica Falsa, 2008), 49.
73 Julie Brown, "Audio-visual palimpsests: resynchronizing silent films with 'special' music," in *The Oxford Handbook of Film Music Studies*, ed. David Neumeyer, (Oxford: Oxford University Press, 2014), 588-610.
74 Richard Warren, *Auditory Perception: An Analysis and Synthesis*, 3rd ed., (New York: Cambridge University Press, 2008), chap. 3.
75 MacKay, 175-76.
76 Justin London, *Hearing in Time: Psychological Aspects of Musical Meter* (Oxford: Oxford University Press, 2004), 27.
77 Heinz-Otto Peitgen, "Continuum, chaos and metronomes – A fractal friendship," in *György Ligeti: Of Foreign Lands and Strange Sounds*, ed. Louise Duchesneau & Wolfgang Marx, (Woodbridge, UK: The Boydell Press, 2011), 87-106.

(anachronistically) as a piece based on granular synthesis.[78] Jane Piper Clendinning identifies *Continuum* as one of Ligeti's "pattern-meccanico" pieces, which were inspired by his fascination with machines and mechanical sounds. The pattern-meccanico pieces are constructed from "small groups of pitches rapidly repeated in a mechanical fashion with gradual changes of pitch content," the units of which are "repeated quickly enough that the pitches almost fuse into a chord."[79] Clendinning provides a helpful visualization of the varying pitch densities and compasses that unfold over the course of the piece (Figure 18). This graph, essentially a condensation of the score, depicts pitch on the y axis and time on the x axis. Any "division" (they are not really measures, as Ligeti's barlines are dotted and he specifically prohibits metric accent) in which a pitch appears in a meccanico pattern is represented by a black box, and any division in which a pitch is sustained is represented by a grey box. The thick, filled regions of the graph in Figure 18 thus represent areas of high pitch density, whereas areas with space between horizontal bands represent defined intervals. If, as is commonly assumed, pitch density correlates with sound mass perception, we would thus expect the thick, filled areas to correspond with the places in the piece that exhibit the highest degree of perceptual fusion.

Figure 18: Analysis of the pitch structure in *Continuum*, © Jane Piper Clendinning 1993. Reproduced by permission.

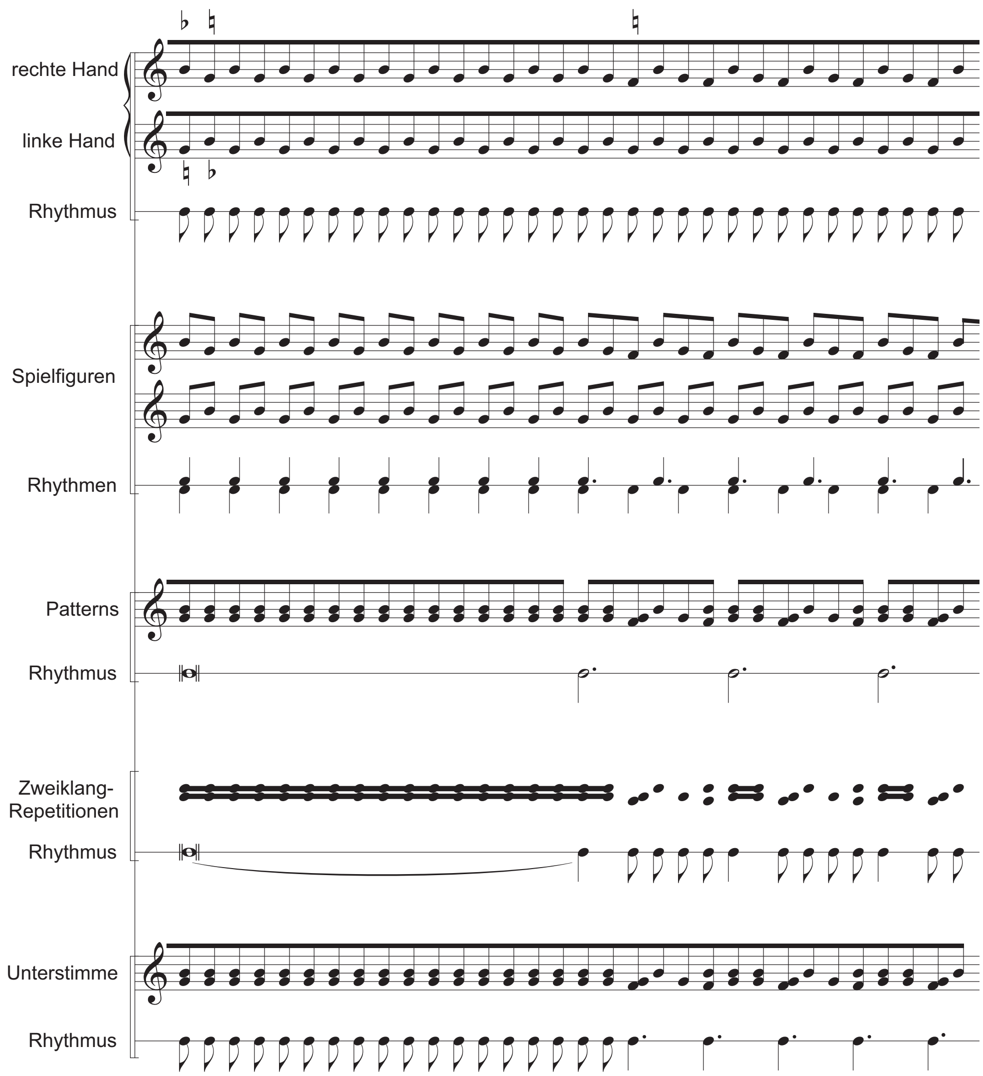


[78] Cambouropoulos & Tsougras, 123. John MacKay's study "On the perception of density and stratification in granular sonic textures: An exploratory study" (*Journal of New Music Research* 13, no. 4 (1984): 171-186) approaches similar perceptual questions to those explored in this paper, with specific focus on the textures of granular synthesis.
[79] Jane Piper Clendinning, "The Pattern-Meccanico Compositions of György Ligeti," *Perspectives of New Music* 31, no. 1 (Winter, 1993): 195.

A comprehensive analysis of the piece's rhythmic organization is provided by Peter Petersen,[80] who describes it as composed of three types of building blocks: "Pendel, Sägezahn und Welle" (pendulum, sawtooth, and wave). The first is the directionless alternation of two notes, the second is a unidirectional pattern of three notes or more, always ascending in the left hand (LH) and descending in the right hand (RH), and the third is a bidirectional oscillating pattern of three notes or more. The superposition of such patterns, especially when the patterns in RH and LH are of different lengths or are asynchronous, gives rise to many possible perceived rhythmic groupings depending on the directed attention of the listener. In the excerpt analyzed in Figure 19, the left hand plays a pendulum pattern throughout, while the right hand begins with a pendulum and moves to a sawtooth. As this figure shows, the rhythm (after the right hand has initiated the sawtooth pattern) may be perceived in several different ways depending on the directed attention of the listener: as a steady stream of eighth notes if the listener attends to the most basic level of rhythmic organization (*Rhythmus* on line 3), as a two-against-three pattern if the listener attends to the groupings played by each hand (*Spielfiguren*), as an overall pulse of six eighth-notes if the listener attends to completed cycles of the two-against-three pattern (*Patterns*), as a group of four non-repeating pitch combinations followed by a repeated G – B-flat dyad if the listener attends to repetition (*Zweiklang-Repetitionnen*), and as a period of three eighth-notes if the listener attends to the lowest pitch F as the marker of periodicity (*Unterstimme*). In other words, the rhythm of the piece is *emergent*, determined by factors such as pitch organization and periodicity that at times can cause the music to segregate perceptually into multiple streams if those factors attract the listener's attention. Over the course of the piece, changing periodic patterns and pitch structures of varying degrees of complexity exploit emergent rhythm as a primary organizational feature, with potentially significant implications for sound mass fusion which will be explored below.

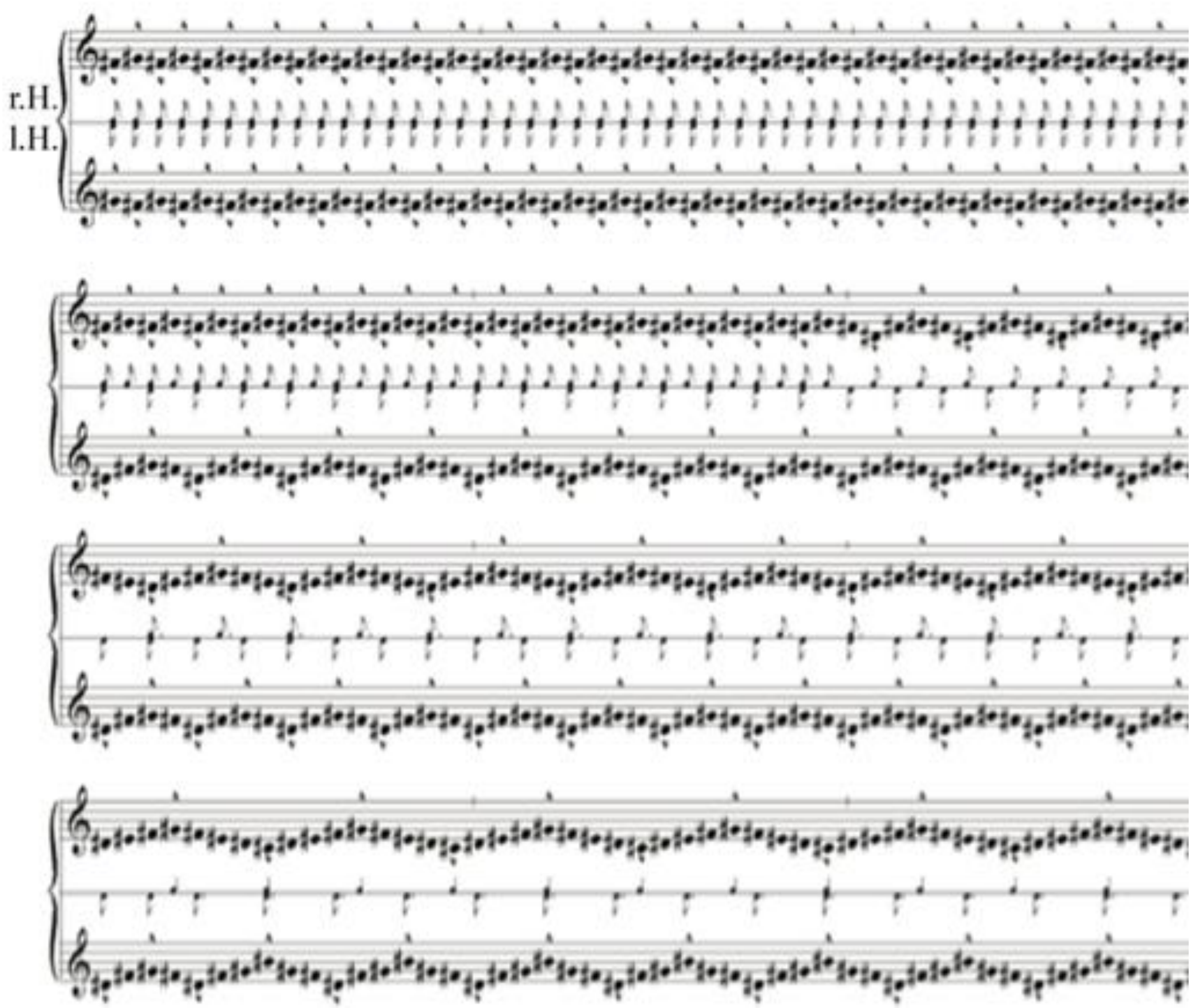
[80] Peter Petersen, *Jede zeitliche Folge von Tönen, Klängen, musikalischen Gestalten hat Rhythmus. Über die Rhythmik in Ligetis Cembalostück* Continuum [Each time sequence of tones, sounds, musical forms has rhythm. On rhythm in Ligeti's harpsichord piece Continuum], 2008.

Figure 19: Analysis of component rhythms in *Continuum*, © Peter Petersen 2008. Reproduced by permission.



An interesting consequence of the construction of *Continuum* as a series of dyads is that the greater the number of pitches present in any given pattern, the more distinct its emergent rhythm will become. Other pieces, such as Ligeti's orchestral works *Lontano* and *Atmosphères*, may use density or complexity of pitch structure as a mechanism by which to evoke sound mass, but here the situation is rather different. Because only two pitches are articulated at any given instant, emergent rhythm and pitch structure are likely to operate at cross-purposes in terms of perceptual fusion. This inverse relation is illustrated visually in Figure 20: the pendulum pattern in the first system appears as a continuous stream of identical dyads, but the wave that emerges as more notes are added to the pattern below segregates into a series of discrete gestures with clear high and low points. At a tempo of 18 attacks/s, the pendulum would have a periodicity of 55 ms (ca. 1090 beats per minute) and would certainly be sub-rhythmic, whereas the longest wave patterns (8 notes long) would have a periodicity of 444 ms (ca. 135 beats per minute), well within the range London identifies for beat or pulse perception.[81] Thus more complex pitch structures, which under other circumstances may result in greater sound mass integration, here result in emergent rhythm likely to promote auditory stream segregation; and conversely, simpler pitch structures, which might otherwise promote stream segregation, result in the attenuation or abolition of emergent rhythm and hence promote sound mass fusion.

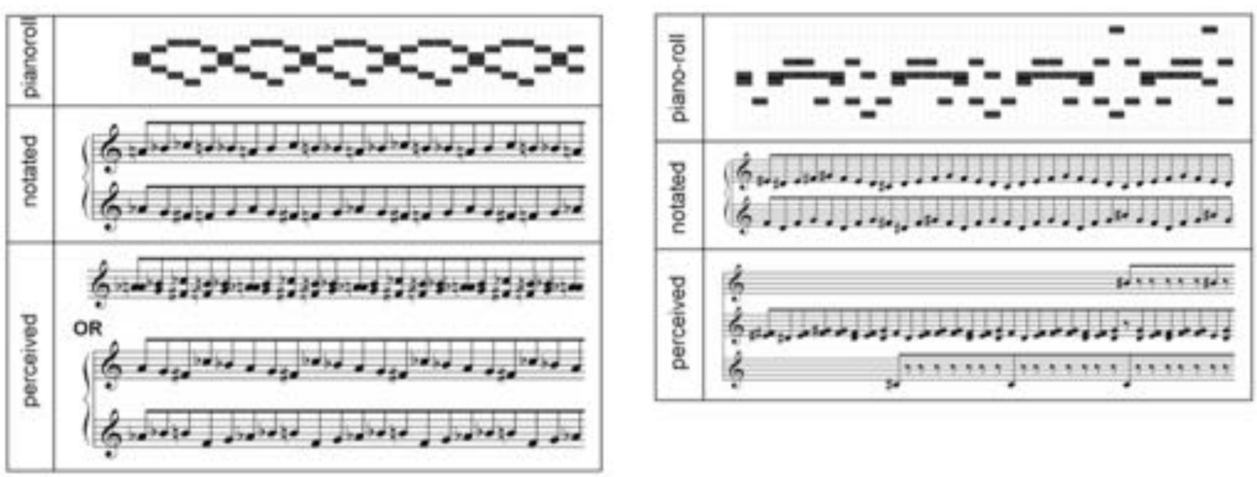
Figure 20: Pendulum and wave patterns of varying lengths in *Continuum*, © Peter Petersen 2008. Reproduced by permission.



[81] London, *Hearing in Time*, 46.

Because, as we have seen, emergent rhythm and other cues likely to promote stream segregation vary with musical organization, it is likely that the degree of sound mass perception will vary over the course of the piece, being highest when such cues are most attenuated, and lowest when they are most clear. Emilios Cambouropoulos and Costas Tsougras have analyzed the piece explicitly in terms of auditory scene analysis, presenting "a theoretical-analytical discussion of the implication of perceptual principles on our understanding of the structure of *Continuum*," and thereby analyzing the differences between the music as "notated" (a continuous series of eighth notes) and "perceived" (superposed auditory streams of variable organization). For example, in Figure 21, two excerpts from the piece are depicted first in "piano roll" notation, then as they appear in the score, and finally as they are "perceived," with each staff representing a distinct auditory stream. Note that in the second example, the pitch proximity principle described in Chapter 1 is particularly important as the high B#s, separated by a major third while all other pitches are separated by seconds, emerge as a separate stream of "outliers."

Figure 21: Piano-roll notation, notation in the score, and putative perceived organization as interpreted by Cambouropoulos and Tsougras (2009). © 2009 by *Journal of Interdisciplinary Music Studies*. Reproduced by permission.

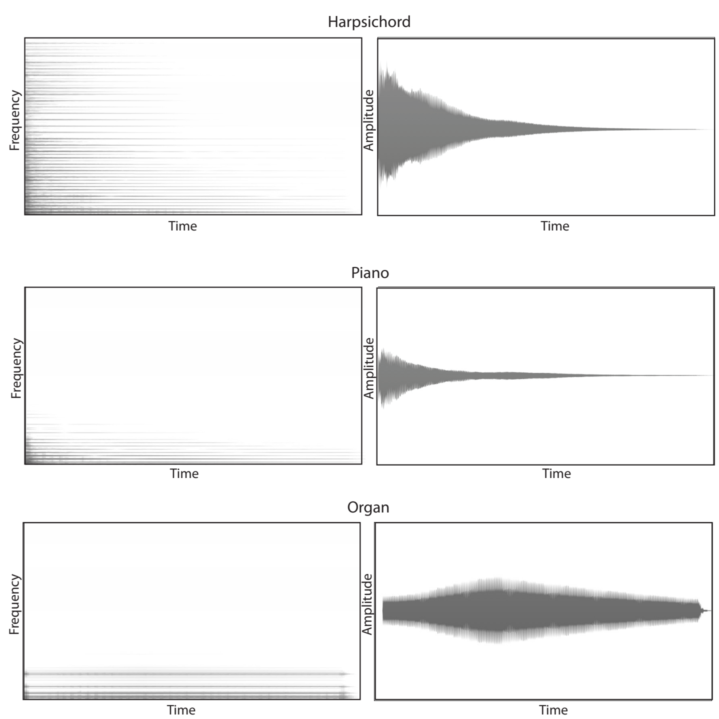


Cambouropoulos and Tsougras did not test their findings empirically, relying instead on musical analysis to determine how the piece will be perceived and stating that "in future work, a perceptual study may be carried out testing the hypothesis of streaming in this musical piece."[82] This is one of the aims of the present study.

[82] Cambouropoulos & Tsougras, 127.

Continuum is likely best known in its original version for harpsichord, but Ligeti also produced two other versions: one for two player pianos, the other for barrel organ. The piece thus provides an interesting opportunity to compare the effect of different timbres on sound mass perception without artificially modifying the composer's work. As can be seen in the amplitude envelopes on the right in Figure 22, the harpsichord's attack is much sharper and decay much more rapid than those of either the piano or the organ. As seen in the spectrographs on the left of Figure 22, the harpsichord also has a considerably greater spectral extent leading to a higher spectral centroid, which can be expected to correlate with a higher degree of perceived "brightness" and timbral saliency. These perceptual cues would seem likely to draw attention to the individual identities of harpsichord notes, creating obstacles to perceptual fusion. The organ, on the other hand, has a very soft attack, homogeneous sustain, and much lower spectral centroid, which would seem to provide fewer cues for the demarcation of individual notes and to promote fusion. All other things being equal, then, we would expect the harpsichord to yield an overall lower degree of sound mass perception than the other two instruments, or to require a higher attack rate in order to achieve the same degree of sound mass perception.

Figure 22: Spectrographs (left panels) and amplitude envelopes (right panels) of the pitch G4 played on the harpsichord, the piano, and the organ.



To summarize, in Experiment 1 we sought to experimentally evaluate the following hypotheses with respect to the three versions of Ligeti's *Continuum*:

(1) The degree of sound mass perception will vary over the course of the piece according to musical organization.

(2) The rate of attack required for sound mass perception is not an absolute value as has been previously suggested. It will interact with other musical and psychoacoustic factors such as timbre, register, and musical organization.

(3) Pitch density correlates positively with sound mass perception but this correlation does not indicate simple one-to-one causation, as is often assumed. Pitch density interacts with other musical and psychoacoustic factors in sound mass perception. In *Continuum*, the interaction between pitch structure and emergent rhythm will be especially consequential.

(4) The three instrumental timbres will differ in their proclivity for sound mass perception in the following increasing order: harpsichord, piano, organ. This ranking is based on sharpness of attack, brightness of timbre (spectral centroid), and rate of decay.

2.3 Experiment 1

2.3.1 Introduction

We sought to determine whether sound mass perception in *Continuum* is constant (like its attack rate) or variable (like its musical organization). We also sought to determine whether or not instrumental timbre affected sound mass perception when attack rate and musical organization remained constant. By comparing listeners' self-reported continuous responses of degree of sound mass perception between the three versions of *Continuum*, we expected to observe: (1) changing responses over the course of the piece, varying according to register, pitch organization, and emergent rhythm, and (2) overall lower ratings for the harpsichord, medium for the piano, and higher for the organ, based on their acoustic characteristics.

2.3.2 Method

2.3.2.1 *Participants.*

Forty participants, between 18 and 64 years of age (M = 25, SD = 9.6), completed the experiment. Twenty-one participants reported formal music training, ranging from 5 to 52 years of practice (*M* = 13, *SD* = 9.8). The remaining participants reported no music training at a collegiate level and no more than a year of formal music training during childhood (*M* = 0.35, *SD* = 0.49). Prior to completing the experiment, all participants passed a pure-tone audiometric test using a MAICO MA 39 (MAICO Diagnostic GmbH, Berlin, Germany) audiometer at octave-spaced frequencies from 125 Hz to 8 kHz (ISO 389–8, 2004; Martin & Champlin, 2000) and were required to have thresholds at or below 20 dB HL to proceed. Each participant completed the same task and was paid $5 Canadian as compensation. All signed informed consent forms prior to participating in the experiment.

2.3.2.2 *Stimuli*.

The stimuli consisted of recordings of the three versions of *Continuum*: for harpsichord, piano, and organ. Besides instrumentation, all musical parameters were identical in the three versions, following Ligeti's score exactly. The stimuli were created in Finale 2011 rendered into sound with the Garritan Sound Library and were 3 min 48 s in duration with a consistent tempo of 16 attacks/s. Audio signals were sampled at 44.1 kHz with 16-bit amplitude resolution. Additionally, a recording of Ligeti's organ étude *Coulée* was used as a practice trial to familiarize participants with the type of music they would be hearing and the experimental interface.

2.3.2.3 *Procedure.*

Participants completed the experiment individually inside an Industrial Acoustics model 120-act3 double-walled sound isolation booth (IAC Acoustics, Bronx, NY). The pieces were amplified with a Grace Design m904 monitor system and heard over circumaural Sennheiser HD280 Pro earphones (Sennheiser Electronic GmbH, Wedemark, Germany) at an average level of 60 dB SPL for all participants. The different instrument versions were presented once each in a randomized order for each participant.

The participants completed the experiment on an iPad interface (Apple Computer, Inc., Cupertino, CA). The interface was created in the mrmr OSC controller application (Redlinger, 2008) and consisted of four play buttons, one for the practice trial and one for each of the three test trials, as well as a continuous slider scaled from "No Sound Mass" to "One Complete Sound Mass." The iPad communicated via OpenSoundControl (Center for New Music and Audio Technologies, Berkeley, CA) messages over a wifi network with a Max/MSP version 5.1.9 (Cycling

'74, San Francisco, CA) patch run on a Mac Pro computer (Apple Computer, Inc., Cupertino, CA). The Max/MSP patch was designed to randomize and play the stimuli as well as record and output the ratings.

Participants continuously rated sound mass perception while listening to each version of *Continuum*. Data were collected at a rate of 2 Hz. In the instructions, they were given the following description:

> Sound mass is a type of music in which sounds lose their individual identities and are heard as a totality; it is similar to the way that voices in a crowd can become difficult to distinguish as individuals, but become integrated into the sound of the crowd as a whole.

Participants were informed that a rating of "No Sound Mass" meant that the sounds they heard retained their distinct, individual character. A rating of "One Complete Sound Mass" meant the sounds they heard were completely integrated into a single mass. Finally, an intermediate rating would represent situations in which some but not all of the sounds were integrated into a sound mass or the sounds were partially integrated but still retained some of their individual identities. In the Results section, we will refer to ratings towards "One Complete Sound Mass" as high ratings and ratings towards "No Sound Mass" as low ratings.

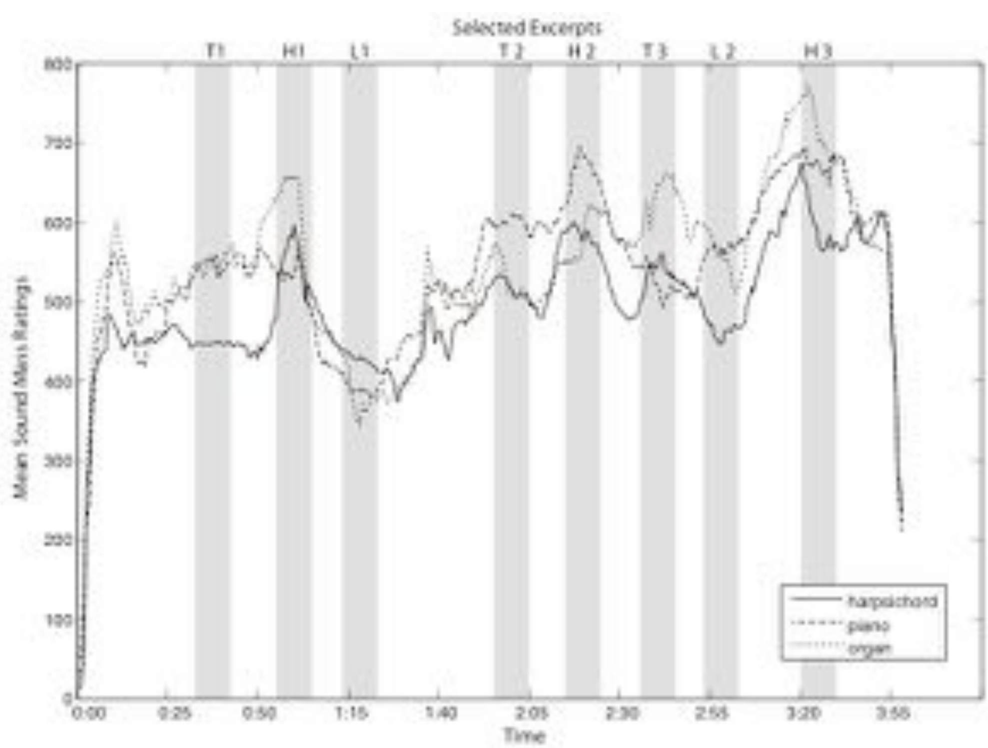
2.3.3 RESULTS

The averages of the continuous ratings of all participants for each instrumental version are shown in Figure 23. Based on this visual representation of the results, we chose eight excerpts to analyze statistically. We specifically chose excerpts that represented areas of high ratings and low ratings so we could analyze these sections musically and use the theoretical analysis to explain the differences in the perceptual ratings. Additionally, we wanted to examine excerpts in which there appeared to be difference in ratings between the instrumental versions, to determine whether or not timbral differences were significant predictors of variance in these excerpts. All selected excerpts were 10 s in duration and therefore consisted of 20 data points each. Of the eight excerpts, three represented areas of high sound mass ratings (labeled H1, H2, H3 in Figure 24) and two represented areas of low sound mass ratings (L1, L2). Additionally, three excerpts (T1, T2, T3) were chosen for comparisons of influences of the three different instrumental timbres. In all analyses of variance, Mauchly's test was used to test for violations of sphericity, and if significant, the degrees of freedom were corrected using the Greenhouse-Geisser epsilon if $\varepsilon \leq 0.75$ and the Huynh-

Feldt epsilon otherwise. Original degrees of freedom, epsilon, and the corrected p-value are reported where appropriate.

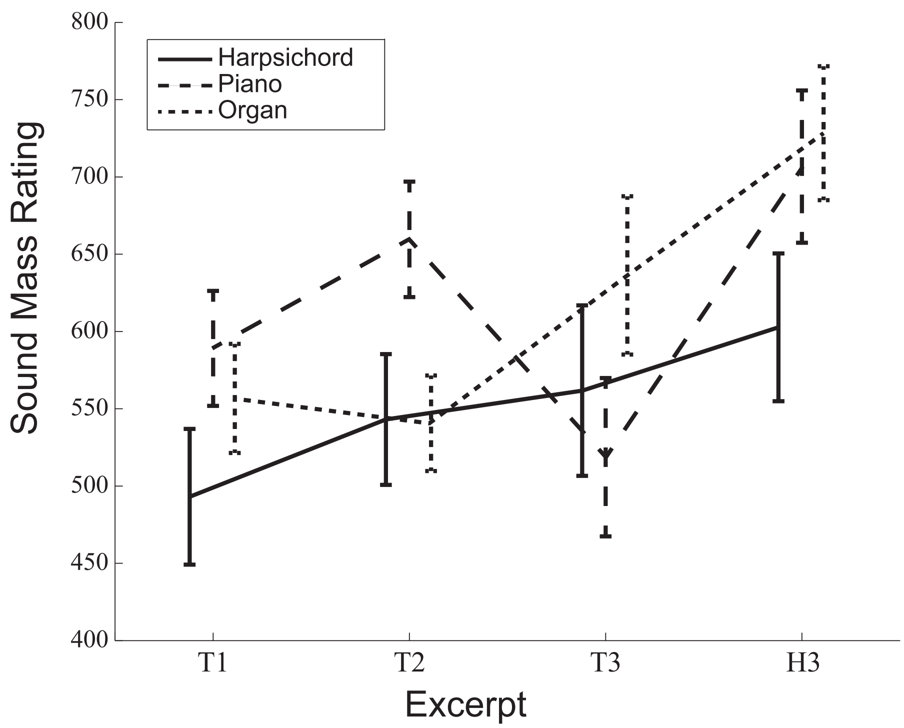
An initial mixed analysis of variance (ANOVA) was conducted primarily to determine whether the between-subjects factor of musicianship (musician, nonmusician) interacted with any of the within-subject factors of instrument (harpsichord, piano, organ) and excerpt (H1, H2, H3, L1, L2, T1, T2, T3). The main effect of musicianship was not significant, nor were any of its interactions with the other factors, $F<1.2$, $p\geq 0.35$ in all cases. There was a marginally significant main effect of instrument, $F(2,76) = 2.58$, $p = .083$, $\eta_p^2 = .063$, and a significant main effect of excerpt, $F(7, 266) = 10.50$, $\varepsilon = .51$, $p < .01$, $\eta_p^2 = .216$. More importantly for our purposes, the interaction between instrument and excerpt was also significant, $F(14, 532) = 3.90$, $\varepsilon = .86$, $p < 0.001$, $\eta_p^2 = .093$. Paired-sample t-tests comparing the mean across the highly-rated excerpts against that of the lowly-rated excerpts (H1, H2, H3 vs. L1, L2) were statistically significant for each instrument, $t(39) \geq 4.36$, $p < .001$. We conclude that sound mass perception varies over the course of a piece depending on musical attributes and is affected by the type of instrument playing the piece, but music training does not influence sound mass ratings.

Figure 23: Average sound mass rating profiles, Experiment 1. Selected excerpts are shown by vertical grey bars and are labeled at the top.



To further evaluate differences among ratings of the three instrumental versions, we ran a repeated-measures ANOVA, examining the within-subject factors of excerpt and instrument on excerpts T1, T2, T3, and H3, specifically because these were the excerpts with apparent differences between the ratings of the different instrumental versions. We did not include musicianship as a factor, because we had found no differences between the groups in the previous analysis. Figure 24 is a plot of the mean rating of each instrumental version for excerpts T1, T2, T3 and H3. Generally, the ratings increase across these excerpts, with the piano and organ ratings being typically higher than the harpsichord ratings. However, the piano ratings become lower than the other instrumental versions in excerpt T3, and this difference results in a significant interaction between instrumental version and excerpt, $F(6, 234) = 4.01$, $p = .001$, $\eta_p^2 = .093$. We conducted 12 paired-sample t-tests between the three pairs of instruments for each of the four excerpts. After Bonferroni-Holm correction, only one significant difference was found: the organ means are higher than the harpsichord means in excerpt H3, $t(39) = –3.33$, *p(corrected)* = .036. We conclude that, overall, the instrumental differences are not reliable predictors of sound mass ratings throughout the piece.

Figure 24: Average sound mass ratings for excerpts with apparent instrumental differences.



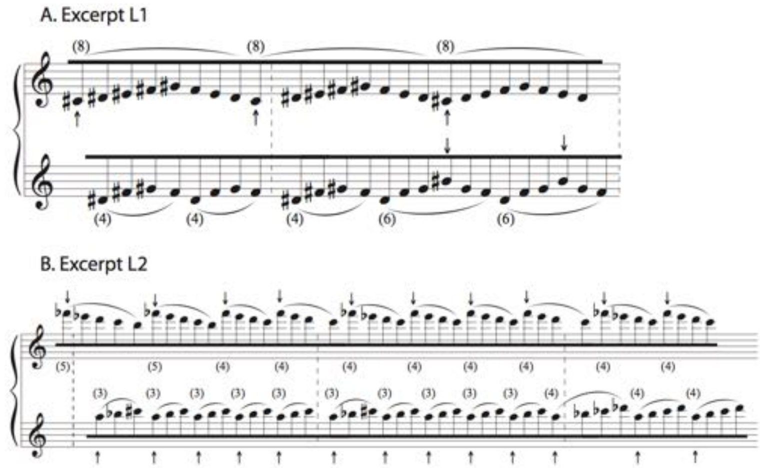
2.3.4 DISCUSSION

The observed results are coherent with the organizational properties of the music. The three highly-rated excerpts had very short, synchronized periodicities. The first (Figure 25A) consists of two notes separated by a major second (F# 4 – G#4), repeated with the fastest possible periodicity of one note (0.063 s = 16 cycles/s). The second (Figure 25B) consists of a 6-note whole-tone chord spread over more than three octaves (F2-B2-F3—G4-C#5-G5), repeated with a very fast periodicity of three notes (0.19 s ≈ 5 cycles/s). Technically the compass of this second excerpt is even wider, because the 16' and 4' couplers double each note an octave below and an octave above, resulting in a spread of over 5 octaves. Therefore, the two excerpts are virtually opposite in their pitch density, the first consisting of a single small interval in a very narrow compass, the second of a chord built of larger intervals spread over a very wide compass. Excerpt H3 (Figure 25C) is a rapid minor-second trill (F♭6—E♭6), with a periodicity of two notes (0.125 s = 8 cycles/s). The commonality appears not to be pitch density, but rapid, synchronous, periodic repetition.

The two sections with low sound mass ratings (Figure 26) also exhibit striking organizational similarity. Both consist of patterns between the two hands having either unequal durations or asynchronous phase relations. The periods individually tend to be relatively longer, and the highest and lowest pitches are placed in positions of contour and/or register that draw attention to them, potentially causing them to segregate into separate streams.

Figure 25: The three excerpts (H1, H2, and H3) with high average sound mass ratings.

Figure 26: The two L excerpts (L1 and L2) with low average sound mass ratings.



It would thus appear that regular patterns with short periodicities and synchronous (or singular) onsets promote sound mass fusion, while patterns with unequal periodicities or asynchronous onsets tend to promote segregation. Even though the attack rate was constant at 16 notes/s, the emergent rhythm caused by pitch organization resulted in the perception of periods that could be much longer, disintegrating the perception of fusion. This tendency would appear to override pitch density as a predictor of sound mass fusion, as is evident in a comparison between a chromatically saturated excerpt like L2 with a widely spaced excerpt like H2.

A simple explanation for any relations that may exist between instrumental timbre and sound mass fusion in this experiment is not as forthcoming. The three sections that were selected for apparent differences in ratings based on instrumental timbres exhibit little similarity in terms of musical organization: T1 is a chromatic section with unequal periods similar to L2 but in a middle register (F#4 – B♭4), T2 is a volatile section with constantly changing periodicity and diverging registers between the hands, and T3 is a major second trill (B5 – C#6) similar to H3 but with sustained notes in the left hand. In spite of the visual appearance of the graph, the distribution of the data for the three instrumental versions in these sections overlaps a great deal. Although the tendency of the harpsichord version to have lower mean ratings compared to the other two lends some support to our intuitive assumption that timbre and perceptual fusion are related, the effect is not statistically reliable in this study, and further research will be needed to draw any strong conclusions about the nature of the relation.

2.4 Experiment 2

2.4.1 Introduction

Having found in Experiment 1 that sound mass perception in *Continuum* varied significantly over the course of the piece in accordance with changing musical organization, we wondered whether varying selected musical parameters would affect these results. We chose three excerpts from the piece, two with high average ratings and one with low average ratings of sound mass perception (labeled H1, L1, and H2 above), and created multiple versions of those excerpts by playing them at different speeds and transposing them to different octaves. We expected to observe that (1) ratings would increase when excerpts were transposed to very high or very low registers since, as noted in Chapter 1, human hearing is most acute in the middle register; (2) sound mass perception would be positively correlated with attack rate; and (3) instrumental timbre would affect ratings (harpsichord ratings lowest and organ ratings highest).

2.4.2 Method

2.4.2.1 *Participants*.

The 40 participants (23 females) were between 18 and 66 years of age (M = 25, SD = 9.6). Twenty participants reported formal music training ranging from 8 to 19 years of practice (M = 12, SD = 3.2). The remaining participants reported no music training at a collegiate level and less than two years of formal music training during childhood (M = 0.55, SD = 0.83). Prior to completing the experimental task, participants passed the hearing test detailed in the previous experiment. Each participant completed the same task and was paid $10 Canadian as compensation. They all signed informed consent forms prior to participating in the experiment.

2.4.2.2 *Stimuli*.

As noted above, excerpt H1 (beginning at division 49 in the score, Figure 25A) was rated very highly for sound mass perception and consists of a repeating dyad (F#4 – G#4) with a periodicity of 1 (i.e., pattern repeated each note). Excerpt L1 (beginning at division 68, Figure 26A) had a very low rating and consists of a complex superimposition of several patterns of differing periodicities and pitch organizations. Excerpt H2 (beginning at division 126, Fig. 25B) was rated very highly and consists of an arpeggiated six-note chord with a periodicity of 3 (LH: F2-B2-F3; RH: G5-C#5-G5) with each note doubled at the octave above and the octave below.

Seventy-five versions of each excerpt were created in Finale 2011 with the Garritan Sound Library, using three instrumental timbres (harpsichord, piano, organ), five speeds (8, 12, 16, 20, and 24 attacks/s), and five transpositions (original pitch, ±1 and ±2 octaves). Audio signals were sampled at 44.1 kHz with 16-bit amplitude resolution. Loudness-equalized stimuli were presented via the same equipment outlined in Experiment 1 at 60 dB SPL.

Ten participants who did not participate in Experiment 2 completed a loudness equalization task in the PsiExp software environment (Smith, 1995). The task was completed in three blocks, one for each excerpt, presented in random order. Each block consisted of 45 samples from the three instruments, five octaves, and three attack rates. The reference samples for each block were the organ versions of each excerpt played at the original octave at 16 attacks/s, and the remaining 44 samples in each block were presented individually in a randomized order. The level of each one was adjusted to equal the loudness of the reference. The median adjustment rating from the 10 participants' ratings for each sample was then used to determine its level in Experiment 2. Only samples with an attack rate of 8, 16, and 24 attacks/s were equalized by participants and then, based on those results, an appropriate loudness level for each sample with an attack rate of 12 or 20 attacks/s was linearly interpolated between the level adjustments of the surrounding attack rates.

2.4.2.3 *Procedure*.

The equipment used was the same as the first experiment, although in this experiment the iPad interface was designed with TouchOSC (Hexler.net, Berlin, Germany) which allowed for OpenSoundControl messages to be sent not only from the iPad to the MaxPatch, but also from the MaxPatch back to the iPad. This was necessary to reset the slider to the start position after each trial, ensuring independent ratings across trials. The interface consisted of a continuous scale with Likert-type labels from 1 to 9. The anchor corresponding to 1 was labeled "No Sound Mass" while the anchor corresponding to 9 was labeled "1 Complete Sound Mass." Additionally, there was a button labeled "Next" in the top right corner. Participants were given the same definition of sound mass as the previous experiment and instructed to complete a single rating per trial after hearing the excerpt. Upon completing the rating, they were cued to press the next button, which reset the scale and played the next sample.

2.4.3 RESULTS

Statistical analyses were completed with a linear mixed model method (West, Welch & Galecki, 2007), which performs a regression-like analysis while controlling for random variance in factors such as participant and stimuli. Because each participant rated all of the stimuli, the model included crossed random effects for subject and item (Baayen, Davidson & Bates, 2008). Analyses were completed with the software R (3.0.2) using the lmer function from the lme4 package (Bates, Maechler, & Bolker, 2011) and the pamer.fnz function from the LMERConvenienceFunctions package (Tremblay & Ransijn, 2013). To decrease a skew in the ratings, we performed a logit transform on the data, which resulted in a more normal distribution ranging from about –6 to 6.

We created a model for each excerpt to examine music training, instrument, octave, and attack rate as factors influencing sound mass perception. The results from a Type III F test for each excerpt are displayed in Table 2. Consistent with the previous experiment, the influence of the examined factors differed across excerpts, confirming that the musical structure influences the perception of sound mass. Furthermore, music training alone was not a significant factor for any of the three excerpts, but interactions involving this factor were sometimes significant.

As shown in Figure 27, significant differences were observed among the ratings for the three instruments in this experiment. The excerpts that were highly rated in experiment 1 (H1 and H2) were once again more highly rated overall in Experiment 2. However, the ratings for H1 (Figure 25A), consisting of a single major-second dyad, are much more consistent between instruments than H2 (Figure 25B), which consists of major seconds and tritones spread over a much wider compass. L2 (Figure 26B), which, as discussed above, contains several perceptual cues likely to promote stream segregation, was rated lower overall and with greater consistency between instruments than was H2.

Table 2: Linear Mixed Effects Model with Type III Wald F Tests for Perceived Sound Mass Ratings.

		H1 ($R^2 = 0.42$)	H2 ($R^2 = 0.44$)	L1 ($R^2 = 0.42$)
	df	F	F	F
Music Training	1, 2587-2700	0.26	0.84	0.34
Instrument	2, 2587-2700	0.00	**176.41 *****	**14.34 *****
Octave Change	4, 2587-2700	0.32	**28.60 *****	**51.44 *****
Attack Rate	4, 2587-2700	0.27	**68.39 *****	**76.38 *****
Music Training * Instrument	2, 2587-2700	**3.65 ***	**12.46 *****	2.47
Music Training * Octave Change	4, 2587-2700	**5.22 *****	0.55	**7.80 *****
Instrument * Octave Change	8, 2587-2700	0.01	**5.33 *****	1.81
Music Training * Attack Rate	4, 2587-2700	1.58	1.74	1.00
Instrument * Attack Rate	8, 2587-2700	0.05	1.93	**2.38 ***
Octave Change * Attack Rate	16, 2587-2700	0.02	0.77	**2.11 ****
Music Training * Instrument * Octave Change	8, 2587-2700	1.07	1.48	0.73
Music Training * Instrument * Attack Rate	8, 2587-2700	0.69	0.75	0.32
Music Training * Octave Change * Attack Rate	16, 2587-2700	0.62	1.17	**1.77 ***
Instrument * Octave Change * Attack Rate	32, 2587-2700	0.01	0.99	1.18
Music Training * Instrument * Octave Change * Attack Rate	32, 2587-2700	0.92	0.80	0.43

Notes: N = 2850. All predictors are sum coded factor variables. Results of Type III Wald F test:
** p < .05 ** p < .01 *** p < .001. The following random effects were included:*
random intercepts for participants and stimuli.

Figure 28 represents the mean sound mass ratings across the different attack rates for each octave transposition. We originally predicted that extreme registers, both high and low, would have high sound mass ratings, because human hearing is less discriminating in those registers. However, stimuli in the lowest octaves had consistently high ratings and stimuli in the highest octave were rated lower, despite changes in other variables. So, although we were correct to think that register would be a significant factor, the tendency is a monotonically decreasing pattern rather than the parabolic pattern we had expected. A similar linear tendency was observed for speed: increased attack rate was consistently correlated with increased sound mass ratings. We also originally predicted that a faster attack rate would be required for sound mass perception in the middle register, and relatively slower rates would be sufficient in the registral extremes, but the observed interaction between attack rate and octave was modest.

Figure 27: Overall sound mass ratings for three musical excerpts played with different instruments.

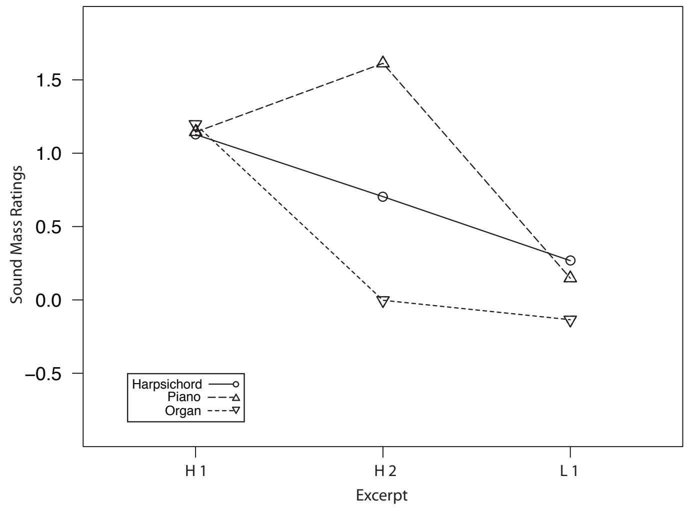
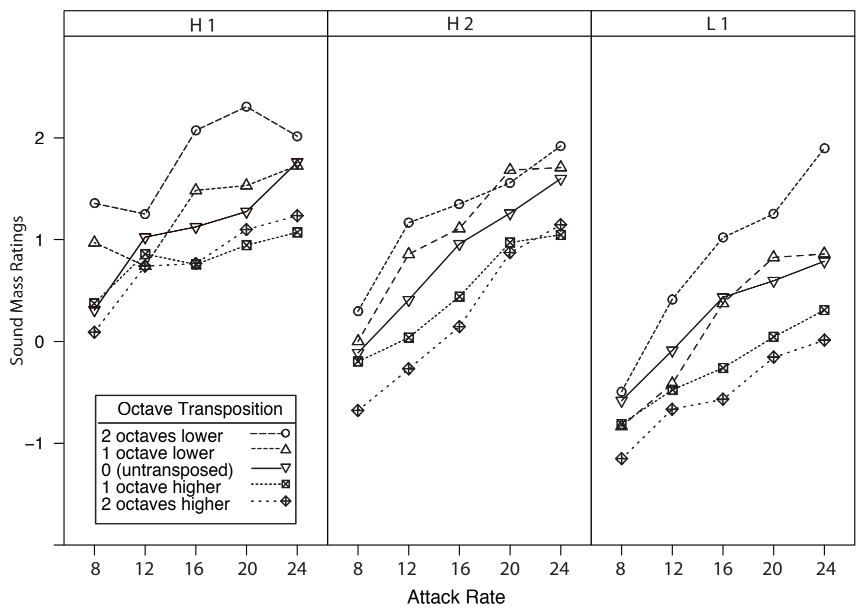
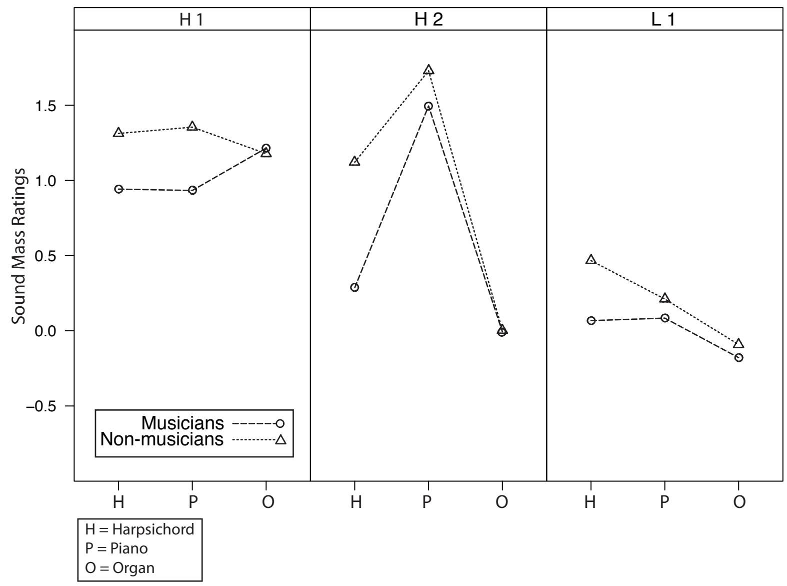


Figure 28: Sound mass ratings at different attack rates and octave transpositions.



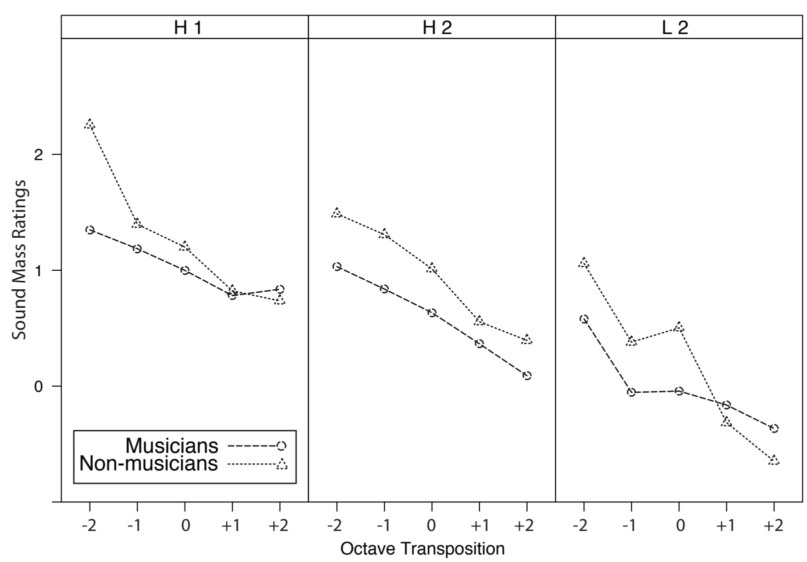
In excerpts H1 and H2, significant interactions between music training and instrumental timbre with respect to sound mass ratings were observed (Figure 29). In H1, musicians rated harpsichord and piano stimuli slightly lower than did nonmusicians, but rated organ stimuli higher than did nonmusicians. In H2, nonmusicians' ratings for harpsichord stimuli were higher than musicians' ratings, but both groups rated organ stimuli very similarly. In L1, the musicians' harpsichord stimuli ratings are lower than were the nonmusician's ratings—a trend that was apparent in all three excerpts—but the difference in this case was not statistically significant.

Figure 29: Sound mass ratings for different instruments by musicians and nonmusicians.



A significant interaction between music training and octave transposition was observed in H1 and L1 (Figure 30). Both groups typically gave higher sound mass ratings in lower octaves and lower ratings in higher octaves, but the effect at both ends was more potent in nonmusicians. In H2 nonmusicians gave higher ratings at all transpositions, but no significant interactions were observed.

Figure 30: Sound mass ratings for different octave transpositions by musicians and nonmusicians.



2.4.4 DISCUSSION

These results suggest that Truax, Roads, and Ligeti are right to claim that faster attack rate (or granulation) results on average in a higher degree of continuous perceptual fusion or sound mass. However, we have not found evidence supporting an absolute threshold attack rate, at least not within the range of speeds we tested (up to 24 attacks/s). Other factors such as register, timbre, emergent rhythm, pitch structure, and musical training appear to be relevant as well, as the principles of auditory scene analysis led us to predict.

As shown in Figure 27, sound mass ratings for excerpt H2, whose pitch density is lower and whose compass is far greater than the other two, varied much more across the different instruments than did the ratings for the other excerpts. Excerpt L2, whose unequal periodicities and 'outlier' pitches at the crest and nadir of wave-like pitch patterns are likely to promote stream segregation, had overall lower ratings in Experiment 2, as was the case in Experiment 1.

Figure 28 shows that sound mass ratings for all three excerpts followed an approximately linear pattern of positive association with attack rate (higher rate = higher rating), and a negative association with octave transposition (lower octave = higher rating). However, the start and end points of these linear trajectories varied considerably among the three musical excerpts, calling into question the notion of an absolute value in either parameter that would be universally applicable regardless of musical content or context.

The fact that sound mass ratings can be affected significantly by interactions between music training and other parameters such as instrumental timbre and register, as shown in Figures 29 and 30, respectively, provides evidence that sound mass perception is dependent on both the subjective contexts of listeners and objective properties of the musical stimulus. This complicates the search for threshold values of sound mass fusion, which may not only covary across interactive parameters but may also exhibit considerable intersubjective variation.

The above findings contradict the assumption that higher pitch density necessarily results in higher sound mass perception, as many other contextual factors are at play as well. But the question remains: if those contextual factors are neutralized (to the greatest extent possible), will a simple correlation between pitch density and sound mass perception be observed?

2.5 Experiment 3

2.5.1 Introduction

As noted above, an idiosyncratic feature of *Continuum* is that pitch structures with higher cardinality result in longer periodic patterns and thus more perceptible emergent rhythm (owing to dyadic construction and constant rate of attack). In other words, as regards sound mass fusion, pitch and rhythm operate at cross-purposes: when pitch structures putatively promote sound mass fusion, rhythmic structures inhibit it, and vice versa. Therefore, the musical textures of the stimuli from Experiments 1 and 2, while ecologically valid, interfere *de facto* with any attempt to evaluate the relation between pitch structure and sound mass fusion. We therefore wondered how the results might be affected if the harmonic structures of the musical patterns in *Continuum* were preserved but the rhythmic dimension was neutralized.

2.5.2 Method

2.5.2.1 *Participants*.

The 42 participants (25 females) were between 19 and 49 years of age (*M* = 27, *SD* = 7.1). Twenty-four participants self-identified as musicians with formal music training ranging from 7 to 35 years of playing an instrument (*M* = 16.1, *SD* = 8), and all but one additionally reported between 1 and 16 years of ear training (*M* = 6.7, *SD* = 5). The remaining participants reported no music training at a collegiate level, from 0 to 4 years of childhood or casual training on an instrument (*M* = 0.5, *SD* = 1.1), and no formal ear training. Prior to completing the experimental task, participants passed the hearing test detailed in the previous experiments. Each participant completed the same task and was paid $10 Canadian as compensation. They all signed informed consent forms prior to participating in the experiment.

2.5.2.2 *Stimuli*.

Forty-six musical patterns were selected from *Continuum* and harmonically reduced to vertical sonorities (i.e., the pitches were preserved while the rhythmic dimension was neutralized; see Figure 31). Each example was analyzed along a number of different parameters: (1) number of notes, (2) compass interval (number of semitones between the lowest and highest pitches), (3) density (defined as number of notes divided by compass interval), (4) largest interval (between two consecutive pitches), (5) diatonic subset (whether or not all of the pitches belong to a single diatonic collection), (6) chromatic subset (whether or not all of the pitches form a single chromatic cluster, i.e., all intervals between consecutive pitches are minor seconds), (7) double-diatonic subset (the pitches form two diatonic subsets; this was hypothesized to be relevant because the RH and LH pitches sometimes formed different, registrally distinct diatonic subsets), (8) double-chromatic (the pitches form two chromatic clusters), (9) instrumental timbre (harpsichord, piano, or organ), (10) number of semitones (total number of minor seconds between consecutive pitches), and (11) number of pitch classes (number of pitches excluding octave doublings at one or more octaves). These categories were chosen to provide measures of pitch distribution, as well as to evaluate the perceptual importance of referential pitch structures (especially the diatonic and chromatic collections).

Onset synchrony has a strong tendency to promote perceptual fusion, and it was felt that if the notes of these harmonic structures were attacked simultaneously, almost everything would sound like a mass and the ratings would be illegitimately inflated. Therefore, stimuli were rapidly arpeggiated from the outer voices inward, and then sustained for 2 seconds. Three versions of each arpeggiated sonority were created in Finale 2011 with the Garritan Sound Library, using three instrumental timbres (harpsichord, piano, organ). Audio signals were sampled at 44.1 kHz with 16-bit amplitude resolution. Loudness-equalized stimuli were presented via the same equipment outlined in Experiments 1 and 2 at an average level of 60 dB SPL. Five participants who did not participate in Experiment 3 completed a loudness equalization task in the PsiExp software environment (Smith, 1995), with the excerpts presented in random order.

Figure 31: Example of adaptation from score to vertical sonority to arpeggiated sonority.

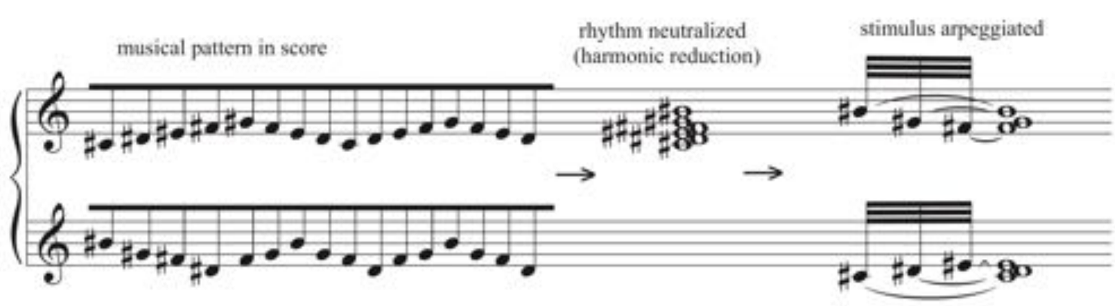


Figure 32: Harmonically-reduced pitch structures from *Continuum* used in Experiment 3.

If sound mass and cluster are synonymous or closely related, we would expect density, chromatic subset, double-chromatic subset, and number of semitones to correlate positively with sound mass perception, while compass interval and largest interval should correlate negatively with sound mass perception. Since the chords we expected participants to be most familiar with are diatonic, we expected diatonic subsets and to a lesser extend double-diatonic subsets to be more likely to be perceived as chords (and therefore to have lower ratings for sound mass fusion). Although number of notes and number of pitch classes do not specifically refer to distribution in pitch space, we expected that these parameters would correlate positively with sound mass perception as greater numbers of pitches or pitch classes result in more complex harmonies that are more difficult to parse perceptually (as per the "*un, deux, trois, beaucoup*" phenomenon mentioned in Chapter 1). Finally, as in the previous experiments, we expected the organ timbre to promote sound mass perception the most, and harpsichord timbre the least.

2.5.2.3 *Procedure*.

The equipment used was the same as for the first two experiments, but using an interface designed in PsiExp and operated on a computer rather than an iPad. The interface consisted of a continuous scale with Likert-type labels from 1 to 9. The anchor corresponding to 1 was labeled "Chord" while the anchor corresponding to 9 was labeled "Mass." Additionally, there was a button labeled "Next" in the top right corner. Participants were given the same definition of sound mass as in the previous experiments, along with the following instructions:

> In this experiment, you will hear groups of two or more notes. Some of these groups may seem more like a *chord*, in which you feel you are aware of the number of notes and/or the harmonic relations among them, while others may seem more like a *mass*, in which you are aware of multiple notes but feel their number and/or harmonic relations are unclear. Each group of notes will be played either simultaneously or in rapid succession and then sustained for approximately 2 seconds. You will hear each group only once...After listening to the sample, use the slider to indicate whether you felt the group of notes was more like a *chord* or more like a *mass*. Intermediate values between *chord* and *mass* are also possible: these might include groups in which some notes or harmonic relations seem to stand out clearly while others seem to blur together.

Participants provided a single rating per trial after hearing the excerpt. Upon completing the rating, they were cued to press the Next button, which reset the scale and played the next sample.

2.5.3 Results

Statistical analyses were conducted using IBM SPSS Statistics software. To determine whether or not the responses of musicians and nonmusicians were significantly different, independent samples t-tests were conducted to compare their ratings for each of the 138 excerpts: only 28 of them were rated significantly differently by the two groups. A paired samples t-test comparing the global mean ratings for musicians and nonmusicians revealed that the two were not significantly different ($p = .296$), and that they were significantly correlated with one another ($R^2 = .679$, $p < .001$). Nevertheless, further statistical tests treated musicians and nonmusicians as separate populations in order to confirm the similarity of their responses.

Linear regression analyses were performed on the musicians' and nonmusicians' data for each of the parameters used to analyze the stimuli. While the effects varied somewhat between the two groups and were generally stronger for musicians overall, (1) number of notes and (5) diatonic subsets emerged as the strongest correlations for both populations, with somewhat lesser contributions from (10) number of semitones and (11) number of pitch classes. However, some of the parameters were significantly correlated with one another, calling into question which of the correlated parameters was contributing to the variance in the data.

Table 3: Simple linear regression analyses for analytical parameters of Experiment 3 stimuli.

Adjusted R^2 *p* (ANOVA)	Musicians	Nonmusicians
(1) Number of Notes	.927** .000	.723** .000
(2) Compass Interval	.052** .004	-.007 .976
(3) Density	-.004 .486	.064** .002
(4) Largest Interval	.016 .076	-.003 .426
(5) Diatonic Subset	.657** .000	.277** .000
(6) Chromatic Subset	.018 .061	.074** .001
(7) Double-Diatinic Subset	.023* .042	-.002 .392
(8) Double-Chromatic Subset	.009 .134	-.006 .711
(9) Instrument	.020 .054	.035* .016
(10) Number of Semitones	.283** .000	.111** .000
(11) Number of Pitch Classes	.527** .000	.095** .000

****. Correlation is significant at the 0.01 level (2-tailed).**
*. Correlation is significant at the 0.05 level (2-tailed).

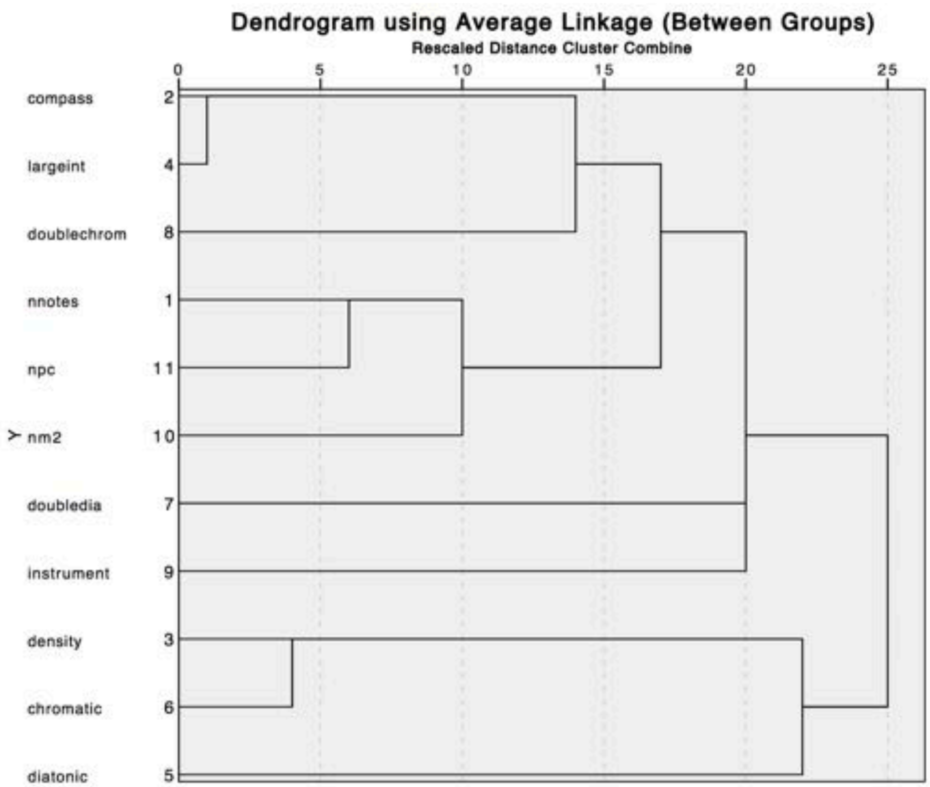
Table 4: Correlation matrix for analytical parameters of Experiment 3 stimuli.

R^2 *p*	N Notes	Compass Interval	Density	Largest Interval	Diaton.	Chrom.	Double-Diaton.	Double-Chrom.	N m2s	N PCs
N Notes	1.000 -	.159 .063	.091 .289	-.005 .955	-.719** .000	.194* .022	.163 .056	.122 .155	.509** .000	.589** .000
Compass Interval	.159 .063	1.000 -	-.924** .000	.916** .000	-.284** .001	-.494** .000	.200* .019	.186* .029	-.153 .073	.534** .000
Density	.091 .289	-.924** .000	1.000 -	-.966** .000	.011 .901	.624** .000	-.173* .043	-.141 .100	.411** .000	-.287** .001
Largest Interval	-.005 .055	.916** .000	-.966** .000	1.000 -	-.079 .358	-.627** .000	.144 .093	.255** .003	-.279** .001	.368** .000
Diaton.	-.719** .000	-.284** .001	.011 .901	-.079 .358	1.000 -	-.149 .082	-.175* .040	-.099 .250	-.555** .000	-.714** .000
Chrom.	.194* .022	-.494** .000	.624** .000	-.627** .000	-.149 .082	1.000 -	-.112 .191	-.063 .462	.398** .000	-.183* .032
Double-Diaton.	.163 .056	.200* .019	-.173* .043	.144 .093	-.175* .040	-.112 .191	1.000 -	-.039 .647	-.317** .000	.384** .000
Double-Chrom.	.122 .155	.186* .029	-.141 .100	.255** .003	-.099 .250	-.063 .462	-.039 .647	1.000 -	.259** .002	.245** .004
N m2s	.509** .000	-.153 .073	.411** .000	-.279** .001	-.555** .000	.398** .000	-.317** .000	.259** .002	1.000 -	.360** .000
N PCs	.589** .000	.534** .000	-.287** .001	.368** .000	-.714** .000	-.183* .032	.384** .000	.245** .004	.360** .000	1.000 -

****. Correlation is significant at the 0.01 level (2-tailed).**
*. Correlation is significant at the 0.05 level (2-tailed).

These correlations are visualized in the following dendrogram:

Figure 33: Hierarchical cluster analysis of analytical parameters of Experiment 3 stimuli.



To account for correlations between the parameters, we conducted stepwise multiple regression analyses for each group in which all of the 11 parameters were entered. For both musicians and nonmusicians, the best fitting model excluded all but two parameters: number of notes and number of pitch classes, with the former emerging as by far the most significant contributor. The effect was stronger for musicians, but the difference appeared to be of degree rather than of kind.

Table 5: Multiple regression analyses for analytical parameters of Experiment 3 stimuli.

	Adjusted R^2 for model	Standardized Coefficients	
		Number of Notes	Number of Pitch Classes
Musicians	**.949**** **.000**	**.840**** **.000**	**.193**** **.000**
Nonmusicians	**.806**** **.000**	**1.091**** **.000**	**-.376**** **.000**

****. Correlation is significant at the 0.01 level (2-tailed).**

2.5.4 Discussion

These results challenge the assumption that pitch density is a determining factor in sound mass perception, unless density is taken to refer simply to the number of concurrent notes irrespective of their distribution in pitch space (as in Huron's Principle of Limited Density; see Chapter 1). The results also have potential implications for sound mass aesthetics: if a large number of concurrent notes tend to fuse into a mass irrespective of intervallic content, registral compass, and so forth, then Danuta Mirka's suggestion that the "crucial point in forming clusters is not so much the size of the intervals between adjacent pitches in itself, but rather that the identity and equality of that size thoroughly dominate the cluster"[83] may be questioned. Our observations suggest that, at least for this particular set of stimuli, large groups of notes may achieve a massed effect regardless of their distribution in pitch space, and whether or not they are evenly distributed. Mirka goes on to note that in such clusters "individual, simultaneously occurring pitches are...not to be perceived as such by the listener because of their very high number, which reaches up to eight or even twelve"[84]: this, divorced from the requirement of even distribution, is consistent with the results of this experiment.

The definition we used for "density" in parameter 3 (number of notes divided by compass interval) is in some ways intuitive: it makes sense that 5 notes over a compass interval of 8 semitones (5/8 = 0.63) should have a higher density than 5 notes over a compass interval of 11 semitones (5/11 = 0.45). However, in some instances the definition is problematic: for example, two notes separated by a minor second yield the highest possible equal-tempered density (2/1 = 2), while seven notes separated by minor seconds yield a lower density (7/6 = 1.17) even though there is little doubt that it would be perceived as denser in virtue of its greater number of notes. Our analysis accounts for this by incorporating other parameters, such as chromatic subset (i.e. chromatic cluster), double-chromatic subset, and number of semitones, which provide other indices of density *qua* distribution of notes in pitch space. Some of these emerged as significant, but relatively weak, contributing factors in simple regression analysis, but were eliminated in multiple regression. Only number of pitches and number of pitch classes remained in the model as significant parameters for sound mass perception. Neither of these indicates distribution of notes in pitch space, which is essential to the "cluster" concept. Surprisingly, diatonicity (which we had

[83] Mirka, 96.
[84] Ibid, 97.

expected to be a strong predictor since it provides the underlying structure for familiar chords) was also eliminated from the multiple regression analysis, as was instrumental timbre. The same trends were observed in musicians and nonmusicians, though the effect was stronger for musicians. This may be because musicians have a more vested and considered concept of what a chord is, and "chord" was positioned as the polar opposite of "mass" in this experiment. But for both groups, sheer cardinality of notes was the unambiguous determining factor in sound mass perception.

While this finding is provocative, it should not be uncritically generalized beyond the present experiment. The pitch collections studied in this experiment were extracted from Ligeti's *Continuum*: they were not devised systematically in order to evaluate the parameters listed above. Further study would be required to draw definitive conclusions about the relation of pitch distribution to sound mass perception in a broader context. Furthermore, listeners' reports of equivalence in perceptual fusion should not be interpreted as indicating *aesthetic* equivalence: it may be that two groups of notes that are perceived as equally fused may differ in other ways, and may therefore have different perceptual and/or aesthetic values. As such, equal spacing may well have been crucial to the sonorities of Penderecki described by Mirka in the passage quoted above, if not for their fusion as masses then perhaps for other aspects of their perceptual and/or aesthetic effects.

2.6 Supplementary Pilot Study

2.6.1 INTRODUCTION

A preliminary exploration of such other aspects of sound mass aesthetics was made in a supplementary pilot study conducted with Eddy Kazazis, under the supervision of Dr. Stephen McAdams. It is beyond the scope of this discussion to address this study in detail, but a brief description of some relevant aspects is germane here.

2.6.2 METHOD

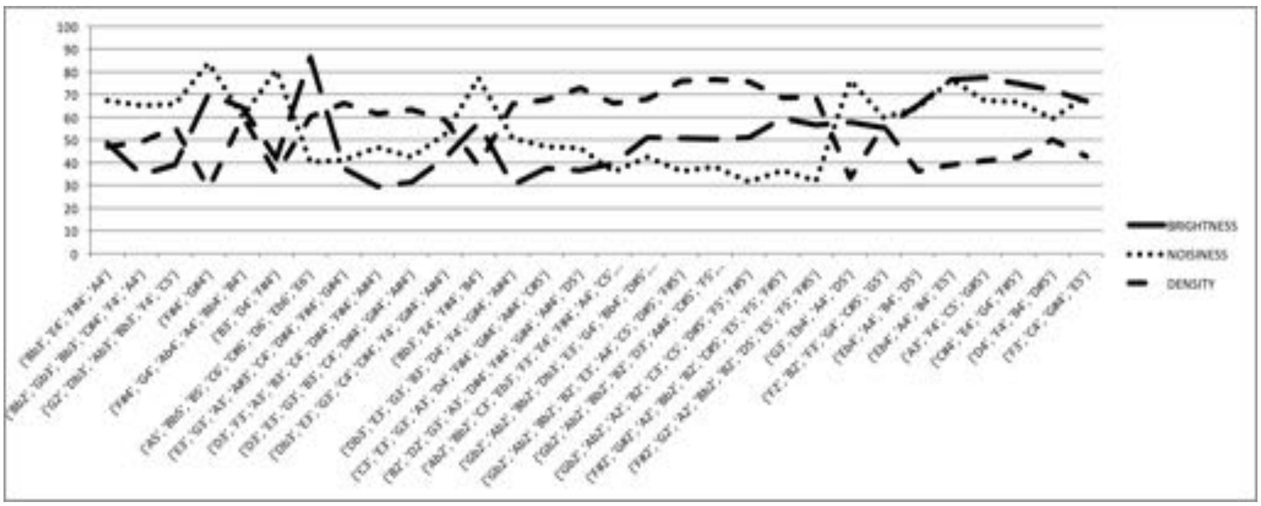
There were 22 participants, all of whom were either musicians or people with significant knowledge of music perception and cognition research. The stimuli consisted of pitch structures from 19 of the examples tested in Experiment 3, along with 11 chords from Arnold Schoenberg's

Klavierstuck Op. 11 No. 2. Stimuli were 0.5s in duration, and were rendered using sawtooth waves with synchronous onsets/offsets and flat dynamic envelopes. Participants rated stimuli on three different scales: *bright-dark*, *pitched-noisy*, and *density*.

2.6.3 RESULTS

Each of the three categories yielded a distinct rating profile:

Figure 34: Ratings for Brightness, Noisiness, and Density in supplementary pilot study.



Analysis revealed that each category was significantly correlated with parameters that relate directly to the distribution of notes in pitch space. Brightness was strongly related to registral distribution, as indicated by the chordal centroid (weighted average of chord tones; $R^2 = .733$, $p < .001$), lowest pitch ($R^2 = .643$, $p < .001$), and highest pitch ($R^2 = .613$, $p < .001$).

Figure 35: Pilot study chords ordered with increasing perceived brightness.

Pitchedness was negatively correlated with number of notes ($R^2 = -.940$, $p < .001$), perceived density ($R^2 = -.932$, $p < .001$), and compass interval ($R^2 = -.633$, $p < .001$).

Figure 36: Pilot study chords ordered with increasing perceived pitchedness.

Density was positively correlated with number of notes ($R^2 = .949$, $p < .001$) and compass interval ($R^2 = .672$, $p < .001$), and negatively correlated with pitchedness ($R^2 = -.932$, $p < .001$).

Figure 37: Pilot study chords ordered with increasing perceived density.

Therefore, even if the degree of sound mass fusion of a given collection of notes is determined primarily by the number of concurrent pitches irrespective of their distribution (as suggested in Experiment 3), other aspects of sonorities (including distribution in pitch space) may be aesthetically relevant to other perceptual and semantic categories (including perceived brightness, pitchedness, and density).

2.7 General Discussion and Conclusions

The observations made in these three experiments and supplementary pilot study support our initial suspicion that it is no simple task to say what is or isn't a sound mass, in spite of the matter-of-fact way the term is sometimes used in the musicological literature. Nor is it easy to identify absolute values in sonic parameters that correlate with sound mass perception, because such parameters can covary and because auditory streaming can shift attention to values in the same parameter at a different structural level. This tendency was demonstrated in our experiments when emergent rhythm, which supplanted overall attack rate as the most perceptually salient feature of temporal organization, was correlated with lower sound mass ratings even when pitch structures were dense and complex. Many factors are involved in the perceptual fusion that subsumes many sounds into a single mass, including (at least) attack rate, pitch structure, spectral content, register, and the music training and attention of the listener. In some cases, these factors can be interactive.

Many more experiments will be required to provide a comprehensive account of sound mass perception. As reviewed in Chapter 1, sound mass integration can be achieved in many different ways, and many examples of sound mass in the repertoire are complex and continuously changing. In some cases, as in *Continuum*, complexity in a parameter that might otherwise lead to sound mass integration (such as pitch complexity) can actually decrease the likelihood of integration occurring due to its interaction with other musical or psychoacoustic parameters (such as emergent rhythm). Nevertheless, based on our experimental observations, some consistent tendencies may be noted. The temporal threshold of sound mass fusion, described by Ligeti as the point at which tones "merge into a continuum"[85] and by Truax as "a fusion of grains into a continuous texture,"[86] varies with emergent rhythm resulting from pitch organization, and to a lesser extent with register, timbre, and music training, and therefore is not an absolute value of attack rate as has sometimes been suggested. Although attack rate was held constant in Experiment 1, average sound mass ratings varied continuously over the course of the piece, appearing to respond more closely to periodic patterns in rhythmic organization than to pitch density. Indeed, one of the highest-rated sections (H2 above) had one of the broadest compasses and most widely spaced intervallic structures in the piece, challenging the intuitive assumption that higher pitch density is necessarily correlated with higher sound mass fusion. Timbre also appears to be a relevant factor, with ratings for the three instruments (harpsichord, piano, and organ) varying not only in overall value but also in contour. However, these differences are not very great, and further research is necessary before strong conclusions about the nature and extent of the contribution of timbre to sound mass perception can be drawn.

When isolated excerpts with selectively modified parameters were ranked singularly rather than continuously in our Experiment 2, interactions between parameters became clearer. The already noted variation correlated with different instrumental timbres appears to be stronger when musical organization provides cues that promote auditory stream segregation, such as asynchronous or unequal cyclical patterns and "outlier" pitches with registral separation or position at the

[85] Ligeti, *Continuum*, 1.
[86] Truax, "Real-time," 18.

apex or nadir of relatively longer patterns. Both attack rate and octave transposition were correlated with a roughly linear pattern, with increasing sound mass ratings observed with increasing speed or decreasing register. These factors seemed to operate independently of one another, but both varied according to the musical organization of the excerpts. The subjective context of the listener was seen to be an influential factor as participants with little or no music training gave higher ratings overall than musicians, with this tendency being exaggerated for the harpsichord timbre and for lower octave transpositions.

In the case of isolated pitch structures with the rhythmic dimension neutralized, as studied in Experiment 3 and in the supplemental pilot study, the sheer number of notes appears to be the determining factor in sound mass perception. Other parameters appeared to have some effect when examined individually with simple linear regression analysis, but correlations between them made it difficult to judge which parameters were driving the observed variance. Multiple regression analysis provided statistically robust models that excluded all parameters except number of notes and number of pitch classes (which is only number of notes excluding octave doublings). While the effect was stonger for musicians, the trend was the similar for nonmusicians as well. The distribution of notes was not observed to be an important factor in sound mass perception, calling into question the putative equivalence of sound mass and cluster.

Ligeti himself rarely if ever used the term ‘sound mass’ but described his compositional methods and goals in vivid poetic terms. For example:

> All in all, you cannot hear my music as it appears on paper…The technical process of composition is like letting a crystal form in a supersaturated solution. The crystal is potentially there in the solution but becomes visible only at the moment of crystallization…My aim was to arrest the process, to fix the supersaturated solution just at the moment before crystallization.[87]

In *Continuum*, it might be intuitive to assume that “crystallization” corresponds to the emergence of clearly defined intervals (the so-called Ligeti “signals”[88]), whereas more complex or ambiguous structures correspond to supersaturation, which we might equate with mass. It may thus seem surprising that our data from Experiments 1 and 2 suggest exactly the opposite conclusion: sound mass ratings were highest when the pitch structure was most clear, and when the pitch organization

[87] Ligeti, *Ligeti in Conversation*, 14-15.
[88] Jonathan Bernard, “Ligeti’s Restoration of Interval and Its Significance for His Later Works.” *Music Theory Spectrum* 21, no. 1 (Spring, 1999): 3.

changes so that perceptible rhythm emerges, sound mass integration was weakened even though the clarity of pitch intervals was subverted.[89] Experiment 3 supports the suggestion that complex pitch structures correspond with sound mass, but at least in this experimental context it was cardinality and not interval content that had by far the greatest effect. It may be that, in spite of the emphasis on interval content in much of the music theoretical scholarship, perceptible rhythm and sheer number of concurrent notes are more important factors than pitch distribution for sound mass fusion and its dissolution through auditory stream segregation. However, as seen in the Supplementary Pilot Study, other musical parameters, including those related to pitch distribution, remain aesthetically important for other perceptual and semantic dimensions such as brightness, pitchedness, and density. It is to semantic dimensions of sound mass that we now turn.

[89] Miguel Roig-Francolí, "Harmonic and formal processes in Ligeti's net-structure compositions," *Music Theory Spectrum* 17, no. 2 (1995): 242 – 267.

Chapter 3: Semantic Dimensions of Sound Mass

3.1 Introduction

In some ways, sound mass represents a rather radical departure from earlier musical traditions, the vast majority of which—perhaps all of which—were predicated on intelligible combinations of discrete sound events (i.e., notes). The shift away from discernible syntactic relations between notes and onto the massed totality has important perceptual and aesthetic consequences: does it also have *semantic* consequences? To address the question, it is important to consider the intellectual climate of the 1950s and 1960s—an era that was ideologically hostile towards musical semantics in general—in which sound mass came of age.

3.2 The Anxiety of Reference

The term 'anxiety of influence' is common currency for composers in the 20^{th}- and 21^{st}-century: Joseph Straus writes that the ubiquitous presence of the masterworks of the past inspires "the kind of anxiety that one often feels in the presence of powerful, dominating, and intimidating figures."[90] But music's notoriously problematic relationship with referential meaning begets another enduring source of anxiety, with many composers and scholars nervously or impatiently distancing their work from questions of the extramusical. I would like to call this tendency, or rather the unease that motivates it, the 'anxiety of reference.'

Why should extramusical reference create anxiety? The question invokes the long shadow cast over thinking about musical meaning by the nineteenth-century philosophical confrontation between "programmatic" and "absolute." Remarkably—given the dubiousness of addressing so complex a subject as musical meaning in terms of a binary distinction—these terms still have currency among many musicians and scholars in the present day, albeit with many different interpretations as to what exactly they denote. Charles Nussbaum is "prepared to argue the rather unfashionable claim that *all* Western tonal art music since 1650, including so-called pure music,

[90] Joseph Straus, "The 'Anxiety of Influence' in Twentieth-Century Music," *The Journal of Musicology* 9 no. 4 (Autumn, 1991): 430. See also: Harold Bloom, *The Anxiety of Influence: A Theory of Poetry* (New York: Oxford University Press, 1973).

is program music."[91] On the other side, Peter Kivy continues to write about "absolute music, music alone, without text, title, program, dramatic setting, nor any other extra-musical baggage,"[92] and Arved Mark Ashby claims that "the moralizing influence of absolute music continues in force."[93] A few decades earlier, Carl Dahlhaus expressed the extent and ubiquity of this moralizing influence throughout the twentieth century: "the idea that instrumental music devoid of function or program is the 'true' music [is] a commonplace that determines the day-to-day use of music without our being aware of it, let alone doubting it."[94]

The intellectual climate which permitted Dahlhaus to make so sweeping an assertion has certainly since changed: Penderecki scholar Mieczysław Tomaszewski writes that Penderecki's music "is undoubtedly that of the semiotic age," having "discarded the tradition of art for art's sake together with Hanslick's rejected paradigm [of absolute music]."[95] Nicholas Cook writes "[o]ne of the basic principles of the culturally oriented musicology of the 1990s was that there is no such thing as 'purely musical' meaning."[96] Ashby says of absolute music that "its pretenses to freedom from social condition and contingency – and therefore its very founding principles and *raison d'être* – are discredited, and the construct itself [is] looked upon as a cultural and historical relic."[97] But the *Zeitgeist* of the 1950s and 1960s, during which sound mass music came to prominence with groundbreaking compositions such Iannis Xenakis's *Metastaseis* (1953-54) and *Pithoprakta* (1955-56), György Ligeti's *Apparitions* (1958-59) and *Atmosphères* (1961), Krzysztof Penderecki's *Threnody for the Victims of Hiroshima* (1960) and *Polymorphia* (1961), and Witold Lutosławski's *Jeux vénitiens* (1960-61) and Symphony No. 2 (1965-67), was unquestionably one in which the ideology of absolute music was a dominant force. The influence of Schoenberg and his followers was powerful and far-reaching, and their serialism established a new paradigm of formalism that was regarded by many as a historical necessity.[98] Skepticism over music's ability

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91 Charles Nussbaum, *The Musical Representation: Meaning, Ontology, and Emotion* (Cambridge, Mass.: The MIT Press, 2007), 126.
92 Peter Kivy, "Part IV: Music Alone," in *Sounding Off: Eleven Essays in the Philosophy of Music* (Oxford: Oxford University Press, 2012), 191.
93 Arved Mark Ashby, *Absolute Music, Mechanical Reproduction* (Berkeley: University of California Press, 2010), 7.
94 Carl Dahlhaus, *The Idea of Absolute Music*, trans. Roger Lustig (Chicago: University of Chicago Press, 1989), 7.
95 Mieczysław Tomaszewski, *Krzysztof Penderecki and His Music* (Krakow, Poland: Akademia Muzyczna w Krakowie, 2003), 18.
96 Nicholas Cook, "Theorizing Musical Meaning," *Music Theory Spectrum* 23, no. 2 (2001): 171.
97 Ashby, 7.
98 Pierre Boulez and Paul Thévenin, "Possibly…" in *Stocktakings from an Apprenticeship* (Oxford: Oxford University Press, 1991), 113.

to represent extramusical content, with roots in Edouard Hanslick's criticism in the nineteenth century, gained traction with the rise of serialism and positivistic cultural attitudes: "questions of intentionality and communication began to become acute."[99] In the wake of the world wars, concerns over state control and censorship led many to prefer an approach to composition that admitted of no extramusical content and therefore resisted cooption for state-sanctioned messaging.[100] The idea of perfect musical autonomy, requiring no recourse to validation from external sources, was a seductive ideal that garnered almost religious devotion.[101]

What is represented in the concepts of 'programmatic' and 'absolute'? Lydia Goehr writes, "absolute music has often been described as purely instrumental and expressive of nothing but a musical idea; programme music, by contrast, as an instrumental music whose formal development is guided by, or implicitly refers to, an extra-musical idea."[102] In *On the Musically Beautiful*, Edouard Hanslick's manifesto first published in 1854, the concept of absolute music appears sometimes to denote an ontological status ("the content of music is tonally moving forms"[103]), sometimes a compositional prescriptive ("the composer of a piece of instrumental music does not have in mind the representation of a specific content...[i]f he does this, he places himself at a wrong standpoint"[104]), and sometimes an ethics of listening ("contemplative hearing is the only artistic, true form: the raw emotion of savages and the gushing of the music enthusiast can be lumped together in a single category contrary to it"[105]).

3.2.1 Ethics of Listening

This last emphasis, musical absolutism as an ethics of listening, is of particular interest for this discussion. It is apparent that Hanslick, as well as later apologists of the musical absolute, understood that whether composers intend their creations to be wholly autonomous or not, listeners retain their ability to interpret the music freely, and this may well involve reference to extramusical domains even when none is specified in titles or notes. In an attempt to preempt listeners from

[99] *Oxford Music Online*, s.v. "Serialism" (by Paul Griffiths), www.oxfordmusiconline.com (accessed July 15, 2017).
[100] Lisa Jakelski, "Witold Lutosławski and the Ethics of Abstraction," in *Lutosławski – Music and Legacy*, ed. Stainsław Latek and Maja Trochimczyk (Montreal: Polish Institute of Arts and Sciences in Canada, 2014), 94.
[101] Ashby, 6.
[102] Lydia Goehr, *The Imaginary Museum of Musical Works* (New York: Oxford University Press, 2007), 212.
[103] Edouard Hanslick, *On the Musically Beautiful*, trans. Geoffrey Payzant (Indianapolis: Hackett Publishing Company, 1986), 29.
[104] Hanslick, 35.
[105] Hanslick, 63.

drawing such connections, Hanslick offers a strict program for correct listening ("to take pleasure in one's own mental alertness is the worthiest, the wholesomest, and not the easiest manner of listening to music"[106]) and scolds listeners who opt for different listening behaviours, characterizing them as passive sluggards "slouched dozing in their chairs…[allowing] themselves to brood and sway in response to the vibrations of tones, instead of contemplating tones attentively."[107] The message was clear: music, in both form and content, is nothing more than the aesthetic deployment of tones; music's autonomy is its virtue, and creative attempts to (falsely) communicate extramusical content in music, as well as receptive interpretations that (falsely) attribute extramusical content to music, reveal aesthetic, intellectual, and moral failure. As Susan McClary describes it, Hanslick and his sympathetic contemporaries "took upon themselves…the production of a new kind of consumer: one who would renounce the easy pleasures of sentimentality or virtuosity and gravitate toward music that rewarded what Adorno later would call structural listening."[108] This austere, ascetic conception of music, stripped of reference to the outside world, sequestered from poetry, nature, affect, and purpose, became a powerful image of purity, forming a "separate world for itself,"[109] against which programmatic works that "needed an external literary crutch in order not to fall apart"[110] might be judged quite harshly. The effects of this approach were extensive in music scholarship as well as in musical aesthetics: as Nicholas Cook recounts, the Hanslickian orthodoxy on which postwar music theory and philosophy of music were based stated "that music was to be understood in exclusively structural terms while issues of meaning were ruled out of court."[111]

3.2.2 Sound Mass and the Aftermath of Serialism

The serial landscape of the 1950s represented an apex of the ideology of absolute music, in which the autonomy of the musical work was exalted so completely as to absolve music not only of extramusical reference but, as McClary argues, of all intelligibility, social function, and

[106] Hanslick, 64.
[107] Hanslick, 58-59.
[108] Susan McClary, *Conventional Wisdom: The Content of Musical Form* (London: University of California Press, 2000), 114-115.
[109] Dahlhaus, 7.
[110] Dahlhaus, 137.
[111] Cook, 174.

public reception, a situation which she describes as a "*reductio ad absurdum.*"[112] Ideas hinted at in Hanslick's text – that it is better to be "'cold,' 'unfeeling,' 'cerebral'"[113] than to compromise a work's autonomy; that difficulty is a virtue; that it is better to make "a skeleton out of a flourishing organism" and "destroy all beauty"[114] through rigorous analysis than to yield to misguided interpreting; that musical materials "go stale in fifty, nay, thirty years"[115] and that the plight of music must therefore be one of constant self-reinvention or else stagnation – proved premonitory, leading eventually to a musical culture described by Adorno as "the private activity of specialists, a cultural necessity in some not quite clear fashion, entrusted wholly to the experts; no one is actually challenged, no one recognizes himself in it, or senses in it any binding claim to truth."[116] Interestingly, when faced with the existential crisis of an alienated audience and an uncertain future – the anxiety of indifference, perhaps – the apologists of late serialism have occasionally reverted in language to the very types of subjective expression, extramusical references, and sentimentality that musical absolutism so deliberately exorcised. For instance, Andrew Mead writes, "listening to [Babbitt's] compositions is akin to seeing nature in all its richness. All the immediacy and individuality of light falling through thick forest growth or the play of waves in a tidal rip derive from the interactions of simpler, more universal underlying forces…So too it is with Babbitt's music."[117]

In the aftermath of the apex of the musical absolute in the 1950s, many different strains of music emerged, defining themselves in contradistinction to serialist orthodoxy in various ways. These included minimalism (e.g., Steve Reich, Philip Glass), neoromanticism (e.g. George Rochberg, Frederic Rzewski), polystylism (e.g. Alfred Schnittke, Peter Maxwell Davies), music incorporating mystical elements (e.g. George Crumb, Sofia Gubaidulina), aleatoric music (e.g. John Cage, Cornelius Cardew), and of course sound mass music. Unlike some of these other approaches, sound mass did not abandon the saturated chromatic universe occupied by serialism in favour of resurrected tonal materials, multimedia, or chance procedures, but rather continued the material development of that saturated universe in fully composed works. Crucially, however,

[112] Susan McClary, "Terminal Prestige: The Case of Avant-Garde Music Composition," *Cultural Critique* 12 (1989): 60.
[113] Hanslick, 64.
[114] Hanslick, 14.
[115] Hanslick, 35.
[116] Theodor Adorno, "The Aging of the New Music," *Essays on Music* trans. Susan H. Gillespie (Berkeley: University of California Press, 2002), 185.
[117] Andrew Mead, *An Introduction to the Music of Milton Babbitt* (Princeton: Princeton University Press, 1994), 8.

it adopted a more holistic point of view, no longer seeking aesthetic justification in autonomy and rigour of construction alone, but also prioritizing perceptual results.

In Xenakis's famous critique, published first in the essay "The Crisis of Serial Music" (1955) and later reproduced in his book *Formalized Music* (1971) he wrote:

> Linear polyphony destroys itself by its very complexity; what one hears is really nothing but a mass of notes in various registers. The enormous complexity prevents the audience from following the intertwining of the lines and has as its macroscopic effect an irrational and fortuitous dispersion of sounds over the whole extent of the sonic spectrum. There is consequently a contradiction between the polyphonic linear system and the heard result, which is surface or mass.[118]

Ligeti similarly emphasized (metaphorically in the passage below) the sounding result as both the end goal of composition and the primary material of the composer:

> I can perhaps make this clearer through a comparison with painting…the effect of each colour is the result of the chemical combination of certain dyes. As far as the picture itself is concerned, the chemical composition of the dye is of no immediate relevance…the effect 'white' is produced by a certain arrangement of lead and oxygen atoms or of zinc and oxygen atoms, but in regard to the picture it is only the effect 'white' that is significant, not the question whether the dye contains atoms of zinc or lead. In place of zinc and lead atoms one could speak of crystal lattices, electron orbits, light absorption, and so on – each plane has another plane beneath it – but I am painting *directly* with white and only indirectly with crystal lattices.[119]

Lutosławski held serial music to be "a phenomenon of the first order in the history of music," but one with which his music "lacks any connection."[120] He felt strongly alienated from the post-Webernian music of the 1950s, which made him feel "extremely lonely and isolated."[121] Like Ligeti and Xenakis, he also emphasized perception in his thinking about music: "Of course, music is not only sound...[m]usic is also a collection of psychological reactions, and they are not extra-musical."[122] He elaborates:

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[118] Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition* (Bloomington: Indiana University Press, 1971), 8. The original French term "audience" may be better translated in this context to "hearing" rather than the English word "audience"; thank you to John Rea for bringing this to my attention.
[119] Ligeti, *Ligeti in Conversation*, 130.
[120] Stephen Stucky, *Lutosławski and his music* (Cambridge: Cambridge University Press, 1981), 72.
[121] Witold Lutosławski, qtd in Tadeusz Kaczynski, *Conversations with Witold Lutosławski* trans. Yolanta May (London: J. & W. Chester, 1984), 133.
[122] Witold Lutosławski, qtd in Douglas Rust, "Two Questions of Perception in Lutosławski's Second Symphony," *Perspectives of New Music* 42 (2): 190.

> As a result of recognizing the psychological aspect of art as paramount, I am opposed to all those who consider the existence of a work by itself, independent of its being perceived, as the main aim of its being created. The score or recording are quite certainly necessary for the existence of a piece of music. However, they are not in themselves the actual work but only a stage in its realization, which is fully achieved only when the work is experienced by the listener. I understand the process of composing above all as the creation of a definite complex of psychological experiences for my listener.[123]

Penderecki also has "never been interested in sound and form just for their own sake, which has saved [him] from…abstract formal solutions."[124] For these composers, if autonomy is to be held as a virtue of music, it cannot be an autonomy that excludes the perceptions of the listener: the autonomous work must be conceived in terms of the whole of what Molino and Nattiez would later call the "semiotic tripartition," including the *poïetic* level of production, the *immanent* level of material subsistence, and the *esthesic* level of reception.[125] And having chinked the armour of the ideal of absolute autonomy by embracing perception as the *telos* of their constructions, to varying degrees the sound mass composers also accepted the reality of homologies between those constructions and other, extramusical domains of experience, as evident in their interviews and writings on music (detailed at length below).

3.2.3 Sound Mass and the Programmatic-Absolute Distinction

If serialism was a twentieth-century flourishing of the musical absolute, it may seem tempting to connect traditions such as sound mass—which defined themselves in contradistinction to serialism by emphasizing the *esthesic* level and whose composers frequently drew analogies with extramusical domains—to the programmatic tradition. Any such comparisons should be made with great caution. To begin with, in nineteenth century music, the title (perhaps the most important "extramusical" sign, the first sign with which we usually come into contact when encountering a work) was often a powerful clue as to the orientation of the work with respect to musical meaning. Programmatic titles tended to name the subject of the music, often with literary references—*Prometheus*, *Die Moldau*, *Harold in Italy*, *Also Sprach Zarathustra*—while absolute titles tended to describe the form, genre, and/or instrumentation of the piece—*Symphony No. 4, Violin*

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[123] Witold Lutosławski, *Lutosławski on Music* (Lanham, Maryland: The Scarecrow Press, Inc., 2007), 89.
[124] Krzysztof Penderecki, qtd in Tomaszewski, 84.
[125] Jean-Jacques Nattiez, *Music and Discourse: Toward a Semiology of Music*, trans. Carolyn Abbate (Princeton, NJ: Princeton UP, 1990).

Concerto in E Minor, *Piano Sonata No. 3*, *Waltz in A major*. But titles of canonical sound mass works—*Polymorphia*, *Mi-Parti*, *Apparitions*, *Metastaesis*—are not categorically different from their serial counterparts—*Structures*, *Partitions*, *Kontakte*, *Incontri*—and none of them fit either of the nineteenth-century moulds. As Jennifer Joy Iverson states, titles of this sort made the works "seem self-referential – questions of the work's 'meaning' could only be referred to the structure and processes unfolding in the piece itself."[126] Such titles refer to images, concepts, or processes that are not specifically or exclusively musical, but the meanings of these references are clarified by the internal dynamics of the music rather than deference to an external program. They thus suggest a hybrid ideological inheritance from both the programmatic and the absolute, as well as a point of convergence between serialism and sound mass.

Furthermore, while sound mass composers and scholars invoke a host of rich and varied extramusical metaphors in their writings and interviews, they also tended to be skeptical of programmatic intent and distanced themselves from it. Ligeti acknowledged that the way he spoke about music could be misunderstood as programmatic, and that relations between sense impressions in different modalities were important to him in creating and experiencing music, but characterized this as "not a deliberate programme but an indirect, implied message that is present in all music"[127] and insisted that it was not "literary or illustrative music in the sense of programme music…[s]o I would say: programme music without a programme, music that is developed extensively in its associations, yet pure music."[128] While Xenakis frequently used vivid metaphors in relation to music, he also felt that "identifications of music with message, with communication, and with language are schematizations whose tendency is towards absurdities and desiccations."[129] As is well-known, Penderecki's *Threnody for the Victims of Hiroshima*, was originally titled 8'37" and was retitled after the composer was impressed by the expressive communicability of the piece.[130] According to Tomaszewski, Penderecki "is conscious of living and creating within a universe of signs and symbols."[131] However, since Polish sonorists such as Penderecki "eschewed

[126] Iverson, 257-258.
[127] Ligeti et al, 81.
[128] Ligeti et al, 101-102.
[129] Xenakis, *Formalized Music*, 180.
[130] Wolfram Schwinger, *Krzysztof Penderecki: his life and work* (London: Schott & Co. Ltd., 1989), 124.
[131] Tomaszewski, 71.

any declarations of either aesthetic premises or technological procedures of their work,"[132] his beliefs on the matter are somewhat more elusive.

Lutosławski's comments at times explicitly embrace the formalist ideology of absolute music.[133] He read Hanslick's criticism "with great interest,"[134] and restated almost verbatim one of Hanslick's pejorative stances: "Music must be able to fend for itself, and if it cannot, then so much the worse for its composer…no program, no theories can save it."[135] If ever aspects of his music (or discourse about music) came close to implying extramusical reference, Lutosławski attempted to assuage the suggestion with skeptical caution:

> The fact that certain conventions have been taken from outside the sphere of music to govern the method of developing the musical discourse does not mean that the piece should be described as illustrative or program music. In program music the composer is trying to make the listener associate certain non-musical ideas with the music he hears. In the case described here, nothing was further from my purpose. I do not care whether the analogies between music and speech or music and stage situation are detected by the listener or not. In fact I might even say that I would rather they were not.[136]

Accordingly, scholars have characterized Lutosławski as "a perennial skeptic when it came to music's ability to convey specific concepts"[137] whose "compositions belonged in the domain of absolute music"[138] and are "not intended to have any programmatic meaning."[139] Be that as it may, Lutosławski made many other comments that suggest a picture that is not so black-and-white. He did not admonish listeners for any associations they may draw with his music:

> The experience of listening to music, and getting to know it, exists on many levels; music contains a great deal more than the notes in the score. Nevertheless, the 'something more' need not be translated at once into poetry, philosophy, visual images or emotions…Does it mean I am against such an interpretation and consider it improper? Not at all. Everybody has a right to receive music in his own particular way, if he finds it fulfilling…The fact that there are many ways of looking at the same work, and drawing

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[132] Mirka, 7.
[133] See, for instance, Tadeusz Kaczynski, *Conversations with Witold Lutosławski* trans. Yolanta May (London: J. & W. Chester, 1984), 144; also, Jakelski, 72.
[134] Kaczynski, 133.
[135] Lutosławski, *Lutosławski on Music*, 110.
[136] Lutosławski, *Lutosławski on Music*, 10-11.
[137] Jakelski, 72.
[138] Maja Trochimczyk, "Witold Lutosławski and *Musique Concrète*: The Technique of Composing with Sound Planes and its Sources," in *Lutosławski – Music and Legacy*, ed. Stanisław Latek and Maja Trochimczyk (Montreal: Polish Institute of Arts and Sciences in Canada, 2014), 129-130.
[139] Stucky, 174.

> many associations with other arts and experiences, only proves that the non-musical content of music, if any, must be many-sided.[140]

Furthermore, while Lutosławski may have nominally embraced formalism in some passages, others suggest agnosticism with respect to musical meaning: "I really haven't the courage to tackle the subject of meaning in music. The longer one thinks about it, the more questions one finds."[141] A number of statements suggest that the problem for Lutosławski was the absence of *fixed* meaning in music, or (which, as he says, amounts to the same thing[142]), the *plurality* of possible meanings, not the impossibility of extramusical meaning as such:

> The variety of perception greatly increases when we start to penetrate deeper layers of a musical work. More precisely…when we penetrate the realm of associations, that is, the extramusical interpretations of sensations the work produces. The differences in the perception of music in this layer (if it exists at all) are, of course, the greatest, and even diametrically opposed. Sometimes we encounter amazingly inconsistent relations, according to the personal characteristics of particular listeners, the kind of education they have had, and the circumstances in which they listen to music.[143]

As Lisa Jakelski explains, Lutosławski felt that since each person can interpret music differently and has no access to the perceptions of others, extramusical reference is inherently unstable, and therefore it is best to compose music that makes no attempt to express extramusical content and makes no false pretenses about its reception.[144] Because of the ontological and epistemological instability of musical semantics, Lutosławski prefers to bracket the question: "We must definitely assert that music is not an unequivocal art if one can attach to it so many different meanings. Because of this unequivocalness, it is better to consider music as an asemantic art."[145] This is very different from closing the door to all possibility of extramusical meaning, as for example Stravinsky appeared to do in his famous pronouncement that music is "by its very nature, essentially powerless to *express* anything at all, whether a feeling, an attitude, a psychological mood, a phenomenon of nature, etc."[146]

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140 Lutosławski, qtd in Kaczynski, 89-90.
141 Lutosławski, qtd in Kaczynski, 43.
142 Lutosławski, qtd in Kaczynski, 2.
143 Lutosławski, *Lutosławski on Music*, 92-93.
144 Jakelski, 90.
145 Lutosławski, *Lutosławski on Music*, 102-103.
146 Igor Stravinsky, *An Autobiography* (New York: W. W. Norton & Company, Inc., 1962), 53-54.

Lutoslawski's reflections reveal an issue at the heart of the programmatic-absolute debate, one which all accounts of musical meaning must deeply consider: even granting that some music is composed with the *intent* to refer outside itself and other music is not, this may have little bearing on how the music is *perceived*. As such, a strong case can be made that the membrane between "programmatic" and "absolute" is highly permeable, and depends on one's orientation with respect to the semiotic tripartition. Listeners may fail to make associative connections between music and extramusical references intended by the composer, and they may draw their own extramusical associations that have nothing to do with compositional intent. The terms "programmatic" and "absolute," then, may refer more accurately to particular *acts* of musical creation or interpretation than to musical works. Hanslick and his followers addressed this issue by attempting to legislate listening behaviours that reinforced their assertions of the inherent superiority of absolute music. Lutosławski accepted some of the ontological premises of this position, but maintained "a strong desire to communicate something, through [his] music, to the people."[147] While questioning the notion of extramusical content,[148] he nevertheless admitted to thinking of different chords as "hot" and "cold,"[149] modeling music on drama, other arts, and speech,[150] and attempted to express in music an "ideal world, the world of our dreams, of our wishes, of our vision of perfection."[151]

When scholars squirm to avoid any implications of "naïvely programmatic"[152] interpretations even when they seem "well nigh irresistible,"[153] it can seem as though they are motivated by an anxiety of reference instilled by a cultural ethics of listening, descended from Hanslick's absolutist ideology. Lutosławski's own aversion to discussions of musical meaning, on the other hand—while it may have biographical and political roots, as compellingly explicated by Jakelski[154]—often seems to be motivated by philosophical uncertainty. His comments suggest a conviction that extramusical meaning, if it exists, ought to be self-evident to listeners, which he finds difficult to reconcile with the observed plurality of listeners' interpretations. He does not say that such interpretations are wrong, but rather attempts to circumvent the subject, preferring to discuss features of music that can be asserted more positivistically. This line of thinking is endemic in

147 Lutosławski, qtd in Stucky, 106.
148 Lutosławski, *Lutosławski on music*, 93.
149 Lutosławski, qtd in Kaczynski, 86-88.
150 Lutosławski, *Lutosławski on music*, 9-10.
151 Lutosławski, *Lutosławski on music*, xxi.
152 Stucky, 162.
153 Stucky, 172.
154 Jakelski, 71-98.

music scholarship, especially music theory, which has tended to focus disproportionately on those parameters of sound that are most clearly and efficiently represented in conventional scores – especially pitch, and to a lesser extent duration – to the exclusion of questions of meaning,[155] treating music as an autonomous entity whose properties may be explained through exegesis.

But conceiving of music as isolated from other domains of experience and meaning is, I believe, predicated on a solipsistic fantasy: as Nicholas Cook says, "music never *is* 'alone,'…it is always received in a discursive context…it is through the interaction of music and interpreter, text and context, that meaning is constructed."[156] Focusing on those sonic and musical parameters that are most easily quantified and notated may be analytically expedient, but it artificially restricts the field of inquiry and excludes many important questions about musical experience, especially—for the purposes of this chapter—questions of extramusical meaning. As evidenced by the host of metaphorical associations used by composers and scholars to describe sound mass music, for many listeners sound mass may have strong proclivities for extramusical interpretation. This proclivity does not simply disappear if one adopts a formalist position. Rather than bracketing the question, as Lutosławski may have preferred to do, I want to ask: how does sound mass come into meaningful relation with other domains of experience? How can we account for its plurality of extramusical interpretations? To the end of addressing these question, the following section will review some concepts from contemporary theories of musical meaning, and apply them to several examples from the sound mass repertoire.

3.3 MUSIC SEMIOTICS AND EXTRAMUSICAL MEANING

A profusion of multidisciplinary research in recent years has yielded many fascinating insights into musical meaning. While it is beyond the scope of this dissertation to account for all of the compelling approaches currently being explored, some principles from metaphor theory, cognitive semiotics, and *Unités Sémiotiques Temporelles,* which may be useful in understanding semiotic dimensions of sound mass, will be reviewed in this section. Musical examples from Xenakis and Penderecki will be interpreted according to these principles. Another potentially

[155] Amy Bauer, "Tone-color, movement, changing harmonic planes" : cognition, constraints, and conceptual blends in modernist music," in *The pleasure of modernist music: listening, meaning, intention, ideology*, ed. Arved Mark Ashby (Rochester, NY: University of Rochester Press, 2004), 145.
[156] Cook, 180.

illuminating field—topic theory, which also has potentitally illuminating implications for sound mass—will be briefly discussed.

3.3.1 Metaphor Theory, Cognitive Semiotics, and Extramusical Meaning

Metaphor theory, as articulated by Lakoff and Johnson in their seminal book *Metaphors We Live By* (1980), is founded on the principle that metaphor is not merely a rhetorical and poetical device, but is "pervasive in everyday life, not just in language but in thought and action."[157] Metaphors are mitigated by cultural assumptions, values, and attitudes, such that all experience is "cultural through and through."[158] Many culturally learned metaphors that guide our reasoning, communication, daily activity, aesthetic experience, and any number of aspects of our lives are so deeply ingrained that we often do not even recognize them as metaphors. A familiar example from musical experience, examined by Lawrence Zbikowski in *Conceptualizing Music* (2002), is PITCH IS HEIGHT; as the author remarks, "[p]erhaps more remarkable than the long tradition of construing pitch relations in terms of 'up' and 'down' are the ready reminders of how arbitrary a construal it is."[159] As Marie-Elisabeth Duchez observes, the notion of pitch height was "absolutely new"[160] in the Middle Ages in spite of centuries of prior musical practice, invoking a "musical space" that is "at once psychological and imaginary, abstract and conceptual" and is "different from the empirical, physical and mathematical spaces which also belong to the sphere of the intelligible."[161] Zbikowski mentions three other cultures that use different metaphors for pitch: the Kaluli of Papua New Guinea, who describe melodic relations in terms of characteristics of waterfalls; Balinese and Javanese cultures, in which pitches are conceived as 'small' and 'large' because smaller sounding bodies tend to vibrate more rapidly than larger ones; and the Suyá of the Amazon, who describe pitches as 'young' and 'old' because voices tend to deepen with age.[162] Such metaphors, while they may be naturalized within their respective cultures to the extent of evading notice, are not without consequence for understanding: Zbikowski notes that correlating pitch with vertical position, as we do in our western culture,

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[157] George Lakoff and Mark Johnson, *Metaphors We Live By* (Chicago: University of Chicago Press, 1980), 1.
[158] Lakoff and Johnson, 57.
[159] Lawrence Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (New York: Oxford University Press, 2002), 64-68.
[160] Marie-Elisabeth Duchez, "An historical and epistemological approach to the musical notion of 'form-bearing' element," *Contemporary Music Review* 4 (1989): 200.
[161] Duchez, 205.
[162] Zbikowski, 64-68.

> leads quite naturally to an imaginary world in which pitches become things that move through space: the successive notes of a scale gradually descend and ascend…some notes leap, while still others fall. Within this imaginary world, each traversal of space has a specific and unmistakable sound – that is, descent sounds one way, ascent another.[163]

Amy Bauer specifies that metaphorical expression is intrinsic "not only to descriptions of music with programmatic content, but to the historical notion of absolute music as well"[164] because "musical *understanding*…is never restricted to parsing a work's concrete, self-referential details, but relies on conceptual mappings both from other music and other experiential domains."[165]

As it happens, metaphors of 'up' and 'down' are prolific in our culture. Lakoff and Johnson list several other cultural domains that map onto vertical position in physical space: HAPPY IS UP; SAD IS DOWN; CONSCIOUS IS UP, UNCONSCIOUS IS DOWN; MORE IS UP, LESS IS DOWN; GOOD IS UP, BAD IS DOWN, and so forth.[166] These are all examples—in the terminology of cognitive semiotics— of *cross-domain mappings*, in which "we structure our understanding of one domain (which is typically unfamiliar or abstract) in terms of another (which is most often familiar and concrete)."[167] In other words, the more familiar source domain (e.g. height) becomes a *conceptual model* for the less-familiar target domain (e.g. pitch). In theory, any domain may be mapped onto any other, but not all source domains are equally likely to provide useful models for a given target domain. Zbikowski rather comically demonstrates this with the hypothetical mapping PITCH IS FRUIT, which "works less well because fruit does not (in any ordinary sense) constitute a continuum."[168] He had earlier demonstrated that the property of linear continuity is essential to the mapping of 'up-down' onto musical pitch, and the mapping works so well at highlighting this property that we may often forget that it is a mapping at all. However, there are other properties of pitch that are not captured in this mapping, which require a different model to be understood. For example, neither the height model nor the others mentioned above (waterfalls, size, age) capture the phenomenon of octave equivalence (the perceptual similarity between pitches separated by an octave that gives the impression of a repeating cycle through linear motion in pitch space). This property is highlighted by another embedded metaphor, PITCH

163 Zbikowski, 65.
164 Bauer, 131.
165 Bauer, 132.
166 Lakoff and Johnson, 14-17.
167 Zbikowski, 14.
168 Zbikowski, 70-71.

IS A CIRCLE, which manifests in the "circle of fifths" from music theory and in music teachers' common use of a circular "pitch clock" with each pitch class mapped onto an hour of the day. More complicated metaphors that attempt to capture both properties – linearity and circularity, pitch height and chroma – have been developed by Roger Shepard, such as PITCH IS A HELIX.[169]

Figure 38: "Pitch Clock"

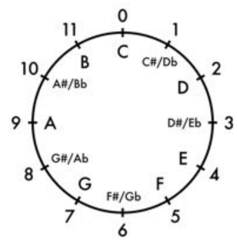
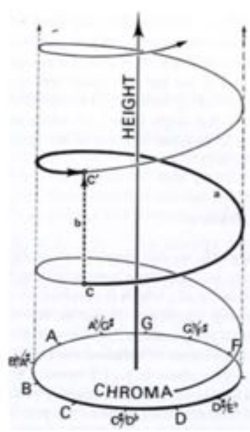


Figure 39: Roger Shepard's Helical Model of Pitch Space. Reproduced by permission.



As these examples demonstrate, the same target domain can be mapped onto many different source domains (and vice versa), and the understanding that results from the modeling will depend on which properties the domains have in common. Zbikowski and Bauer use the term *image schemata*, to refer to such properties. Image schemata, which are "pre-conceptual" and by no means exclusively visual (as the word 'image' may seem to imply[170]) are cognitive constructs connecting a vast range of experiences that manifest the same recurring structure,[171] often

[169] Roger N. Shepard, "Geometrical approximations to the structure of musical pitch," *Psychological Review*, 89 No. 4 (1982): 305-333.
[170] Although the word 'image' tends to evoke visual associations, it has been metaphorically redeployed to other modalities. In "The Auditory Image: A Metaphor for Musical and Psychological Research on Auditory Organization," Stephen McAdams describes the "auditory source image" as a fruitful embodiment of combined aspects of auditory 'impressions' from perception, memory and imagination." (290)
[171] Zbikowski, 68.

grounded in bodily experience and action.[172] Some metaphorical mappings are more effective than others because they maintain invariant image schemata between the source and target domains, while others do not: 'pitch' and 'height' maintain the image schema 'continuity'; 'pitch' and 'clock' maintain the image schema 'circularity'; 'pitch' and 'fruit' do not maintain any obvious schemata. Cook adopts a somewhat more general terminology, referring to the properties of domains that allow for cross-domain mapping and conceptual modeling as "attributes,"[173] and the invariance relationships between them as "homologies."[174] Another important concept from cognitive semiotics is *conceptual blend*, which, like cross-domain mapping, relates two (or more) domains of experience, but unlike cross-domain mapping, produces a new, "blended" domain containing some attributes from one domain and some from the other(s).[175] Bauer suggests that whereas cross-domain mapping facilitates understanding based on homology, conceptual blends create new meanings by combining different attributes, and therefore any domains may be blended with no requirement of invariant image schemata.[176] Familiar examples from musical discourse might include "word painting," "phrase shaping," "*cantus firmus*," "*Klangfarbenmelodie*," and, of particular interest for this discussion, "sound object," "sound plane," and "sound mass."

3.3.2 Metaphor and Absolute Music: A MUSICAL WORK IS A WORLD

The rhetoric of the musical absolute, for all its insistence on autonomy, relies heavily on cross-domain mapping and conceptual blends. As Daniel Chua states, "absolute music is an extramusical idea"[177]: attempting to understand how a musical work can exist as a self-contained entity isolated from all other domains requires a cognitive leap, following the metaphor A MUSICAL WORK IS A WORLD. For example:

> [Music's] realm is truly not of this world…Music demands once and for all to be grasped as music and can be only from itself understood...[178]

> The idea of 'absolute music'…as pure 'structure,' represents itself. Detached from the affections and feelings of the real world, it forms a 'separate world for itself.'[179]

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[172] Bauer, 132-133.
[173] Cook, 178.
[174] Cook, 172.
[175] Zbikowski, 77.
[176] Bauer, 134-135.
[177] Daniel Chua, qtd in Jakelski, 79.
[178] Hanslick, 30.
[179] Dahlhaus, 7.

Music is the domain of an ideal world.[180]

Attempting to understand such statements requires the reader to consider which attributes of a musical work might map onto, or blend with, their concept of a "world." This word, like so many English words, is polysemous, and our understanding of the metaphor depends on the attributes that enter into the mapping or blend. Two common senses of 'world' are:

(1) the universe or all that exists; everything
(2) all that concerns…a specified class, time, domain, or sphere of activity[181]

A musical work, as represented in perception, might seem more "naturally" homologous with the latter—as one sphere of sonic activity among other sounds, other modalities, other domains—but the discourse of absolute music seems to more closely imply the former: the musical work is to be understood as a self-contained, wholly autonomous universe. Thus, perhaps, the internally defined laws by which the musical "world" operates are attributes that map onto the natural laws of the universe; the composer who sets those laws into play might map onto a creator God, or to some secular channel of transcendental causality; the work's boundaries may map onto the transcendental boundaries of existence, and so forth. In any case, the world of the work is defined in contradistinction to the world of daily life, and to experience the work is to enter its world (and by extension—temporarily, imaginatively—to leave our own). Like other culturally embedded metaphors such as PITCH IS HEIGHT, A MUSICAL WORK IS A WORLD might become so familiar as to recede from awareness and seems like a self-evident state of affairs. But music, even music conceived in the image of autonomy, is always open to metaphorical homologies with other domains of experience, and to even think of a music whose autonomy evades such mappings *requires* such a mapping (namely, the mapping A MUSICAL WORK IS A WORLD).

3.3.3 MEANING IS CONTENT

Another, even more fundamental metaphor is at work in the concept of extramusical meaning (and of meaning in general): MEANING IS CONTENT, a generalization of a metaphor identified by Lakoff and Johnson, LINGUISTIC EXPRESSIONS ARE CONTAINERS FOR

[180] Lutosławski, qtd in Jakelski, 73.
[181] *Canadian Oxford Dictionary* (2nd Ed.) ed. Katherine Barber, s.v. "world" (Toronto: Oxford University Press, 2004), 1795.

MEANINGS, which, as the authors say, entails "that words and sentences have meanings in themselves, independent of any context or speaker."[182] The implication of MEANING IS CONTENT is that is that if music has extramusical meaning, then music must be like a container that delivers extramusical meaning to the listener: the meaning must be somehow inside the music, there to be unpacked. Meaning on this account is a property of the music, something that can be revealed through exegesis, something fixed, something about which claims may be true or false. This metaphor is seen to be at work, either positively or negatively, in many descriptions of extramusical meaning:

> [Musical beauty] is self-contained and in no need of content from outside itself...[183]

> Music is capable of modeling semantic *content* as well by motivating the construction of scenarios in musical space that model conceptual content itself...[184]

> I view any discourse about the so-called content of a composition with some scepticism; to my mind this content is absent.[185]

I would like to suggest that the metaphor MEANING IS CONTENT may be a source of much of the controversy and confusion about extramusical meaning. Perhaps there are other, less problematic ways to conceptualize extramusical meaning: not something that the music delivers, but something that arises in the act of interpretation; not something fixed, but something dynamic and contextual; not an objective attribute, but a kind of interaction between subject and object. The crucial point, I believe, is that when we speak of music's extramusical content (or semiotic content, semantic content, narrative content, emotional content, etc), we fashion meaning as something *contained* within the music, which is difficult to square with plural (and especially with contradictory) interpretations listeners frequently draw with the same music. One answer is to adopt a formalist position and gives up on the reality or legitimacy of extramusical meaning. But another option might be to give up on the metaphor MEANING IS CONTENT, and conceive of extramusical meaning instead as something that arises out of the interaction of the listener with the music, based on meaningful (e.g. homologous) relations between musical attributes and the attributes of other domains.

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182 Lakoff & Johnson, 11.
183 Hanslick, 28
184 Nussbaum, 123-25.
185 Lutosławski, quoted In Kaczynski, 91.

3.3.4 EXTRAMUSICAL MEANING, ATTRIBUTE SELECTION, HOMOLOGY, AND SOUND MASS

The model of extramusical meaning I would like to adopt is closely related to Nicholas Cook's theory of attribute selection. As Cook describes it, musical works (or "traces") "can be thought of as bundles comprised of an indefinite number of attributes from which different selections will be made within different cultural traditions, or on different occasions of interpretation."[186] Music may give rise to many meanings, but that does not mean that just any meaning will do, or that the relation between music and its meanings are arbitrary: from the vast (but not infinite) bundle of attributes presented in a given musical entity, the listener (or culture) selects a finite number of attributes that may be understood in terms of models provided by homologous source domains, or combined with attributes selected from other domains in the production of new, blended meanings. Neither bereft of meaning nor bound to fixed meanings, Cook argues that "musical works are unstable aggregates of potential signification."[187] Zbikowski makes much the same point, saying that musical meaning "is not, in the final analysis, simple or direct but multivalent and contingent," reflecting a rich set of activated correspondences,[188] as does Nussbaum in characterizing musical performance as "a non-propositional symbolic utterance that motivates the construction of mental models."[189]

Since the selection of attributes is so critically important in this account of music semiotics, the types of attributes that are considered to make up the musical entity will have extensive repercussions for the types of mappings or blends available to music. Huovinen and Kaila, in a study on extramusical associations in a style very different from sound mass ("production music"), give a sense of the breadth of attributes from which listeners may select:

> As Cook (2001, p. 183) suggests, different attributions of meaning to music may well be grounded on 'different selection[s] of attributes from the musical trace.' Consider, then, that the musical attributes anchoring the listeners' associations might potentially include anything from simple overall parameters (tempo, timbre, etc.) or changes in them (registral sweeps, ritardandi, etc.) through culturally entrenched individual features (a rising fourth to the tonic on the downbeat, a major seventh chord, etc.) or sound types (string orchestra, distorted lead guitar, etc.) to broad complexes of the foregoing such as genre or style ('Motown,' 'Brahms,' 'Italo western,' etc.), and more. Consider further that any culturally pertinent extrinsic meaning—LOVE, for instance—will have been evoked in

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[186] Cook, 178-179.
[187] Cook, 188.
[188] Zbikowski, 74.
[189] Nussbaum, 94.

> countless different musical contexts in our listeners' lives, and for each of the listeners, *love* may have become epitomized in quite individually experienced selections of music—all heard with varying degrees of attention to the various possibly relevant levels of musical detail.[190]

In light of the considerable differences between the musical attributes of sound mass and those of most other styles of music, it is worth reflecting here upon the sorts of things that may be considered "musical entities." To return once more to Hanslick: music, for him, was resolutely an arrangement of tones. In 1950s serialism (in contradistinction to which, as noted above, sound mass emerged), the systems for deploying musical tones had changed surely beyond what could have been foreseen in the nineteenth century, but nevertheless, the tone's axiomatic position as the fundamental unit of music was preserved, and Hanslick's account of the hierarchy of musical parameters was still largely accurate:

> The material out of which the composer creates, of which the abundance can never be exaggerated, is the entire system of tones, with their latent possibilities for melodic, harmonic, and rhythmic variety. Unconsumed and inexhaustible, melody holds sway over all, as the basic form of musical beauty. Harmony, with its thousandfold transformations, inversion, and augmentations, provides always new foundations. The two combined are animated by rhythm, the artery which carries life to music, and they are enhanced by the charm of a diversity of timbres.[191]

The "pecking order" of musical parameters is thus identified as: melody, harmony, rhythm, timbre. In contrast to this, and roughly speaking, sound mass attenuates discretely perceptible pitch and rhythm and emancipates timbre, thus expanding the field of musical experience to include sound patterns excluded from Hanslick's characterization of the musical. In so doing, sound mass potentially makes homologous relations with extramusical domains more plausible than they might seem for music consisting solely of tones.

The vast majority of non-musical sounds[192] that we encounter do not have clearly defined pitch, and those that do (e.g., the human voice, animal calls) tend to modulate continuously rather than establishing stable pitch values for any length of time. Notes in conventional Western music,

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[190] Erikki Huovinen and Anna-Kaisa Kaila, "The Semantics of Musical Topoi: An Empirical Approach," *Music Perception* 33 no. 2 (2015): 237.
[191] Hanslick, 28.
[192] Various developments in the late 20th- and early 21st-centuries have expanded the palette of musical sounds to essentially include *all* sounds, such that there is no such thing as any longer as a "non-musical sound." I am using the term here in the "everyday" sense of sounds other than those produced by musical instruments or voices with the intention of making music (in the traditional sense).

on the other hand, are defined by stable pitches which are organized into scales of discrete and clearly differentiated values (scale degrees), a situation that is highly at odds with the frequentially continuous nature of most non-musical sounds. Harmony, which is often taught as the aesthetic and theoretical foundation of western music, has no clear analogue in non-musical sounds. To be sure, the grouping of harmonically related partials in auditory scene analysis is a fundamental aspect of auditory experience, but the fusion of partials into perceived timbre is usually so complete that we are unaware of the presence of individual partials or the ratios between them. Non-musical auditory stimuli in which multiple pitched sounds are superimposed – crowds of people, flocks of birds, swarms of bees – do not conform to patterns or "rules" anything like those of the harmonic series or tonal harmonic practice.

In the temporal domain, we encounter in our own bodies and behaviours a number of periodic (or quasi-periodic) biorhythms with pulses similar in tempo to conventional musical meters, including footsteps, heartbeats, breathing, chewing, tapping, and speech syllables; however, the kind of hierarchical synchronization characteristic of metrical music (between pulse, subdivisions, metrical and hypermetrical patterns) is rarely if ever encountered in non-musical auditory situations. When multiple periodic stimuli are experienced simultaneously in non-musical situations (e.g. the footsteps of a crowd or herd on the move, or the uncoordinated breathing of a group of people), each typically proceeds at a pace unrelated to the others.

In short, if one conceives of music as a system of clear, stable pitches organized according to defined harmonic structures and recursive metrical rhythms, and if musical meaning consists in homologous relations with exrtramusical domains, then suspicion about music's capacity for extramusical meaning might seem justified: the primary parameter of musical discourse (stable pitch) is particular to music and rarely encountered elsewhere; musical organization (harmony, meter) is incommensurate with the organization of most non-musical auditory experience; and most instances of iconic similarity in music rely on secondary parameters (especially timbre) that are conceived as inessential to the music. Indeed, the lack of obvious homologies between the tonal system of music and extramusical ("natural") sound experience seemed to have played a role in Hanslick's opposition to musical reference:

> Against our claim that there is no music in nature, it will be objected that there is a wealth of diverse voices which wonderfully enliven nature. Must not the babbling of the brook, the slap of waves on the shore, the thunder of avalanches, the raging of the gale have been the incentive to and prototype of human music? Have all the murmuring, squealing,

> crashing noises had nothing to do with the character of our music? We must in fact reply in the negative. All these natural manifestations are nothing but noise, i.e., air vibrations of incommensurable frequencies. Seldom at best, and then only in isolated instances, does nature produce a tone, i.e., a sound of determinate, measurable pitch, high or low. Tones, however, are the basic conditions of all music.[193]

Sound mass, however, turns this situation on its head, and in so doing, gains considerable semiotic power. As reviewed in Chapter 1, it subverts or exceeds in various ways the perception of discrete and stable tones, replacing them with perceptual gestalts or spectromorphologies that blur the distinction between pitch and noise and so bear a more "natural" iconic affinity with many sounds encountered outside of music. Sound mass dispenses with harmonic structures in the traditional sense, replacing them with distributions of density or activity. It dispenses with metrical organization, instead presenting superpositions of events distributed stochastically, aleatorically, micropolyphonically, or in other ways that give rise to perceptual grouping without synchronization. Timbre is considered not to be a secondary or decorative parameter, but a primary *telos* and shaping force of sound mass.

Mappings between musical attributes and the attributes of other domains of experience frequently provide a compelling basis for extramusical interpretation, and may be grounded in sound-specific homologies (as when musical sound masses imitate the sound of real-world sound masses such as herds, crowds, and swarms) or more abstract affinities (as when the deployment of sound events in a mass imitates massed behaviour in other domains or modalities). The latter provide the bases for *Unités Sémiotiques Temporelles* (USTs), a set of archetypes developed by the researchers of the Laboratoire Musique et Informatique de Marseille (MIM) that map musical gestures onto extramusical, physical properties and bevaviours (e.g. "inexorable trajectory," "advancing," "suspended," "in waves") on the basis of morphological properties such as duration, reiteration, continuity, direction, energy, and so forth. USTs are in theory applicable to any music, including tonal and other note-based musics, but given that sound mass tends to focus attention on global morphological properties *eo ipso*, USTs may be especially propitious in sound mass analysis.

[193] Hanslick, 71.

3.3.5 TOPIC THEORY AND SOUND MASS

While homologous cross-domain mapping provides a plausible account of much extra-musical meaning, it should by no means be thought its *only* basis. As Huovinen and Kaila point out, "while Cook (2001) may be right to suggest that meaning attributions are typically constrained by some 'enabling similarities' between the musical and nonmusical domains ... listeners' making sense of music by extrinsic means does not necessarily require such 'isomorphic' relations."[194] In other words, there are other ways (besides similarity) that musical attributes can relate meaningfully to extramusical domains, for example through cultural associations as studied in *topic theory*. Originated by Leonard Ratner in 1980 and developed by many scholars including Raymond Monelle, Kofi Agawu, Carol Krumhansl, and Danuta Mirka, topic theory is predicated on the idea that musical topics (or *topoi*) gain conventional associations through cultural use and exposure, providing composers and listeners with a shared semantic vocabulary for creating and interpreting music. Monelle considers topics to be "culturally enshrined icons or indices."[195] Musical styles, figures, forms, and idioms become culturally enshrined through repeated use in particular contexts such as worship (e.g. hymns), dance (e.g. waltzes), or the hunt (e.g. horn calls), and in time come to evoke the semantic associations of these contexts even when encountered elsewhere: when this happens, they become topics. Much theoretical literature has described the topics of the eighteenth and nineteenth centuries, and Carol Krumhansl[196] and Elizabeth Margulis[197] have empirically demonstrated that such topics have psychological reality.

Might sound mass, or contemporary music in general, have topical significance within our culture? If so, in what contexts might contemporary audiences encounter this music often enough to form enshrined cultural associations? For most audiences, especially non-specialist audiences, the answer is clear: in movies (and perhaps to a lesser extent in television and video games), where this music is used to signify the fantastical, the strange, the horrifying, the supernatural, the sublime. Stanley Kubrick, for instance, prominently featured the music of Ligeti and Penderecki in films such as *2001: A Space Odyssey* (1968) and *The Shining* (1980), respectively. In an empirical

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194 Huovinen and Kaila, 237.
195 Raymond Monelle, *The Sense of Music: Semiotic Essays* (Princeton, NJ: Princeton University Press, 2000), 15.
196 Carol Krumhansl, "Topic in Music: An Empirical Study of Memorability, Openness, and Emotion in Mozart's String Quintet in C Major and Beethoven's String Quartet in A Minor," *Music Perception* 16, no. 1 (Fall, 1998): 119-134.
197 Elizabeth Helmuth Margulis, "Expectation, musical topics, and the problem of affective differentiation," in *The Oxford Handbook of Topic Theory*, ed. Danuta Mirka (New York: Oxford University Press, 2014).

study on narrative listening to excerpts from nineteenth century programmatic music, Baroque music, and minimalist music, Margulis found that participants reported imagining stories or story elements in response to the music 59.3% of the time, suggesting that although it is not known how closely this rate corresponds to spontaneous narrative perception of music in a non-experimental setting, "participants *can* imagine narratives quite easily."[198] Of the positive responses, 88% indicated imagining the story happening to someone else, "consistent with the notion that a model for narrativizing might come from film music."[199] But most remarkable in this study was the consistency between participants in the stories they reported imagining, which were verbally reported by participants in the experiment: for instance, 58% of descriptions of an excerpt from Prokofiev's "The Montagues and the Capulets" from *Romeo and Juliet* connoted violent confrontation, and fully 74% of descriptions of an excerpt from Liszt's *Mephistopheles* used words that evoked a cartoon cat-and-mouse chase. Margulis remarks that the findings suggest "the kind of listening encouraged by movie music might extend to repertoire well beyond its borders,"[200] but also that "the consensus interpretations did not necessarily match anything the composer could have imagined."[201] In other words, topical associations with film music may not be restricted to the specific pieces listeners have heard in movies, but may extend those associations to other pieces with recognizably similar style elements, even when encountered outside a film context. Furthermore, and contrary to the assumption that listeners who are less engaged in the music depend on extramusical imagery to compensate for their lack of other means to engage, Margulis's results showed the opposite: "[w]hen people enjoyed [and] recognized the style" they were "more likely to construct a narrative…whether or not the music was composed with narrative intent."[202] These findings are consistent with the findings presented in Chapter 4, in which listeners who were given the choice of self-reporting associations with sound mass music tended to report science fiction, horror, and fairy tale imagery. It also suggests that the listening habits of the public have strong narrative tendencies, a finding that may be important for composers interested in connecting with broader audiences.

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[198] Elizabeth Helmuth Margulis, "An Exploratory Study of Narrative Experiences of Music," *Music Perception* (in press), 26.
[199] Margulis, "Narrative Experiences,"18.
[200] Margulis, "Narrative Experiences," 27.
[201] Margulis, "Narrative Experiences," 30.
[202] Margulis, Narrative Experiences," 31.

3.4 XENAKIS, *METASTASEIS* (1954); PENDERECKI, *POLYMORPHIA* (1961)

The sections of *Metastaseis* and *Polymorphia* I will examine are both for large string orchestra (46 players and 48 players, respectively) in which each instrument is given an independent part. The passages merit comparison for several reasons: they are both early and canonical entries in the sound mass canon, they are both written entirely in glissandi, and they both draw formal inspiration from extramusical sources in a visually demonstrable way. Moreover, they provide very different sets of musical attributes from which listeners might choose in interpreting the music, providing different plausible cross-domain mappings. To be clear: this process of attribute selection is both subjective and, as Lakoff and Johnson say, "cultural through and through." Attribute selection is always partial, and mappings are promiscuous (i.e., the same musical attributes can map onto attributes in multiple other domains). As such, the analysis presented here makes no pretense to, and in fact is intended to demonstrate the absence of, universality. Nevertheless, adopting the position of this dissertation—that extramusical meaning is not fixed content—does not render extramusical meaning arbitrary or non-existent, because interpretations are still constrained by musical attributes. Music is polysemic, it is not omnisemic or asemic.

3.4.1 *METASTASEIS*

Xenakis was an architect and a mathematician as well as a composer, and some of the drawings he used in his compositions were specifically architectural. He famously used the same design for the Philips Pavilion in Brussels, which he created with Le Corbusier, for the opening and closing sections of his composition *Metastaseis*. These sections assign independent glissando trajectories to each instrument, following the contours used in the pavilion; Xenakis believed "that on this occasion music and architecture found an intimate connection."[203]

[203] Xenakis, *Formalized Music*, 10.

Figure 40: Iannis Xenakis, sketch for Philips Pavilion. Reproduced by permission.

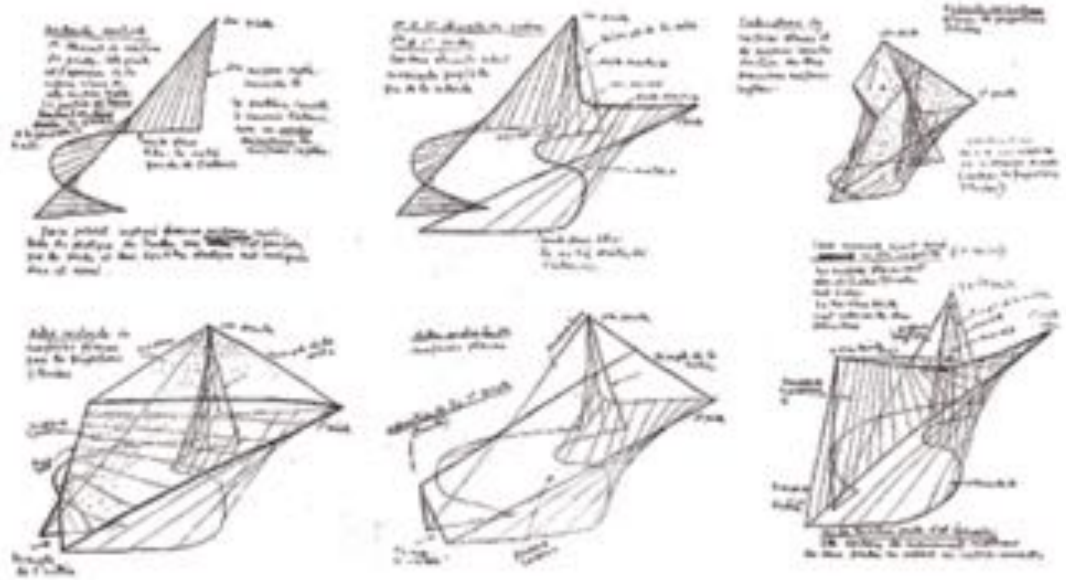
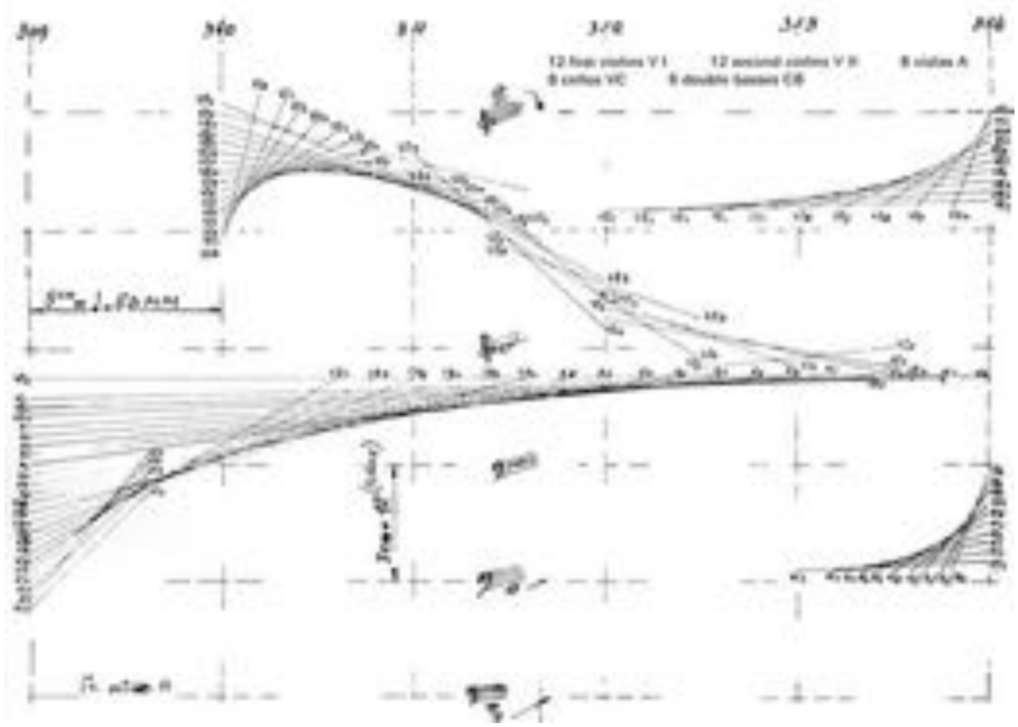
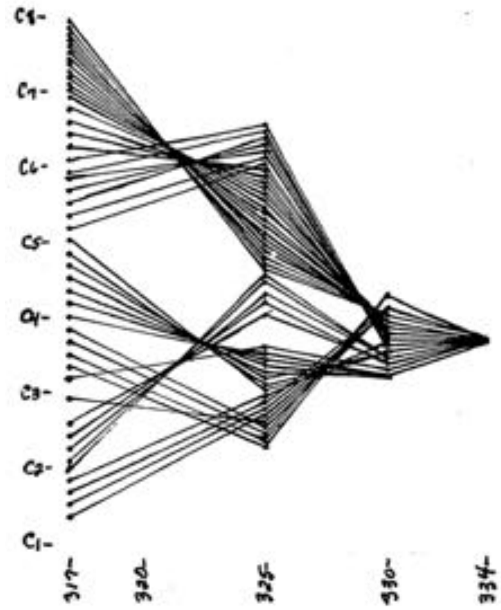


Figure 41: Xenakis, sketch for *Metastaseis*. Reproduced by permission.



Gwyneth Roberts offers the following pitch graph of the final section of *Metastaesis*, presenting more clearly than the score the overall pitch trajectory of the whole:

Figure 42: Gwyneth Roberts, pitch graph of final section of Xenakis, *Metastaesis.*[204]



As this graph makes clear, the overall trajectory is one of CONVERGENCE, from a wide and approximately evenly distributed sound mass[205] to pitch unity on G#3. As this trajectory is continuous, progressive, clear, and goal-directed, its character is also TELEOLOGICAL. The dynamics (not represented in the graph) also follow a progressive (though not linear or uniform) crescendo or INTENSIFICATION. At the same time, the glissandi are not coordinated in a single global gesture, but move as several units in contrary, "common fate" motion (to use Gestalt terminology), creating a kind of contrapuntal METAMORPHOSIS over time. Because the passage consists exclusively of glissandi (until pitch unity is reached), and assuming (as was the case at the time of composition and is arguably still the case today) that stable tones are the standard, normative musical units, the passage is UNSTABLE (at least in the pitch parameter); nevertheless, the glissandi are all even and linear (between the two coordinated direction changes), and as such, are SMOOTH. Taken as a whole, the passage approximately coheres with the description of the UST "STRETCHING"[206]: a globally uniform increase in at least one morphological parameter

[204] Gwyneth Roberts, "Procedures for Analysis of Sound Masses" (PhD dissertation, Indiana University, 1978), 47.
[205] The intervals are not perfectly homogeneous: the upper portion of the "chord" is chromatically saturated while intervals are somewhat more widely spaced in lower parts of the register; however, these notated pitches only represent starting points for the glissandi and are not sustained long enough to have any perceptual significance as discrete values.
[206] François Delalande et al. *Les Unités Sémiotiques Temporelles: Éléments nouveaux d'analyse musicale* (Marseille, France: Éditions M.I.M., 1996), 84.

(here, global pitch density) which gives the impression of moving towards the maximal point in a process, creating a sense of accumulating tension, energy, and anticipation.

This list is of course incomplete, but it already points to many possibilities of interpretation by cross-domain mapping. It also *excludes as implausible* many other possibilities that would contradict the attributes described here. A listener who focuses on the attribute of CONVERGENCE may map this music onto a kind of 'big crunch,' but not a 'big bang' which would involve an explosive divergence; nor onto an 'implosion' which would involve a violent, rapid convergence instead of the gradual one presented. A listener who focuses on the attributes of INSTABILITY and CONTINUAL METAMORPHOSIS may map this music onto a restless state of mind, or changing cloud formations, but not onto steady-state equilibrium. A listener who focuses on SMOOTHNESS may map this music onto a slow and graceful bodily gesture or to the motion of celestial bodies, but not onto jerky, erratic motion. And so forth: an indefinite number of non-arbitrary mappings could plausibly be made, and an indefinite number of others are excluded. The music is not disjunct, it is not heterogeneous, it is not episodic, it contains no discrete events, no periodicity, no sense of foreground-background, its duration extends beyond the proportions that typically characterize a musical event, and yet it is a process with a foreseeable end: hypothetical mappings that contradict these attributes would not make convincing or useful conceptual models. Paul Griffith's description of the opening section of *Metastaseis*, which follows the same process in reverse (beginning at pitch unity and expanding to a wide mass), as "largely built on glissandi of rising volume that could recall an airplane rising during takeoff"[207] is consistent with the attributes described above; the music would make a far less convincing mapping to stop-start inner-city traffic, which would contradict the music's SMOOTHNESS. The model that we know is literally homologous with this music—the Philips pavilion—may seem unlikely to make it into the listener's awareness unless they know about this connection in advance, but it would be possible to hear musical associations with space, geometry, shape: given the frequent analogies between music and architecture (a mapping approved even by Hanslick[208]), there well may be such a thing as "architectural listening."

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[207] Paul Griffiths, "Iannis Xenakis, Composer Who Built Music on Mathematics, Is Dead at 78," *The New York Times* Feb. 05, 2001, http://www.nytimes.com/2001/02/05/arts/iannis-xenakis-composer-who-built-music-on-mathematics-is-dead-at-78.html?mcubz=2.

[208] Hanslick, 6; 29; 83.

Figure 43: The Philips Pavilion, Brussels World Fair, 1958. Reproduced by permission.

3.4.2. *POLYMORPHIA*

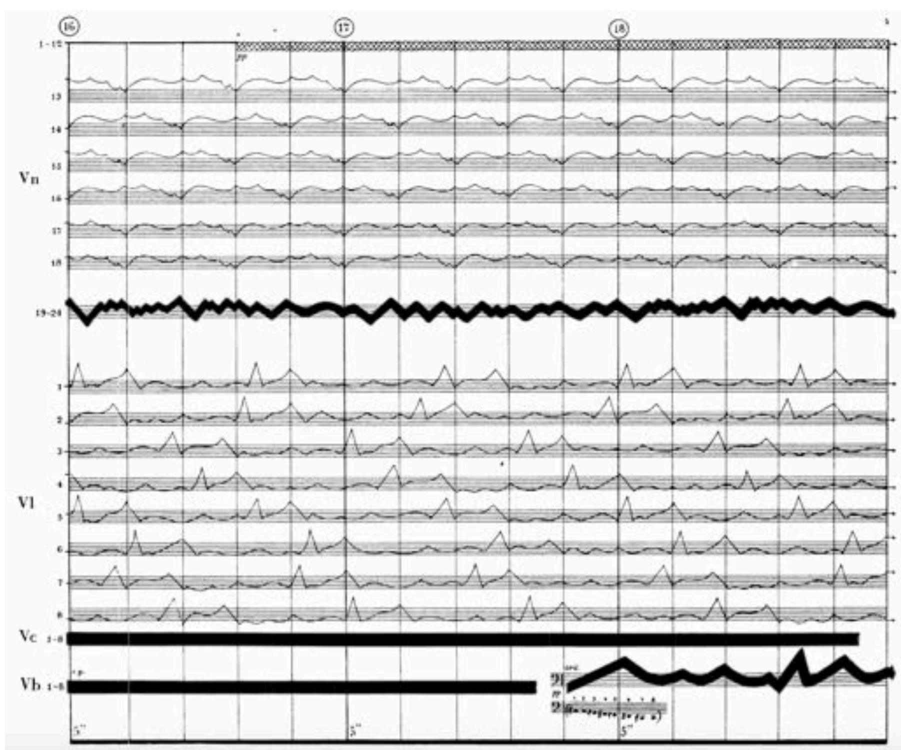
The glissandi in the opening section of *Polymorphia* are "a graphic representation in 'temperature charts', oscillograms and electrocardiograms."[209] The violins and violas execute irregular, periodic, JAGGED glissando patterns with staggered peaks and troughs; the cellos and basses play overlapping oscillations or sustained blocks. Each part moves in patterns within a defined pitch range that does not change, and they are staggered to create a more-or-less consistent occupation of the pitch space, such that the mass is INTERNALLY KINETIC but GLOBALLY DIRECTIONLESS. The notated dynamics do not change, but parts are added throughout this section, progressively filling in the pitch space delineated initially by very high sustained pitches in the first 12 violins and very low pitches in the cellos and basses. As parts are set into motion—violins 1-12 begin oscillating between rehearsal numbers 16 and 17, basses commence an 'electrocardiogram' pattern before 18—the music increases in perceived intensity due to textural DENSIFICATION. As was the case in *Metastaseis*, the preponderant glissandi diminish perceptual stability, but here the sound block and regular oscillations in the cellos and basses ground the global texture in a kind of expanded and indistinct "pedal tone," such that the disappearance of this grounding when the basses begin moving before 18 is a significant destabilizing moment. As such, the

[209] Schwinger, 131.

musical gesture may approximately cohere with the UST "FALLING,"[210] which its researchers describe as a unit divided into two successive phases, the first of which is globally uniform even if the material is animated with internal movement, followed by acceleration and change in pitch (the researchers elaborate with a semantic description that this UST ruptures an equilibrium and converts potential energy into kinetic energy).

An aspect of the effect of this section that is not obvious in the score is that these overlapping, irregular string glissandi can sound surprisingly, even uncannily vocal. But again, depending on the attributes attended to by the listener, an indefinite number of plausible mappings may be enabled while at the same time an indefinite number of others are excluded: a listener who focuses on the INTERNAL KINESIS and GLOBAL DIRECTIONLESSNESS of this section may metaphorically relate it to a disorganized "crowd of people" or a "swarm of insects," but not a chanting slogan or a hibernating hive; listeners who focus on JAGGEDNESS may engage a conceptual model of "jerky motion" but not of "graceful sway."

Figure 44: Krzysztof Penderecki, *Polymorphia*, rehearsal numbers 16-18.[211]



[210] Delalande et al, 48-58.
[211] Penderecki POLYMORPHIA Copyright © 1962 by Schott Music GmbH & Co. KG, Mainz, Germany. Copyright © renewed. Used by permission of European American Music Distributors Company, sole U.S. and Canadian agent for Schott Music GmbH & Co. KG, Mainz, Germany.

Descriptions such as this are difficult to corroborate empirically, due in part to the absence of a clear definition of "attribute," the fact that some of the attributes identified are *already metaphors*, and the fact that this kind of interpretation is necessarily subjective. Attributes, as I am conceiving them here, are defined by the intentionality of the subject and are therefore difficult or impossible to define in a universal or prescriptive way. But to reiterate the point once again, "subjective" is not synonymous with "arbitrary" (as it is often assumed to be in everyday parlance). Perceptual and interpretive matters always involve a subjective component that is contingent on the context, history, personality, and intentionality of the subject, and this is precisely why musical meaning is so "polymorphic" and "metastasizing" and cannot be conceived as fixed or stable content. But, as this discussion has attempted to underscore, it is not on that account a phantom with no basis in reality. Attributes, selected intentionally by the subject and mapped onto attributes of other domains of experience, through homology, topical association, and so forth, provide flexible but non-arbitrary bases for the interpretation of extramusical meaning.

3.5 METAPHORS, ASSOCIATIONS, AND POETICS OF SOUND MASS

Having considered some of the historical, theoretical, philosophical, and semiotic aspects of sound mass semantics, we will now review many of the evocative and poetic terms with which composers and scholars describe sound mass. This discussion will focus on interviews and writings by and about Ligeti, Lutosławski, Xenakis, and Penderecki, but other composers' and scholars' work will also be referenced where relevant. The categories into which these metaphors and associations are organized—*spatial*, *material*, *behavioural*, *cross-modal*, *naturalistic*, *technological,* and *surreal*—are not intended to be mutually exclusive: there may be considerable overlap between them, and any given metaphor (or cluster of metaphors, as they are often articulated in tandem with one another) may fall into more than one category.

3.5.1 SPATIAL METAPHORS

A great many of the metaphorical descriptions of sound mass are *spatial* in nature. Of course, sound (*qua* vibrating air molecules) exists in space in a literal, non-metaphorical sense, and its sensory representation always conveys a sense of the spatial location of the sound source(s).[212]

[212] Plack, 156-74.

Source location in auditory perception is sometimes exploited directly in sound mass composition, as in Xenakis's composition *Terretektorh* in which the performers are dispersed amongst the audience (see Figure 18, Chapter 1), as well as in spatialized acousmatic music and antiphonal choral music. However, the discourse around sound mass often asserts spatiality in a different sense, ascribing to the mass spatial dimensions and properties as though the sound were a physical, geometrical entity, sometimes imbued with material attributes. Charles Nussbaum describes musical space as follows:

> The structure of virtual musical space, unlike that of real physical space, is entirely determined by the acoustics of sound and by human physiology and aural phenomenology…this space is bounded by the highest and lowest musically usable audible frequencies. It is possible, therefore, that a musical episode should put the listener into direct and instantaneous contact with the limits of musical space, or at least come near to doing this…But no physical being *could* be in direct and instantaneous contact with the limits of *physical* space…[which] is unbounded and has no limits.[213]

Nussbaum underscores the metaphorical quality of musical space, which, as the previous section's discussion of the PITCH IS HEIGHT metaphor reminds, is easy to overlook due to its sheer familiarity. In his lecture "Spatiality in Acousmatic Music,"[214] Denis Smalley described three types of space that may be conveyed through music: *perspectival space*, "the relations of spatial position, movement and scale among spectromorphologies viewed from the listener's vantage point"; *source-bonded space*, "the spatial zones and mental images produced by, or inferred from, sounding sources, and their causes (if there are any)," and *spectral spatiality* "impressions of space and spaciousness produced by occupancy and motion within the continuum of audible frequencies." All three are relevant for spatial metaphors in sound mass.

The perspectival illusion of the mass as a tangible physical entity with spatial location is at the heart of pieces such as Ligeti's *Lontano*: "the changes happen in space, the sound of drawing nearer and moving away again."[215] If a mass either bears a strong similarity to a physical, real-world sound source (such as the swarm of bees in Wishart's *Vox 5*) or elicits a physical, fictitious image in the mind of the listener (as might happen if a listener imagines a literal "atmosphere" while listening to Ligeti's *Atmosphères*), source-bonding produces an impression of the space in

[213] Nussbaum, 64.
[214] Denis Smalley, "Spatiality in Acousmatic Music," presentation, CIRMMT Distinguished Lecture Series, McGill University, Montreal, QC, January 23, 2014. See also "Space-Form and the Acousmatic Image," *Organised Sound* 12, no. 1, 35-58.
[215] Ligeti, quoted in Bauer, 140.

which those physical entities are imagined to exist. Ligeti suggests that this is one of two senses of the word '*atmosphere*' that he intended to imply:

> ...the word 'atmosphere' itself has a dual meaning: atmosphere in the literal sense of the word and also in the figurative sense. I would say that the music has a kind of metaphorical relationship to both senses of the word…[*Atmosphères*] has something atmospheric, that is to say, something floating, indeterminate, almost contourless, merging into itself, and on the other hand, something atmospheric in the figurative sense… the work, even if it is not exactly expressive, nevertheless has a quite definite feeling or emotion about it, and that is precisely what is atmospheric or *ambience*-like.[216]

Xenakis also used the term 'atmosphere' to describe rarefied musical textures created using stochastic methods,[217] and Stucky uses it in a discussion of Lutosławski's *Mi-parti*.[218] The title of another of Ligeti's sound mass pieces implies spatial extension more directly: *Volumina*, which literally translates as 'volumes.'[219]

The very idea of sound mass may have been conceived as a spatial metaphor. As noted in the introduction, the first use of the term, to the best of my knowledge, was by Edgard Varèse in the forward-looking manifesto *The Liberation of Sound* (1936). The composer imagines music which is no longer made of notes, but of sonic 'planes' that move and collide,[220] and conceives of music in spatial terms: "[s]ounds were physical for him in the sense that they took up space, and had shapes and positions in space...[as] concrete, touchable objects."[221] The image of the plane, especially the 'static plane,' is also used by Ligeti,[222] Lutoslawki,[223] and others. The term 'plane,' like the term 'mass,' is polysemic, and it is not always clear which connotation authors intend to imply: the geometrical sense of an ideal and infinite flat surface may first come to mind, but given the looseness with which other geometrical terms like 'point' and 'line' are used in reference to musical phenomena, it seems more likely that the term is intended in a more approximate sense. If 'point' connotes a singular event (e.g. a note) and 'line' connotes extension along the time dimension (e.g. a melody), it stands to reason that 'plane' may connote extension along the frequency

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216 Ligeti, *Ligeti in Conversation*, 84-85.
217 Xenakis, *Formalized Music*, 16.
218 Stucky, 193.
219 Sam Gillies, "Investigating the structure of acoustic and electronic noise: an analysis of 'Volumina' by György Ligeti and 'Canaanda' by Merzbow," (Bachelor of Music Honours thesis, Edith Cowan University, 2012), 24.
220 Varèse and Wen-chung, "The Liberation of Sound," *Perspectives of New Music* 5, no. 1 (Autumn-Winter, 1966): 11.
221 Erickson, 49-51.
222 e.g. Ligeti, *Ligeti in Conversation*, 37; 86; 88; Jonathan Bernard, "Inaudible Structures, Audible Music: Ligeti's Problem, and His Solution," *Music Analysis* 6, no. 3 (Oct., 1987): 216.
223 e.g. Trochimczyk, 99-137.

dimension (e.g. a cluster), provided that the resulting musical entity cannot be perceptually reduced to a superposition of lines (as in conventional counterpoint). Another term that appears frequently in the sound mass literature is 'block,'[224] which is also polysemic but usually implies a three-dimensional solid, and perhaps a stronger, more change-resistant character. MacKay considers "massing" in granular synthesis to be the situation in which a texture becomes "so dense that there is no longer any apparent 'space' between the grains."[225] Other terms referring to spatial, geometrical properties also appear, including nouns such as 'band'[226] and adjectives such as 'serried'[227] and 'thick'[228]; in the case of the latter, its polysemic nature once again sometimes makes it difficult to know which connotation is implied, as several are plausible (e.g. width or viscosity); this is sometimes clarified by additional adjectives such as 'gummy'[229] or 'gelatinous.'[230]

The more general term 'shape' is unsurprisingly a frequent descriptor of sound mass,[231] including shapes specifically denoted as "moving through space."[232] The compositional process for sound mass composers seems often to begin with shape, with original sketches frequently taking the form of drawings rather than standard musical notation. Penderecki says:

> In my opinion, architecture and music are very close to each other. What proves correct on the paper, in a sketch—for instance, proportions—proves correct also in music. I have started from the fine arts, drawn and painted…I drew my first pieces. First I sketched the construction, and only then filled it in with music.[233]

Penderecki felt that conventional notation was insufficient to accommodate his sound mass compositions, and so invented new, drawing-based forms of notation better suited to the task:

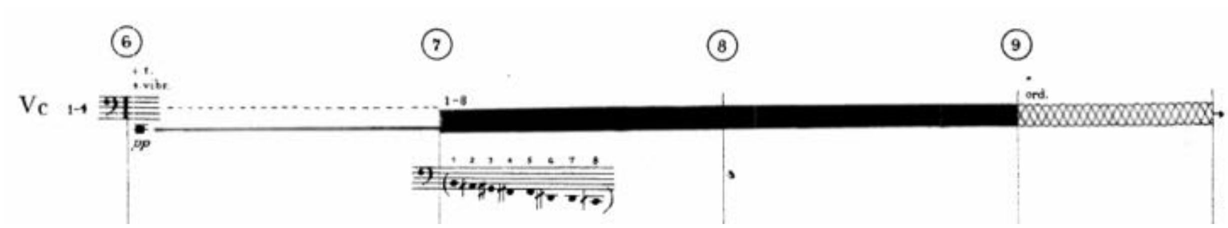
> In fact I first draw a piece. I compose it of graphic elements I can then test in music. I have employed this method from the very beginning and not just for works such as the

224 e.g. Kari Besharse, "The Role of Texture in French Spectral Music" (PhD dissertation, University of Illinois at Urbana-Champaign, 2009), 55; Erickson, 171-73; Gillies, 30; David Metzer, *Musical Modernism at the Turn of the Twenty-First Century* (Cambridge: Cambridge University Press, 2009), 45, 190, 191, 194; Mirka, 335; Trochimczyk, 107-108; 113.
225 MacKay, 177.
226 e.g. Besharse, 12, 55; Erickson, 179; Mirka, 97, 103.
227 e.g. Metzer, 188.
228 e.g. *Lutosławski on Music*, 47; 141; Metzer, 39; 178; 188.
229 *Lutosławski on Music*, 141.
230 Ligeti, qtd in Erickson, 185.
231 e.g. Bauer, 140; Ligeti, *Ligeti in Conversation*, 42; Tristan Murail, qtd in Besharse, 89; Bernard, "Inaudible," 209; "Voice Leading as a Spatial Function in the Music of Ligeti," *Music Analysis* 13, no. 2/3 (Jul.-Oct., 1994), 230; Iverson, 61, 64, 67, 70, 109; Metzer, 178, 209; Trochimczyk, 107-108; 112.
232 Iverson, 108.
233 Penderecki qtd in Mirka, 330.

Threnody, which could be drawn on a small sheet of paper. The logics of drawing works very well with the logics of sound.[234]

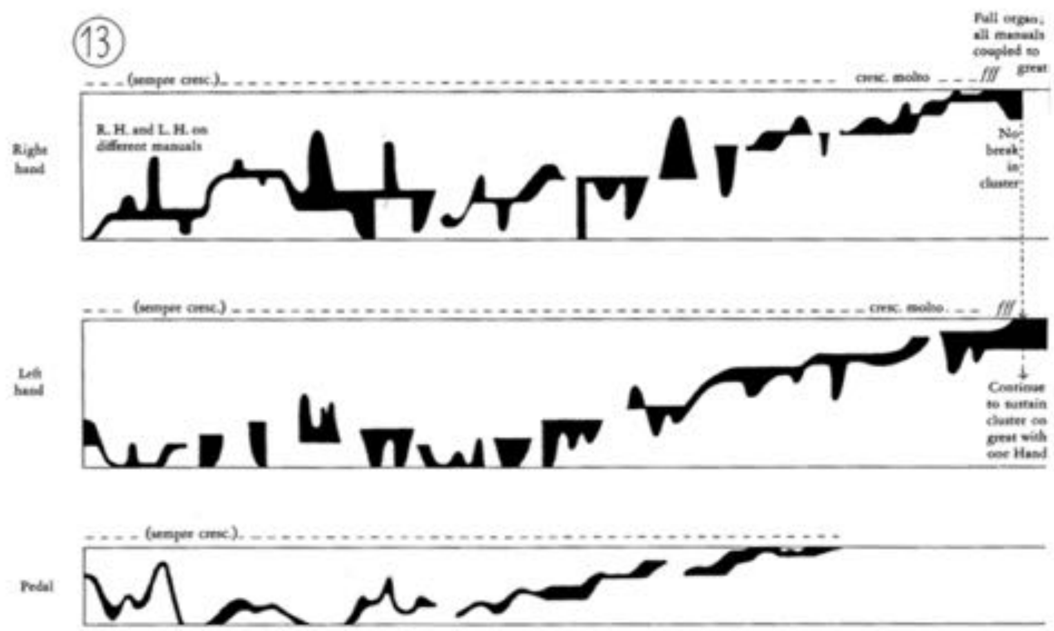
Some of Penderecki's nonconventional notations involve thick black lines indicating saturated regions of the pitch spectrum, and overlapping lines indicating superimposed glissandi:

Figure 45: Krzysztof Penderecki, *Polymorphia*, rehearsals 6-9.[235]



Ligeti also used shape-based graphical notation in his organ piece *Volumina*:

Figure 46: György Ligeti, *Volumina*, rehearsal 13.[236]



Although the graphical notation of *Volumina* is unique in Ligeti's catalogue, other pieces that were published in conventional notation, such as *San Francisco Polyphony* (1973-74), had their origins in shape-based, hand-drawn sketches:

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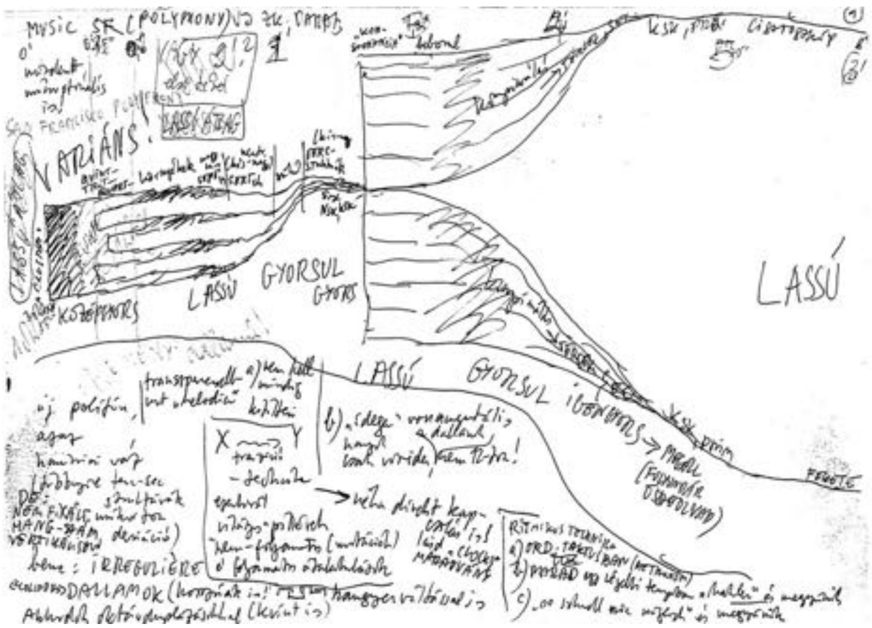
234 Tomaszewski, 31.

235 Penderecki POLYMORPHIA Copyright © 1962 by Schott Music GmbH & Co. KG, Mainz, Germany. Copyright © renewed. Used by permission of European American Music Distributors Company, sole U.S. and Canadian agent for Schott Music GmbH & Co. KG, Mainz, Germany.

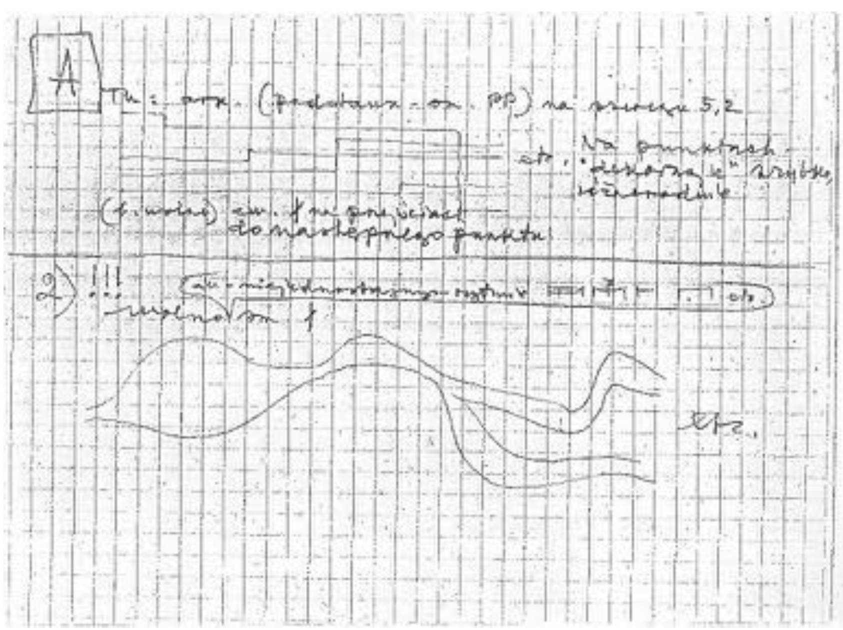
236 *Copyright 1973 by Henri Litolff's Verlag. Used by permission of C.F. Peters Corporation. All Rights Reserved.*

Figure 47: György Ligeti, sketches for *San Francisco Polyphony*.[237]



Lutoslawski's compositional process also often involved hand-drawn shapes:

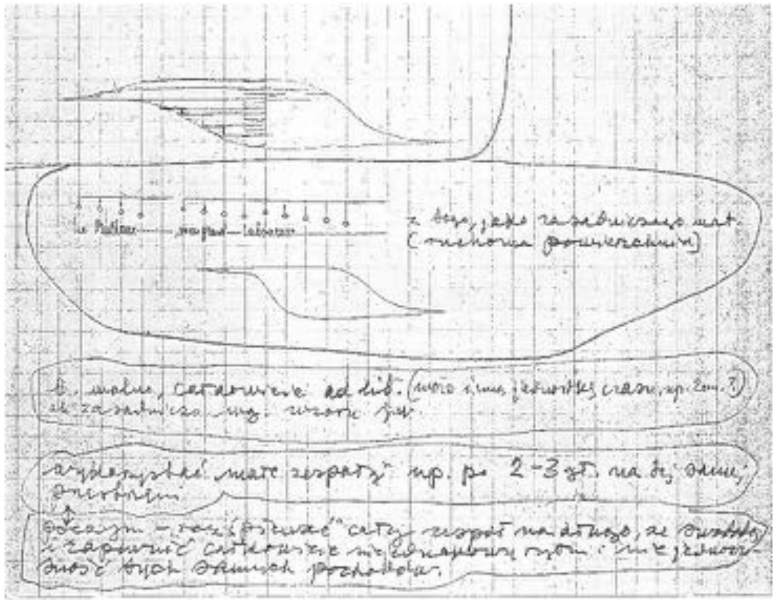
Figure 48: Witold Lutosławski, sketches for *Les espaces du sommeil*.[238]



[237] From the Ligeti Collection, Paul Sacher Foundation, Basel. Reproduced by permission. Originally published in Richard Steinetz, "The Study of Composers' Sketches, and an Overview of those by Ligeti," *Contemporary Music Review* 31, no. 2-3 (2012): 115-134.

[238] From the Lutosławski Collection, Paul Sacher Foundation, Basel. Reproduced by permission. Originally published in Trochimczyk, 108.

Figure 49: Witold Lutosławski, sketches for *Trois poèmes d'Henri Michaux*.[239]



Xenakis went so far with the analogy between shape and sound as to create a computerized musical composition tool called UPIC (Unité Polyagogique Informatique CEMAMu (*Centre d'Études de Mathématique et Automatique Musicales*)), which translated shapes drawn on a digitized tablet directly into sound. He used this invention to create the piece *Mycenae Alpha*:

Figure 50: Iannis Xenakis, excerpt from *Mycenae Alpha*. Reproduced by permission.

[239] From the Lutosławski Collection, Paul Sacher Foundation, Basel. Reproduced by permission. Originally published in Trochimczyk, 127.

Some analysts have followed suit. For example, Jane Piper Clendinning analyzed the pitch structure of Ligeti's *Continuum* with a spatialized graph (see Figure 18, Chapter 2), while Smalley analyzes musical sound in terms of spectromorphologies or "sound shapes."[240]

Since shape is associated with form and the supreme form-bearing dimensions in conventional western music are pitch and rhythm, the tendency in sound mass to undermine these dimensions has sometimes been characterized as an absence of shape, 'formlessness'[241] or 'amorphousness.'[242] Metzer claims that sound in perception "comes across as either a mass or an object,"[243] presumably implying that "objects" have discernible shape or form while "masses" do not. As discussed above, Lutosławski used the term 'sound object' more or less synonymously with 'sound plane.' Ligeti acknowledges the abolition of (or liberation from) traditional form and the shift to timbre as the bearer of form—which appears more as a "surging flow" than an ordered sequence of events—but is ambivalent about shape in this respect, sometimes saying the timbre-form is detached from shape[244] and sometimes saying it is not shapeless.[245] Finally with respect to spatiality, imaginary musical 'space' is sometimes an important association in and of itself (rather than as a necessary formal prerequisite for musical gestalts to populate). This is the case for Ligeti in particular: "For me, spatial associations play a major role in music, but the space is purely imaginary…[I] had been trying to suggest space, or to generate space by association in my works."[246]

3.5.2 Material Metaphors

Metaphors of *materiality* are also frequently used in reference to sound mass music. There are analogies to be found with each of the phases of matter. Solidity has already been implied in spatial-material metaphors such as 'block,' but it is also posited explicitly: Metzer describes masses as strong, 'solid' sonorities[247] whereas Bauer identifies 'SOUND IS A SOLID' as an underlying conceptual metaphor in Ligeti's discourse.[248] 'Impenetrability,' a distinctly solid

[240] e.g. Denis Smalley, "Spectromorphology: Explaining Sound-Shapes," *Organised Sound* 2, no. 2, 107-126.
[241] e.g. Mirka, 16.
[242] e.g. *Lutosławski on Music*, 49; Trochimczyk, 101-102.
[243] Metzer, 175.
[244] Iverson, 144.
[245] *Ligeti in Conversation*, 42.
[246] Ligeti, *Ligeti in Conversation*, 92-3.
[247] Metzer, 189.
[248] Bauer, 140.

property, is also sometimes attributed to masses, especially those that are identified as 'dense.'[249] Stucky describes sound within a registral space "filling it densely or sparsely, evenly or with denser 'lumps' of sound floating within,"[250] and MacKay describes the internal consistency of masses in terms of a contrast between 'evenness' or 'smoothness' and 'clumping.'[251] By contrast, other masses may be characterized by degrees of 'permeability.'[252] One particular type of solid, the 'crystal,' receives special attention from Ligeti,[253] presumably because it has a familiar, distinct aesthetic appeal at the macro level and also a complex yet orderly lattice structure at the micro level, which map convincingly onto perceptual (*esthesic*) and structural (*poïetic*) features of his micropolyphonic sound masses. This was alluded to above with his analogy of the colours of paint, which are made possible by crystalline structures of which the painter is not consciously aware while painting. Several theorists have used similar analogies in reference to macro-level textures in *Atmosphères*[254] and *Lontano.*[255] Crystal structure was also one of Varèse's favourite images for musical organization,[256] and Erickson compares Varèse's sound-blocks to "different types of rocks—igneous, metamorphic, and so on."[257] Xenakis draws a similar comparison, conceiving of a piece of music as "a highly complex rock with ridges and designs engraved within and without, that can be interpreted in a thousand ways without a single one being the best or the most true…music sustains all sorts of fantastic imaginings, like a crystal catalyst."[258]

Masses without discretely defined boundaries, in which voices successively overtake one other, resulting in an overall migration in register, have been described as more like a 'liquid' than a solid, producing "the impression of a fluid."[259] 'Water,' the most ubiquitous liquid in nature and experience, is a running motif in the sound mass literature: in the same manifesto in which he coined the term sound-mass, Varèse imagined entire works as melodic totalities that "will flow as a river flows,"[260] Ligeti imagined his micropolyphony as existing "in a microscopic, under-water

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249 e.g. *Ligeti in Conversation*, 14-15; Iverson, 223.
250 Stucky, 124.
251 MacKay, 173-74.
252 Ligeti, qtd in Erickson, 185.
253 e.g. *Ligeti in Conversation*, 15; 98; 124-125.
254 Iverson, 110.
255 Bruce Reiprich, "Transformation of Coloration and Density in György Ligeti's Lontano," *Perspectives of New Music* 16, no. 2 (Spring-Summer, 1978): 179-180.
256 Erickson, 49-51.
257 Erickson, 184.
258 Xenakis, *Xenakis on Xenakis*, 32.
259 Iverson, 102-3.
260 Varèse, 1.

world,"[261] and Stucky describes the orchestral opening of Lutosławski's *Trois poèmes d'Henri Michaux* as an "extraordinarily fluid texture…an 'indistinct sea' of sound."[262] Barry Truax's piece *Riverrun*, the first piece realized entirely from real-time granular synthesis (a technique Truax helped create), is predicated on fusing large numbers of very brief, simple sound events into "sound masses of great internal complexity, much like environmental sound generally and water sound in particular."[263] MacKay compares some of the textures of granular synthesis to the impression of "running water in a stream heard at close range."[264] Ideas of 'submerging,'[265] 'dissolution,'[266] and 'saturation' also have some currency in the literature: returning to the image of the crystal, Ligeti likened his "supersaturated polyphony" to the formation of a crystal in a "supersaturated solution," with the stated aim of arresting the process "just before the moment of crystallization."[267]

The image of 'gas' behaviour served as a model for mm. 52-59 of Xenakis' *Pithoprakta*[268] which has become one of the best-known examples of stochastic composition (even acquiring the honourific moniker "the historical measures"[269]). The speeds of the movements of the molecules of a gas at a constant temperature and pressure follow a Gaussian (normal) distribution, and Xenakis used such a distribution (albeit at a much-expanded scale) to determine the speed of glissandi for each individual string instrument in this section. In a review of *Pithoprakta*, Norman Kay suggests that modeling the music on sub-atomic behaviour in this way may result in "a new pseudo-parallelism not very different in origin from, and much more dangerous in results than, the literary parallelism of the nineteenth century."[270] Xenakis insisted that his modeling procedures did not compromise artistic freedom, however, saying that "[m]athematical formulae are ... tamed and subjugated by musical thought."[271] In this instance, the overall shape of the mass and its global evolution are left to the free choice of the composer.[272]

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[261] *Ligeti in Conversation*, 14-15.
[262] Stucky, 143.
[263] Barry Truax, "Composing with Real-Time Granular Synthesis," *Perspectives of New Music* 28, no. 2 (Summer, 1990), 124.
[264] MacKay, 180.
[265] Bauer, 132.
[266] Metzer, 194.
[267] *Ligeti in Conversation*, 14-15.
[268] *Formalized Music*, 60.
[269] Antonios Antonopoulos, "*Pithoprakta:* The historical measures 52-59. New evidence in glissando speed formalization," in *Proceedings of the Xenakis International Symposium, London: April 2011*, www.gold.ac.uk/ccmc/xenakis-international-symposium/programme, 1-21.
[270] Norman Kay, "Xenakis's 'Pithoprakta,'" *Tempo* 80 (Spring, 1967), 23.
[271] Xenakis, *Formalized Music*, 34.
[272] Antonopoulos, 19.

At a macro level, the metaphor of ‘wind’ is sometimes used: critic Alex Ross compares Xenakis’ music to “the voice of the wind.”[273] Another common image related to macro-level gas behaviour is the ‘cloud,’[274] which Xenakis used to describe vast groups of sound events governed by characteristics such as density and determined by mathematical operations,[275] while Ligeti used it to differentiate gestalts without clear harmonic identity from those with a defined interval structure.[276] Lutosławski conceived of musical clouds as masses made of sound “points” (instead of “lines”).[277]

A final material metaphor deserves special mention because of the frequency with which it is referenced and the significance it held for Ligeti in particular: the ‘web.’[278] While technically a solid, the web, made of tiny fibrous strands organized in fine patterns that are easily changed or destroyed, lacks many prototypical “solid” characteristics; in Ligeti’s famous description of a childhood dream in which he was in a room filled with cobwebs in a state of continual transformation, he refers to only the densest parts of the web as “an almost solid mass.”[279] Many authors have been compelled by potential parallels between this dream-image and the music Ligeti later wrote.[280] The metaphor of the web is used to denote layered concatenations of many voices resulting in a perceptual emphasis on texture and timbre rather than the individual properties of the lines, just as the perception of a cobweb focuses on emergent texture rather than the properties of individual strands.[281] Lutosławski also refered to ‘bundles’ of lines or melodic strands,[282] and to ‘tightly meshed’ sound masses.[283] MacKay relates textural percepts in music to “the visual image of a rug” which is “a product of a large number of hairs or threads.”[284] A related material association of Ligeti’s is fabric: he refers specifically to ‘gossamer’[285] and ‘moiré.’[286]

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[273] Alex Ross, “Waveforms: The Singular Iannis Xenakis,” *The New Yorker,* Mar. 01, 2010, http://www.newyorker.com/magazine/2010/03/01/waveforms.
[274] Erickson, 179.
[275] *Formalized Music*, 181; Mirka, 335.
[276] Bauer, 143.
[277] Trochimczyk, 107-108; 133.
[278] Erickson, 185.
[279] *Ligeti in Conversation*, 25.
[280] e.g. Iverson, 8-9; Bernard, “Inaudible Structures, 209.
[281] Iverson, 3; 131-2; Mirka, 335; Thoresen, 345.
[282] Kaczynski, 38; Trochimczyk, 130; 133.
[283] *Lutosławski on Music*, 141.
[284] MacKay, 172-73.
[285] *Ligeti in Conversation*, 25.
[286] Ligeti, qtd in Bauer, 140.

3.5.3 Behavioural Metaphors

Having discussed spatial and material metaphors, we turn now to a third major category, those invoking types of kinetic *behaviour* or *motion*. Nussbaum distinguishes between two kinds of illusions of motion that are important for musical experience: "object motion," in which one instrument or voice is in motion against the relative motionlessness of the rest of the ensemble, and "observer motion," in which the entire ensemble moves, creating the impression that the observer moves through a sonic environment.[287] Erickson provides a succinct example in relation to sound mass:

> These recognizable bits are constantly emerging and submerging in a rather mysterious way, and the listener may feel that *he* is in motion, because these experiences of changing perspective of the details in a mass are so much a part of modern life, where we see things (and hear things) from moving automobiles and airplanes.[288]

Both types of motion may be important in sound mass compositions, but the latter is more important in sound mass *qua* sound mass, since it emphasizes the collective, "common fate" motion of the musical whole. Following from the web image just discussed, the act of 'weaving' (or 'interweaving'[289]) is a common metaphor: perhaps the terms "web" and "weaving" are functionally a noun-verb pair. As Iverson describes it, "Weaving is an appropriate metaphor for the structural process at work – voices begin to overlap and pile on top of one another as the shape condenses."[290] A number of other terms also emphasize active assimilation of parts into a perceptual whole in ways that suggest greater or lesser degrees of disorder, such as 'entwining,'[291] 'tangling,'[292] 'entangling,'[293] 'mingling,'[294] 'intermingling,'[295] 'coalescing.'[296] Still others place the emphasis more directly on the whole rather than the behaviour of its constituent parts, such as 'merging'[297] and 'transmutation.'[298] The reverse process is also represented in the literature, with terms describing a previously cohesive whole disintegrating into a concatenation of parts:

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[287] Nussbaum, 49.
[288] Erickson, 192.
[289] Iverson, 108; Kaczynski, 38.
[290] Iverson, 70.
[291] Ligeti qtd in Besharse, 60.
[292] Rust, 197.
[293] Iverson, 130.
[294] Metzer, 195.
[295] Besharse, 60-61.
[296] Erickson, 171-73.
[297] Thoresen, 343, 463.
[298] Erickson, 53.

‘crashing,’[299] ‘shattering.’[300] Global behaviours of sound masses are described in terms implying various types of motions and degrees of busyness, coherence, and excitation: ‘languid,’[301] ‘melting,’[302] ‘flowing,’[303] ‘babbling,’[304] ‘shifting’[305] ‘undulating,’[306] ‘swirling,’[307] ‘mutating,’[308] ‘quivering,’[309] ‘unstable,’[310] ‘unpredictable,’[311] ‘volatile,’[312] ‘chaotic.’[313] At the opposite end of the kinetic spectrum is the oft-cited term ‘static,’[314] whose exact connotations may sometimes be unclear: it is not always obvious whether an author intends to refer to the stasis of the individual parts or to the properties of the whole; it is not always clear which parameters must be held invariant in order to produce an impression of stasis (even as there may be change in other parameters); and the term is arguably overused for a wide variety of textures and temporalities in contemporary music in spite of significant differences between them.[315]

3.5.4 CROSS-MODAL METAPHORS

A fourth category of sound mass metaphors involves *cross-modal* associations, especially those involving visual or tactile impressions. Erickson points out that words from visual and tactile sense modalities are often appropriated for descriptions of texture-based music, of which he identifies works of Penderecki and Ligeti as exemplars.[316] As Bernard notes, “Ligeti seems susceptible to visual and tactile parallels to auditory phenomena to a degree that approaches synaesthetic sensitivity…It is tempting to speculate that Ligeti may have been impelled by this intersensory facility to his particular choice of compositional method.”[317] Lutosławski’s music is frequently described

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299 Metzer, 177.
300 Rust, 215.
301 *Lutosławski on Music*, 141.
302 Erickson, 171-73.
303 Rust, 197; Stucky, 124.
304 *Lutosławski on Music*, 143.
305 e.g. Metzer, 186; Trochimczyk, 114; Varèse, 11.
306 Metzer, 178.
307 Metzer, 195.
308 Metzer, 177.
309 Besharse, 60-61.
310 Metzer, 45.
311 Stucky, 111.
312 Metzer, 193.
313 *Lutosławski on Music*, 47; Trochimczyk, 107-108; Schwinger, 124.
314 e.g. Iverson, 95, 115; Besharse, 51, 90; Stucky, 123-124; *Lutosławski on Music*, 18-19.
315 Robert Adlington, “Moving Beyond Motion: Metaphors for Changing Sound,” *Journal of the Royal Musical Association* 128 (2003), 300.
316 Erickson, 139.
317 Bernard, “Inaudible Structures,” 210.

in terms of 'sound visions.'[318] MacKay views musical sound masses analogously to "static and atemporal visual texture[s]."[319] A term used in the sound mass literature that suggests assimilation but with specifically visual connotations is 'blur'[320]; another such term is 'smudge.'[321] The visual analogue for 'impenetrable,' 'opaque,' is used to denote textures in which individual events are indiscernible[322] while the emergence of clear intervallic structures from such an opaque texture is referred to as 'illumination' or 'light.'[323] Sound masses are described as 'shimmering',[324] 'iridescent,'[325] and 'opalescent.'[326] References to colour are ubiquitous in the sound mass literature, but of course colour is embedded in our culture's musical discourse as a metaphor for timbre ('tone colour,' '*Klangfarben*'). Though there are many references to colour as constantly changing[327] or transforming,[328] the specific nature of the colours or their metamorphoses is seldom if ever described in detail (as compared, for example, to Messiaen's descriptions of colours[329]). Both Ligeti and Lutosławski conceived of colour as a symbiosis between instrumental timbre and harmonic structure: Ligeti says "*Atmosphères* was to a large extent grey: it was colourful in the sense of tone-colour but harmonically grey,"[330] while Lutosławski finds that even elaborate instrumental combinations "sound almost 'grey' to me if the intervals and chords don't co-operate in creating tone colour."[331] Lutosławski also refers to chords as 'hot' and 'cold,'[332] as well as 'icy'[333] and 'frozen.'[334] Visual-tactile metaphors are invoked with reference to familiar patterns such as 'brick,' 'tile,' and 'wallpaper,'[335] as well as techniques and brush-strokes from movements in

[318] e.g. *Lutosławski on Music*, 57; Stucky, 125.
[319] MacKay, 172.
[320] e.g. Besharse, 54; Bauer, 136; Iverson, 70; Stucky, 125.
[321] Stucky, 160; Trochimczyk, 101-102.
[322] Bauer, 136; Ligeti qtd in Bauer, 143.
[323] Bauer, 142; Ligeti qtd in Bauer, 143.
[324] Iverson, 140; Griffiths qtd in Besharse, 12; Ligeti, qtd in Besharse, 60-61; Stucky, 175.
[325] Ligeti qtd in Besharse, 61.
[326] Schwinger, 128.
[327] e.g. Ligeti qtd in Bauer, 140.
[328] e.g. Reiprich, 168-172.
[329] Jonathan Bernard, "Messiaen's Synaesthesia: The Correspondence between Color and Sound Structure in His Music," *Music Perception* 4, no. 1 (Fall, 1986), 41-68.
[330] Ligeti, *Ligeti in Conversation*, 99.
[331] Lutosławski qtd in Kaczynski, 43.
[332] Kaczynski, 86-88.
[333] Stucky, 116; *Lutosławski on Music,* 174.
[334] Stucky, 193.
[335] Rust, 194.

visual art such as 'pointillism'[336] and the 'abstract expressionism' of Mark Rothko.[337] The image of the 'kaleidoscope' is invoked by Ligeti,[338] Reiprich,[339] and Schwinger[340]: interestingly, Hanslick also described music as "a kind of kaleidoscope" that "produces beautiful forms and colours in ever more elaborate diversity."[341]

3.5.5 Naturalistic Metaphors

Another family of metaphors invokes *naturalistic* imagery. 'Galaxy' was a metaphor to which Xenakis referred several times in relation to sound mass[342]; both Ligeti and Lutosławski referred to the related metaphor of 'constellation.'[343] In one passage (quoted in the introduction), Xenakis emphasizes the importance of perspective and scale in determining whether we observe molecules, stars, or galaxies.[344] Xenakis lists numerous other naturalistic metaphors for the sound masses he created from large numbers of sound events, including "the song of the cicadas or the sound of hail or rain, the crashing of waves on the cliffs, the hiss of rain on shingle."[345] Another of Xenakis's metaphors, a large crowd of people, is politically-charged and draws on his personal experiences:

> Athens – an anti-Nazi demonstration – hundreds of thousands of people chanting a slogan which reproduces itself like a gigantic rhythm. Then combat with the enemy. The rhythm bursts into an enormous chaos of sharp sounds; the whistling of bullets; the crackling of machine guns. The sounds begin to disperse. Slowly silence falls back on the town.[346]

This last example is arguably less "naturalistic," but large numbers of organisms, be they 'crowds,' 'herds,' or 'swarms,'[347] have been an important metaphor for both Xenakis[348] and a number of

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336 Iverson, 61; Schwinger, 126.
337 Iverson, 3-4.
338 *Ligeti in Conversation*, 38; 135.
339 Reiprich,180.
340 Schwinger, 125-26.
341 Hanslick, 29.
342 e.g. Iannis Xenakis, Roberta Brown, and John Rahn, "Xenakis on Xenakis," *Perspectives of New Music* 25, no. 1/2 (Winter-Summer, 1987): 36; *Formalized Music*, 182; Mirka, 335.
343 Ligeti qtd in Bauer, 143; *Lutosławski on Music*, 68.
344 Xenakis, *Formalized Music*, 49.
345 Xenakis qtd in Roger Reynolds, "Xenakis:…Tireless Renewal at Every Instant, at Every Death…," *Perspectives of New Music* 41, no. 1 (Winter, 2003): 46-47.
346 Xenakis qtd in Reynolds, 46-47.
347 MacKay, 171.
348 e.g. *Formalized Music*, 8.

other composers and scholars.[349] Tristan Murail describes his sound mass composition *Sables* in terms of "grains of sand, bereft of significance, but whose accumulation furnishes the music with both its form and its content, just as grains of sand supply a dune both shape and substance."[350] Schwinger speaks of Penderecki's 'musical landscapes,'[351] Bauer describes Ligeti's *Lontano* as a 'landscape' we move through,[352] and Rust describes Lutosławski's music as "a terrain of peaks and valleys."[353] Erickson describes Cage's *HPSCHD*, which he identifies as "much concerned with the effects of massing and multiplicity," as "a walk through the forest" and "a sprawling jungle of sound."[354]

3.5.6 Technological Metaphors

Still other sound-mass metaphors are *technological*. Of particular importance is Ligeti's interest in 'machinery,'[355] especially "recalcitrant machinery, unmanageable automata."[356] This interest may draw from another of Ligeti's childhood experiences—a memory of reading a story about a widow in a house full of ticking clocks—and again, it may provide a compelling explanation for the music he later composed, especially in his "pattern-meccanico" period.[357] Several of Ligeti's compositions, notably *Poème symphonique* (1962) for 100 metronomes and *Clocks and Clouds* (1972) make explicit references to the clock metaphor; the latter also references a text of Karl Popper's that Ligeti admired: "Of Clouds and Clocks: An approach to the problem of rationality and the freedom of man" (1965). Also significant is the influence of the then-new field of electronic music on the sound mass composers, whose instrumental music is in some ways a "post-electronic" reflection of the technology of their times. Penderecki and Ligeti both acknowledge the impact that their experiences in electronic music studios had on their compositions,[358] and although Xenakis' response to electronic music technology was in some ways initially negative—in *Formalized Music* he implores readers to open their eyes "towards the immediate future of musical thought, before we perish suffocating from electronic technology, either at the instrumental level

[349] e.g. Ligeti qtd in Besharse 60-61; Metzer, 43; 46; 180.
[350] Tristan Murail, qtd in Besharse, 89.
[351] Schwinger, 132.
[352] Bauer, 140.
[353] Rust, 195.
[354] Erickson, 190-92.
[355] Bauer, 139.
[356] Ligeti, qtd in Clendinning, 193.
[357] Clendinning, 192-193.
[358] Besharse, 51-52; Iverson, 92-97; 115; 127-128.

or at the level of composition by computers"[359]—his music nevertheless responds to the changing technological reality, and he in turn made significant contributions to the development of electronic music and computer-assisted composition, for example by laying the theoretical foundation for granular synthesis.[360] Lutosławski was also deeply influenced by electronic music, especially *musique concrète* which he regarded as "the most important sound invention of our time."[361] Erickson relates textural and sound mass-based music to environmental sounds including that of "traffic, airports, factories."[362] Another metaphor which is technological in origins, if in a more primitive sense than we often use the term today, is 'labyrinthine,' which Ben Gillies[363] uses to relate the movements of clusters in Ligeti's *Volumina* to a complicated a man-made maze.

3.5.7 Surrealistic Metaphors

A final category of metaphors involves *surreal* imagery and altered states of consciousness. Iverson describes sections of Ligeti's music as 'surreal' and 'magical.'[364] Bauer describes how Ligeti's music evokes aspects of 'psychotic experience'[365] and the experience of 'schizophrenia.'[366] Closely related to such metaphors is a sense of an altered experience of time: Ligeti speaks of "music as frozen time," which Bauer relates to schizophrenic experience.[367] Charles Bodman Rae speaks of "arresting moments in time" in Lutosławski's *Mi Parti*,[368] while John Casken relates Lutosławski's music to "dreamlike visions,"[369] and "the sense of time standing still."[370]

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[359] Xenakis, *Formalized Music*, 194.
[360] Kai Seidenburg, "Approaching Real-Time Granular Synthesis Feedback" (presentation, *Xenakis International Symposium*, London, England, 1-3 April 2011).
[361] *Lutosławski on Music*, 84; Trochimczyk, 99-137.
[362] Erickson, 171-73.
[363] Gillies, 27-28; 31; 35.
[364] Iverson, 109-110.
[365] Bauer, 129.
[366] Bauer, 124.
[367] Ligeti, quoted in Bauer, 129.
[368] Charles Bodman Rae, "Lutosławski's Sound World: A World of Contrasts," in *Lutosławski Studies*, ed. Zbigniew Skowron (Oxford: Oxford UP, 2001), 25.
[369] John Casken, "The Visionary and the Dramatic in the Music of Lutosławski," in *Lutosławski Studies*, ed. Zbigniew Skowron (New York: Oxford University Press, 2001), 45.
[370] John Casken, "The Visionary and the Dramatic in the Music of Lutosławski," in *Lutosławski Studies*, ed. Zbigniew Skowron (Oxford: Oxford UP, 2001), 45.

3.6 CONCLUSION

The list of associations discussed here, while large, makes no pretense of exhaustiveness, and may at best be considered a representative sample. It demonstrates that, in conception and practice, sound mass reached outside of the norms and assumptions of conventional (tonal, atonal, serial, combinatorial, intervallic) music, emulating electroacoustic procedures that invert or abolish the old hierarchies in which pitch reigns supreme and timbre is a secondary parameter. Sound mass conceives of sound in spatial and material terms, emphasizes cross-modal and surreal perceptions, embraces behavioural, naturalistic, and technological metaphors, and brings music into close contact with other domains of experience. Since composers and scholars describe sound mass with so many evocative metaphors and associations, a natural next question is: do images and concepts such as those listed above relate in any meaningful way to the experiences of other listeners? To the best of my knowledge, no studies on this question have been conducted to date, so the experiments presented in Chapter 4 represent first steps in attempting to understand a very complicated and intersubjectively variable phenomenon.

Chapter 4: Empirical Research on Sound Mass Semantics

4.1 Introduction

As was described in detail in Chapter 3, composers and theorists of sound mass relate the music to many evocative metaphorical associations. It remains to be seen, however, if such associations are relevant to listeners' experiences. There is no doubt that listeners can and do experience extramusical associations in relation to music: as Erikki Huovinen and Anna-Kaisa Kaila say, "there appears to be a large consensus that music can importantly function as a carrier of extramusical meaning...the implication is not merely that music might help any personally significant imagery to emerge from one's psyche...but that it is the *music* that means—or is taken to mean—something extramusical."[371] If this were not the case, the "anxiety of reference" would be baseless and non-existent, the formalist position would be a self-evident truism, and the "ethics of listening" described in the previous chapter would never have been necessary. But are listeners consistent with one another in the extramusical associations that they draw with music? Some anecdotal evidence, such as that recounted by Lutosławski,[372] suggests not, and this inconsistency is likely the basis of much formalist skepticism. But little empirical research has investigated the question, especially with regards to late-20th and early-21st century music. Some studies have investigated topical associations in classical music,[373] Romantic (programmatic) music,[374] and commercial "production music,"[375] with findings suggesting that musical *topoi* have psychological reality and are consistently identified by listeners in at least some contexts. Might the associations listeners draw with sound mass music, which is presumably less familiar to most people than the styles used in the above-cited studies, be similarly consistent? If so, do those associations match the ones described by composers and theorists of this music? And, can they be explained in terms of musical properties? In sum: do musical attributes of sound mass (detailed in Chapter 1) map consistently onto metaphorical associations of sound mass (detailed in Chapter 3)?

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371 Huovinen and Kaila, 217.
372 Lutosławski, *Lutosławski on Music*, 92-93.
373 Krumhansl, 120-1.
374 Margulis, "Narrative Experiences," 236.
375 Huovinen and Kaila, 222.

4.2 Experiment 4

4.2.1 INTRODUCTION

The experiments reported in Chapter 2, which study relations between musical attributes and sound mass perception, all used stimuli derived from Ligeti's *Continuum* because it is a canonical piece from the sound mass repertoire that keeps some attributes constant (tempo, instrumental timbre, and surface rhythm). In order to approach the subject of semantic dimensions of sound mass, however, it was deemed necessary to branch out into a broader sample of the repertoire. Pieces were selected to cover many different approaches to fusion-based aesthetics, providing a diverse range of attributes for potential conceptual modeling and cross-domain mapping. These pieces span several decades, from the canonical sound mass compositions of the 1950s and 1960s to music from the early 21st century, including both acoustic and electroacoustic music. Table 6 provides a list of the pieces from which the excerpts used as stimuli in Experiments 4 and 5 were selected.

Table 6: Sources of excerpts used as stimuli in Experiment 4.

Composer	Title	Instrumentation/ Media	Date of Composition
Iannis Xenakis	*Metastaseis*	orchestra	1953-1954
Iannis Xenakis	*Pithoprakta*	string orchestra	1955-1956
Witold Lutosławski	*Musique funèbre*	string orchestra	1954-1958
Krzysztof Penderecki	*Threnody to the Victims of Hiroshima*	string orchestra	1960
György Ligeti	*Atmosphères*	orchestra	1961
Witold Lutosławski	*Jeux vénitiens*	orchestra	1961
Krzysztof Penderecki	*Polymorphia*	string orchestra	1961
Witold Lutosławski	*Trois Poèmes d'Henri Michaux*	orchestra and choir	1962-1963
György Ligeti	*Requiem*	orchestra and soloists	1965
György Ligeti	*Volumina*	organ	1967
Witold Lutosławski	*Symphony No. 2*	orchestra	1965-1967
Veljo Tormis	*Jaanilaulud*	choir	1967
Karlheinz Stockhausen	*Stimmung*	amplified voices	1968
György Ligeti	*Double Concerto*	flute, oboe, and orchestra	1972
Gérard Grisey	*Partiels*	chamber orchestra	1975
Witold Lutosławski	*Mi-parti*	orchestra	1975-1976
Henryk Górecki	*Symphony No. 3*	orchestra and soprano	1976

Iannis Xenakis	*Mycenae Alpha*	electronics (UPIC)	1978
Toru Takemitsu	*Asterism*	orchestra	1979
Jonathan Harvey	*Mortuos Plango, Vivos Voco*	electronics	1980
Witold Lutosławski	*Double Concerto*	oboe, harp, and chamber orchestra	1980
Francis Dhomont	*Points de Fuite*	electronics	1982
Jean-Claude Risset	*Sud*	electronics	1985
Barry Truax	*Riverrun*	electronics	1986
Trevor Wishart	*Vox*	voices and electronics	1986
Barry Truax	*The Wings of Nike*	electronics	1987
Kaija Saariaho	*Du cristal*	orchestra	1989
Barry Truax	*Pacific*	electronics	1990
Philippe Hurel	*Six Miniatures en Trompe-l'œil*	chamber orchestra	1991/1993
Stéphane Roy	*Mimetismo*	guitar and electronics	1992
Stéphane Roy	*Crystal Music*	electronics	1994
Georg Friedrich Haas	*Hyperion*	orchestra	2006
Franck Bedrossian	*Tracés d'Ombres*	string quartet	2007
Robert Normandeau	*Clair de Terre*	electronics	1999, 2009

Also, a list of semantic categories related to sound mass was compiled from the literature (Table 7).

Table 7: List of semantic categories used as ratings scales in Experiment 4.

Terms involved in the definition of sound mass	Adjectival metaphors used to describe sound mass	Nominal metaphors used to describe sound mass
Fusion *Density* *Complexity* *Homogeneity*	*Volatile* *Atmospheric* *Busy* *Static* *Formless* *Impenetrable* *Voluminous* *Kaleidoscopic*	*Gas* *Liquid* *Solid* *Clouds* *Wind* *Water* *Webs* *Galaxies* *Crystals* *Machinery* *Herds/Crowds/Swarms*

This list represents a relatively small subset of the terms catalogued in Section 3.5 of Chapter 3: while it would be interesting to explore them all, it would have made the experimental design and resulting data set unwieldy and impractical. Categories were chosen to represent the main types of metaphors used to describe sound mass in the literature as outlined in Chapter 3 (spatial, material, behavioural, cross-modal, naturalistic, technological, and surreal). For the most part, there was no presumption of one-to-one correspondence between the metaphors and the musical excerpts used in the experiments. For instance, in spite of Ligeti's various references to 'webs' and 'crystals' in comments about his music, there is no reason to assume that the particular Ligeti examples used in this experiment are intended to be prototypical musical 'webs' or 'crystals.' In a few cases, such as the "historic measures" section of Xenakis's *Pithoprakta* which was modeled on gas behaviour[376] and Truax's *Riverrun* which deliberately evokes water sounds,[377] specific, documented mappings were invoked in the compositional process. In general, however, the rating categories and musical excerpts were selected because they present *in toto* a wide variety of sound mass attributes and a wide variety of domains onto which they might plausibly map, not because of any implication of exemplary or 'correct' mappings.

We expected to observe correlations between sonic/musical attributes in the excerpts and the ratings participants provided for the categories. We further expected these correlations to be explicable in terms of homologous attributes between the excerpts and the categories, sometimes based in sonic similarity (for example, the excerpt from *Vox*, which samples the sound of buzzing bees, would probably be rated highly for "herds/crowds/swarms") and sometimes in abstract affinities (for example, the excerpt from *Threnody to the Victims of Hiroshima*, which consists of a loud quarter-tone cluster saturating a wide range of the audible spectrum, would probably be rated highly for "impenetrable"). Finally, we hypothesized that excerpts which achieve sound mass integration in the same way (for example, by exploiting the low register, or through dense kinetic activity) would have some similar musical attributes and would therefore invite some similar mappings: in other words, we expected to see some evidence for semantic associations of sound mass types *eo ipso*, generalizable beyond the peculiarities of these examples. However, we understood that our ability to draw strong conclusions would be limited by the complex nature of the stimuli (since it is difficult to know to which musical attributes participants attend) and by the polysemic nature of the categories (since it is difficult to know which connotation(s) provide the basis for cross-domain mapping).

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376 Xenakis, *Formalized Music*, 235.

377 Mara Helmuth, 'Barry Truax's *Riverrun,*' in *Analytical Methods of Electroacoustic Music*, ed. Mary Simoni (New York: Routledge, 2006), 187.

4.2.2 METHOD

4.2.2.1 *Participants*.

Thirty-eight participants (24 female) between 18 and 50 years of age (*M* = 24.9, *SD* = 6.0) completed the experiment. Twenty-one participants self-identified as professional musicians and reported an average of 11.7 years of training on a primary instrument (*SD* = 5.0) with additional training in aural skills (*M* = 4.7, *SD* = 4.5) musical analysis (*M* = 2.4, *SD* = 2.2), and music history (*M* = 3.2, *SD* = 2.5); the remainder did not consider themselves professional musicians and reported an average of 0.8 years of childhood or casual training on an instrument (*SD* = 2.3) and no training in aural skills, harmony, analysis, and music history. 9 of the musicians and none of the nonmusicians indicated familiarity with sound mass music. All participants were fluent in English. Prior to completing the experiment, all participants passed a pure-tone audiometric test using a MAICO MA 39 (MAICO Diagnostic GmbH, Berlin, Germany) audiometer at octave-spaced frequencies from 125 Hz to 8 kHz (ISO 389-8, 2004; Martin & Champlin, 2000) and were required to have thresholds at or below 20 dB HL to proceed. All participants completed the same task and each was paid $15 CAN as compensation. They all signed informed consent forms prior to participating in the experiment.

4.2.2.2 *Stimuli*.

The stimuli consisted of 40 excerpts from commercially available recordings of the pieces listed above. Stimuli ranged in duration from 10s to 18s, with an average duration of approximately 15s.[378] Because we were interested in studying participants' responses to ecologically valid stimuli, the excerpts were not matched for loudness. Audio signals were sampled at 44.1 kHz. Additional excerpts from Robert Normandeau's *Clair de Terre* (1999, 2009; electronics) and Tristan Murail's *Désintégrations* (1982-1983; orchestra and electronics) were used in practice trials to familiarize participants with the type of music they would be hearing and the experimental interface. Table 8 provides a description of the attributes of each excerpt (using the labels that will identify them forthwith; if multiple excerpts were selected from the same piece, they are labeled with (1), (2), etc.). The descriptions recount my own subjective hearings/analyses of these

[378] Excerpts were intended to be relatively texturally homogeneous for their full durations, and the available durations for which this was possible varied from piece to piece.

examples, focusing on recordings and sometimes (where applicable) informed by a reading of the score. They were discussed and validated with a second listener (Dr. Stephen McAdams).

Table 8: Descriptions of attributes of stimuli in Experiment 4.

Atmosphères (1)
Rhythm: Little if any perceptible rhythm; some minor micro-fluctuation. *Pitch*: Broad compass over wide range, densely and evenly distributed, sustained chromatic cluster. *Dynamics*: Medium-soft, sustained dynamics. *Timbre*: Consistent, well-blended orchestral tutti; exclusively pitched sounds. *Gesture*: No sense of gesture except sustain.
Threnody
Rhythm: Little if any perceptible rhythm; some sense of irregular, uncoordinated fluctuation. *Pitch*: Broad compass over wide range, densely and evenly distributed, sustained microtonal cluster. *Dynamics*: Loud, sustained dynamics. *Timbre*: Consistent, homogeneous string timbre; pitched sounds with some noise content. *Gesture*: No sense of global gesture; some very slight sense of local gestures in fluctuation (e.g. bow changes).
Volumina
Rhythm: Low activity, no perceptible periodicity; two rhythmic events (cluster expansion). *Pitch*: Broad compass over mid-low range, expanding into higher register *Dynamics*: Medium-loud, getting louder with the addition of notes as the register expands upwards. *Timbre*: Consistent and uniform organ timbre. *Gesture*: Predominantly sustained, two discrete upward gestures.
Musique Funèbre
Rhythm: Regular, coordinated, periodic rhythm; progressive rallentando. *Pitch*: Discrete pitches, mid-range tessitura, fairly narrow compass progressively diminishing, complex chromatic harmony contracting into a dense, narrow cluster. *Dynamics*: Loud, sustained dynamics. *Timbre*: Consistent and uniform string timbre. *Gesture*: Clear, coherent, goal-directed gesture (contraction + rallentando to sustained cluster).
Mi-Parti
Rhythm: Low activity; some perceptible rhythm as voices breathe and re-enter. *Pitch*: Discrete pitches, medium-high tessitura, fairly wide compass; sustained complex chromatic harmony. *Dynamics*: Medium-soft, sustained dynamics. *Timbre*: Wind instruments; exclusively pitched sounds; heterogeneous but well-blended, consistent, emergent timbre. *Gesture*: No sense of gesture except sustain.
Partiels
Rhythm: Low activity; staggered soft entries result in minimal perceptible rhythmic activity. *Pitch*: Discrete pitches, low-mid range, fairly wide compass; sustained harmonic spectrum. *Dynamics*: Medium-loud low register followed by soft harmonic “shadow.” *Timbre*: Heterogeneous instruments but well-blended, evolving, emergent timbre. *Gesture*: Upward migration of tessitura in a coherent global gesture, unified by harmonic spectrum.
Six Miniatures
Rhythm: Low activity; staggered entries resulting in some perceptible rhythm but no periodicity. *Pitch*: Discrete, relatively stable pitches; wide range and compass; sustained inharmonic spectrum. *Dynamics*: Medium-soft, sustained dynamics. *Timbre*: Heterogeneous instruments; evolving, emergent timbre. *Gesture*: No sense of gesture except timbral evolution.
Du Cristal
Rhythm: Almost no perceptible rhythmic activity.

Pitch: Discrete, sparsely distributed, stable pitches; medium-low range; fairly wide compass; inharmonic spectrum. *Dynamics*: Very soft, sustained dynamics. *Timbre*: Sustained, predominantly string timbre. *Gesture*: No sense of gesture. Static, sustained texture.
Stimmung
Rhythm: Some rhythmic events created by entries. Superimposed periodic patterns created by vowel modulation. *Pitch*: Stable, sustained pitches, middle register (vocal), harmonic spectrum. *Dynamics*: Sustained, moderately soft dynamics. *Timbre*: Vocal, continuously modulating with vowel changes. *Gesture*: Mild sense of gesture created by oscillating timbral modulation and thickening harmony.
Polymorphia (1)
Rhythm: Little if any rhythmic differentiation. *Pitch*: Very low register; dense, sustained pitches and glissandi; little or no perceptual resolution of discrete pitches. *Dynamics*: Sustained, moderately loud dynamics. *Timbre*: Homogeneous string timbre, but perceptually indistinct in this dense texture and very low register. *Gesture*: Little or no sense of gesture.
Atmosphères (2)
Rhythm: Some sense of irregular internal dynamism but no clearly articulated rhythm. *Pitch*: Very low register, narrow compass, chromatically saturated. *Dynamics*: Sustained, medium-loud dynamics. *Timbre*: Homogeneous string timbre, but perceptually indistinct in this dense texture and very low register. *Gesture*: Little or no sense of gesture.
Górecki Symphony No. 3
Rhythm: Clear, metrical, moderately slow, periodic rhythm. *Pitch*: Very low register, narrow compass, diatonic structure. *Dynamics*: Sustained, medium-soft dynamics. *Timbre*: Homogeneous low string timbre. *Gesture*: Sense of gesture created by melodic counterpoint; no strong sense of global direction.
Requiem
Rhythm: Rhythmic events created by syllables and introduction of new notes; no clear sense of metre or synchronous coordination between voices. *Pitch*: Low register, narrow compass, chromatic structure. *Dynamics*: Sustained, medium-soft dynamics. *Timbre*: Predominantly vocal timbre, bottom of male vocal range. *Gesture*: Sense of gesture created by melodic counterpoint; global contour of slow divergence.
Mycenae Alpha
Rhythm: Some internal dynamism but little if any clear rhythmic delineation. *Pitch*: Mid-register; fairly narrow compass; little or no pitch salience; perceptual saturation. *Dynamics*: Loud dynamics with some fluctuation. *Timbre*: Synthetic, noisy timbre. *Gesture*: Some sense of gesture created by shifting contour; no clear sense of global direction.
Asterism (1)
Rhythm: Some internal dynamism, but difficult to discern because of the near-saturation of noise. No discernible coordination or periodicity between parts. *Pitch*: Noise-based spectral saturation, little if any perceptible pitch structure. *Dynamics*: Sustained, loud dynamics. *Timbre*: Emergent from heterogeneous instruments, but percussion dominates (especially very loud cymbal roll). *Gesture*: Global crescendo.
Sud
Rhythm: Rhythmic events created by event onsets and dynamic crests; no clear sense of metre, periodicity, or coordination.

Pitch: Diffuse (filtered noise) and unstable (glissandi) sense of pitch; middle register, fairly narrow compass. *Dynamics*: Sustained, medium dynamics. *Timbre*: Consistent, noise-based timbre, weak sense of pitch created by filtering. *Gesture*: Shepard tone-like arrangement of staggered, descending glissandi.
Vox
Rhythm: Rhythmic events created by modulation of voice and by shifting sound sources; no clear sense of metre or periodicity. *Pitch*: Narrow, mid-register pitch band corresponding to the approximate frequency of bees buzzing; overlapping and superimposed pitches within this range; no clear sense of harmonic structure. *Dynamics*: Medium dynamics, inverted arch contour resulting from shifting sound sources. *Timbre*: Beginning with vocal imitation of bees buzzing, shifting to sample of actual bees buzzing, returning to vocal sounds. *Gesture*: Transformation-return gesture created by deployment of sound sources.
Pacific
Rhythm: Rapid, quasi-percussive rhythmic rearticulations; some local periodicity but no clear sense of metrical coordination; irregular accent structure. *Pitch*: Little or no perceptible pitch; mid-register noise-based sounds. *Dynamics*: Fluctuating medium-loud dynamics. *Timbre*: Noise-based, granular, fluctuating timbre. *Gesture*: Stratification between rapid foreground and drone-like background
Tracés d'Ombres
Rhythm: Some sense of rhythm created by timbral and dynamic modulation; little if any articulation of event onsets; no sense of metre or periodicity. *Pitch*: Weak sense of unstable pitch in predominantly inharmonic sounds produced by extended techniques; medium and high tessituras; some loose pitch centricity but with continuous fluctuation and jitter; no clear sense of harmony. *Dynamics*: Fluctuating medium-loud dynamics. *Timbre*: Stratification of several timbral layers distinguished by register as well as spectral complexity: a rich, inharmonic mid-register layer, and a very high, squeaky, scratchy layer. *Gesture*: Undulation within each of the stratified layers; no sense of global directedness.
Clair de Terre
Rhythm: Very dense activity from a panoply of sound sources; clear, periodic pulse at the beginning of the excerpt, followed by a montage texture with much rhythmic activity but no clear synchronicity. *Pitch*: Some pitch in the various sound sources but no clear pitch structure in the montage; broad and constantly changing tessitura and compass. *Dynamics*: Fluctuating loud dynamics. *Timbre*: Highly complex and continuously changing; the composite of the many, densely superimposed sound sources creates an impression of saturation. *Gesture*: Frenetic bombardment.
Pithoprakta
Rhythm: Very dense rhythmic activity; many clearly defined event onsets (pizzicati) densely superimposed; no sense of metre or synchronicity. *Pitch*: Wide tessitura and compass, changing over the course of the excerpt (at times broad saturation, at times emphasizing the low register); pizzicato onsets most perceptually salient, but each note glisses following the onset; no clear harmony or pitch structure. *Dynamics*: Covarying with tessitura; ranging from medium-soft to medium-loud. *Timbre*: Homogenous string timbre, covarying somewhat with register. *Gesture*: Globally shifting register creates downward-migrating gestural gestalt.
Ligeti Double Concerto (1)
Rhythm: Dense, rapid, tremolo-like rearticulations; local, superimposed, shifting periodicities; no clear sense of metrical synchronicity. *Pitch*: Brief but stable pitches; narrow, middle-register compass; diatonic intervals (m3 + M2) emphasized initially, followed by chromatic filling in. *Dynamics*: Soft dynamics; slight crescendo over the course of the excerpt.

Timbre: String timbres, gradually transforming to emphasize upper harmonics (SP). *Gesture*: Gradual timbral shift and chromatic filling-in create a progressive intensification.
Lutosławski Symphony No. 2
Rhythm: Asynchronous, attack-dense, superimposed patterns between multiple instruments; some individual metrical organization but no synchronous coordination or common pulse. *Pitch*: Fairly narrow compass, middle-register tessitura, chromatically saturated overall pitch structure but with continuously and indeterminately changing configurations as per the aleatoric texture. *Dynamics*: Fluctuating, loud dynamics; slight decrescendo over the course of the excerpt. *Timbre*: Fairly homogeneous brass timbre; some notes standing out as brasher. *Gesture*: Slight decrease in compass / tessitura and loudness creates slight but progressive diminishing of intensity.
Riverrun
Rhythm: Very dense, granular texture; a very large number of very short, superimposed sound events; continuous activity but no sense of pulse, meter, or synchronous coordination. *Pitch*: Distributed stochastically and microtonally across broad range. *Dynamics*: Sustained medium-loud dynamics; imposed decrescendo at the end. *Timbre*: Sine tones and frequency-modulated sine tones distributed stochastically via granular synthesis; possible to hear multiple strata if low and high registers are perceived as distinct layers; also possible to hear as an amalgamated whole. *Gesture*: No clear sense of gesture, apart from continuous, frenetic activity.
Wings of Nike
Rhythm: Rapid, granulated rearticulation of short sound events; no clear sense of metrical synchrony. *Pitch*: Stable pitches; prominent m7 in middle register; other lower sounds in background. *Dynamics*: Sustained, medium-loud dynamics. *Timbre*: Synthesized sounds; quasi-vocal quality in one stratum; indistinct rumble in another. *Gesture*: No clear sense of gesture; continuous, dense rhythmic activity and sustained pitch.
Crystal Music
Rhythm: At least three distinct layers: (i) many short, very rapid micro-events similar to a “shatter” pattern, (ii) slow-moving notes, and (iii) a drone with no rhythmic differentiation. *Pitch*: (i) has predominantly medium-high sounds with little pitch salience, (ii) consists of mid-register notes with strong pitch salience and diatonic intervals (parallel m3s), (iii) is a low rumble with little if any pitch salience. *Dynamics*: Fluctuating medium-soft – medium-loud dynamics. *Timbre*: Distinct timbres for each layer: (i) inharmonic / noisy; lack of clear pitch due to large number of very brief, superimposed events; (ii) harmonic synthetic timbre, “flutey” sound; (iii) indistinct, noisy. Other sounds include sine wave-like timbres in brief, granular textures. *Gesture*: Pitch ascent in (ii) gives an overall ascending character; movement towards a brighter, synthetic timbre at the end gives a sense of intensification.
Mimetismo
Rhythm: Very rhythmic texture; relatively sparse, short sound events with clearly defined attacks. Some periodicity in guitar tremolo, but at too rapid a pace to be perceived as metrical; some loose sense of meter emerges towards the end of the excerpt. *Pitch*: Little sense of pitch in electronic sounds; strong sense of pitch in guitar sounds; low “pedal tone” with upward bending throughout excerpt, some mid-register chords emphasizing m3s in a chromatic ascending pattern in the latter part of the excerpt. *Dynamics*: Soft for most of the excerpt, becoming louder towards the end. *Timbre*: Inharmonic granular electronic sounds, juxtaposed with unprocessed acoustic guitar. *Gesture*: Overall sense of ascent and intensification, primarily driven by the guitar layer.
Lutosławski Double Concerto
Rhythm: Very dense, uncoordinated activity; local periodicity in individual parts, but no common pulse or meter. *Pitch*: Chromatic saturation in mid-low register; less dense motion in counterpointed voices in low and medium-high registers. *Dynamics*: Sustained loud dynamics. *Timbre*: Relatively homogeneous string timbre.

Gesture: Mini-Shepard-tone-like gesture in repeated rapid descent in mid-low register; gradual splitting off of contrapuntal voices creates increased stratification and consequently a diminishing sense of unity or coherence.
Ligeti Double Concerto (2)
Rhythm: Fairly dense rhythmic activity in fluctuating degrees throughout the excerpt; periodicity in local gestures whose phases change relative to one another somewhat irregularly, such that there is no overarching sense of meter but quasi-metrical moments emerge and then disappear. *Pitch*: Chromatically saturated m3 in mid-register. *Dynamics*: Fluctuating soft dynamics. *Timbre*: Homogeneous flute-dominated timbre, fairly dull and diffuse at the bottom of the instrument's range. *Gesture*: Interweaving and overlapping of similar gestures; gradual thinning of texture over course of excerpt.
Polymorphia (2)
Rhythm: Very dense activity; some rhythmic pop-outs caused by rapid registral displacement but predominant sense of rhythmic saturation and therefore indiscriminability. *Pitch*: Little or no clear sense of pitch, due to spectral saturation and pervasive glissandi. *Dynamics*: Sustained medium-loud dynamics with micro-fluctuations as voices move transiently into different registers. *Timbre*: Homogeneous string timbre, but creating a "vocal" illusion of a crowd of people through its organization. *Gesture*: No clear sense of global gesture.
Ligeti Double Concerto (3)
Rhythm: Tremolo-type rapid rearticulation; some local periodicity but continuously changing, with no clear or sustained sense of pulse or meter. *Pitch*: Mid-low register, narrow compass, only two pitches separated by m3 for most of the excerpt; small amount of chromatic expansion towards the end. *Dynamics*: Medium-soft dynamics with some minor fluctuation. *Timbre*: Somewhat heterogeneous woodwind timbre, shiftting from clarinet-based to bassoon-based. *Gesture*: Little sense of gesture; subtle trajectory of expansion and timbral intensification.
Jeux Vénitiens
Rhythm: Complex, active, and moderately dense polyrhythm; some local periodicity but no coordination, pulse, or meter between the parts. *Pitch*: Fairly wide compass from mid-low to mid-high register; complex chromatic pitch content, which, combined with lack of synchronous coordination, inhibits the emergence of a discernible or stable harmonic structure. *Dynamics*: Medium-loud dynamics, fluctuating with changes in other parameters. *Timbre*: Very heterogeneous, woodwind-based timbre. *Gesture*: Strong sense of superposition of multiple gestures, each with its own contour, trajectory, and rhythmic profile, but with no global sense of gestural coherence or coordination.
Asterism (2)
Rhythm: Complex, active, fairly dense polyrhythm. Some local periodicity but no coordination, pulse, or meter between the parts. *Pitch*: Fairly wide compass from medium to high register; complex chromatic pitch content, which, combined with lack of synchronous coordination, inhibits the emergence of discernible or stable harmonic structure. *Dynamics*: Medium-loud dynamics, fluctuating with changes in other parameters. *Timbre*: Very heterogeneous ensemble timbre, with prominent woodwinds and percussion. *Gesture*: Strong sense of superposition of multiple gestures, each with its own contour, trajectory, and rhythmic profile, but with no global sense of gestural coherence or coordination.
Ligeti Double Concerto (4)
Rhythm: Highly varied over the course of the excerpt, with moments of dense activity alternating with moments of relatively long sustained events (pitch bends in addition to stable pitches). Strong sense of rhythmic coordination between the parts but no clear periodicity or meter.

Pitch: High register; fairly narrow compass varying over the course of the excerpt from about a tritone to near-unison with microtonal inflection. *Dynamics*: Fairly steady, medium-loud dynamics; some fluctuation with changes in pitch and rhythm. *Timbre*: Fairly heterogeneous ensemble timbre, with prominent woodwinds. *Gesture*: Coordinated global gestural alternation between kinetic activity and relative repose.
Metastaseis
Rhythm: Little if any rhythmic differentiation due to continuous glissandi; some "events" created by local crests and troughs of pitch structure. *Pitch*: Very wide initial compass ranging from very low to very high; no sense of stable pitch as all voices move in continuous glissandi; gradual process of contraction over the course of the excerpt with some irregular trajectories. *Dynamics*: Varying smoothly over the course of the excerpt, ranging from medium-soft to loud. *Timbre*: Homogeneous string timbre. *Gesture*: Coherent, coordinated gesture of progressive registral contraction in "common fate" motion.
Mortuos Plango
Rhythm: Little rhythmic differentiation due to continuous glissandi; rhythmic events created by the introduction of new discrete pitches which then proceeds to glissando, and (less saliently) by the disappearance of other voices. *Pitch*: Fairly wide compass from medium to high; continuously changing inharmonic pitch structure; greater and lesser degrees of instability in pitch due to continuously changing slope of glissandi. *Dynamics*: Varying (mostly smoothly) over the course of the excerpt, ranging from soft to medium. *Timbre*: Synthetic sine-tones, some emergent timbre from combinations of tones. *Gesture*: Coherent, coordinated, two-phase gesture, first of contraction to a point of harmonic arrival (similar to a minor chord), followed by progressive ascent and divergence of sine tones.
Jaanilalud
Rhythm: Relatively low degree of rhythmic activity; unwavering rhythmic unison; clear 4/4 meter; steady tempo at a moderate pace. *Pitch*: Parallel "planing" of diatonic chord (M9) under diatonic melody; moderately wide compass ranging from mid-low to mid-high register. *Dynamics*: Fairly sustained medium-loud dynamics. *Timbre*: Fairly homogeneous vocal timbre (mixed-voice choir). *Gesture*: Completely unified, globally coherent melodic gesture; prototypical "common fate" motion.
Trois Poèmes d'Henri Michaux
Rhythm: Rhythmic differentiation most salient in percussion and wind instruments, with clearly defined events and quasi-periodic timing; no clear rhythm in voices, which are coordinated neither with the percussion nor with one another. *Pitch*: Fairly wide compass from medium to high range; little stable pitch content due to continuous glissandi. *Dynamics*: Sustained loud dynamics with some internal fluctuation. *Timbre*: Two timbral strata: continuous wash of vocal shouts / downward glissandi, and heterogeneous, sparse percussion-piccolo overlay. *Gesture*: Clear stratification between voices and instruments; voices create a noisy, quasi-Shepard-tone effect; instruments punctuate with brief rhythmic gestures; little sense of coherence between the two layers, or of global gestural direction.
Hyperion
Rhythm: Fairly high degree of rhythmic activity, increasing (accelerating) over the course of the excerpt; local periodicity and gestural coordination but little or no sense of overall pulse or meter. *Pitch*: Discrete, stable pitches, gradually decreasing in duration over the course of the excerpt; wide compass with most pitches concentrated in the mid-low register; superimposed octatonic and chromatic scale patterns. *Dynamics*: Medium-loud dynamics with some internal fluctuation; small crescendo over the course of the excerpt. *Timbre*: Very heterogeneous instrumental ensemble, some instruments standing out more than others (especially the piano). *Gesture*: Orchestrated accelerating Shepard tone.

Points de Fuites
Rhythm: Very dense rhythmic activity, many very brief (granular) events, clear coordination into overlapping descending gestures, no clear sense of pulse or meter. *Pitch*: Quasi-whole-tone scale patterns in descending gestures, microtonally superimposed; pitch content concentrated in a fairly narrow mid-register compass, with non-pitched sound components extending to both high and low registers. *Dynamics*: Fluctuating medium-soft – medium-loud dynamics. *Timbre*: Synthetic, granulated timbre; mixture of inharmonic and noise-based sounds. *Gesture*: Synthetically orchestrated, irregular Shepard tone.

4.2.2.3 *Procedure*.

Participants completed the experiment individually inside an Industrial Acoustics model 120-act3 double-walled sound isolation booth (IAC Acoustics, Bronx, NY). Musical excerpts were amplified with a Grace Design m904 monitor system and heard over circumaural Sennheiser HD280 Pro earphones (Sennheiser Electronic GmbH, Wedemark, Germany) at an average level of 60 dB SPL for all participants.

Participants were told that the experimenters were researching semantic dimensions of sound mass perception, and given the following explanation of sound mass:

- *Sound mass* exists when multiple sound events or sources are heard as a single meaningful unit. Examples are encountered on a daily basis: a large crowd of people, a flock of birds, rustling leaves, traffic noise, shattering glass, etc. In each of these cases, the individual sound sources are no longer heard as individuals, but they contribute to the sound of the whole (i.e., the sound mass).

  Music, especially contemporary music, frequently makes use of this phenomenon, creating textures in which many notes, sounds, instruments, voices, etc. are grouped into a mass. Musical sound masses may be very different from one another in their sound quality, organization, and behaviour, but they always involve multiple sounds being grouped into a unit. In this study, we will refer to this grouping of sounds into a mass as *fusion*. There may be degrees of fusion, as some sounds may be grouped more strongly than others. It is possible for some of the sounds that you hear at any given time to fuse into a mass while others retain their individual identities, as when a single voice stands out from a crowd.

Participants heard a series of 40 excerpts of 20th- and 21st-century music (described in Table 8, extracted from the pieces listed in Table 7), and rated them along three batteries of scales in three blocks. Each excerpt was heard and rated in each block, such that each of the 40 excerpts was encountered three times (for a total of 120). On each encounter, participants heard the excerpt at least once, and had the option to hear it a second time.

The first block featured terms involved in the definition of sound mass (Density, Complexity, Homogeneity). The second block featured adjectival metaphors used to describe sound mass (Volatile, Atmospheric, Busy, Static, Formless, Impenetrable, Voluminous, Kaleidoscopic). The third block featured nominal metaphors used to describe sound mass (Gas, Liquid, Solid, Clouds, Wind, Water, Webs, Galaxies, Crystals, Machinery, Herds/Crowds/ Swarms). Additionally, participants rated Fusion, which was taken to be a proxy for sound mass, in each of the three blocks, in order to assess how consistently sound mass is perceived in response to the same stimuli.

Participants completed the experiment on a Mac Pro computer (Apple Computer, Inc., Cupertino, CA). The interface was created in PsiExp (Smith, 1995) and consisted of a series of sliders (one for Fusion at the top, followed by others for each category in the block), which participants used to provide one rating per category for each excerpt in each block. Next to each of the Block 2 and Block 3 sliders was a "Questionable Relevance" button that listeners could select if they felt the scale was inapplicable to their experience; nevertheless, all participants were required to provide a value for each scale for all excerpts in all blocks. Additionally in Blocks 2 and 3, there was an optional "Other (please specify)" slider that participants could use to add a scale if they wished to indicate an association not listed in the battery. At the bottom of the screen were a 'Play' button, used to listen to the excerpt, and a 'Next' button that loaded the following excerpt. The order of the blocks, the order of the stimuli within each block, and the order of the categories within each block were all randomized for each participant.

In Block 1, the question was worded "Please rate the example on each of the following scales," with a brief definition provided for each category: Density (compactness of sound components); Complexity (intricacy or interconnectedness of sound components); Homogeneity (degree of similarity between sound components). These definitions did not identify specific musical parameters (e.g., pitch, rhythm, timbre); rather, participants were left to freely decide which attributes contribute to impressions of density, complexity, and homogeneity. At the end of Block 1, participants were asked to briefly describe their method for each of these categories. In Block 2 (adjectival metaphors), the instruction was worded "Please rate the degree to which you perceive the example to be:" with a range defined for each individual category (for example, from "Not volatile at all" to "Very volatile"; from "Not formless at all" to "Completely formless"; etc.). Brief definitions were provided for each term. In Block 3 (nominal metaphors), the question was worded "Please rate the degree to which the example reminds you of:" with a range for each individual category from "Very much" to "Not at all." No definitions were provided because these terms were considered to be basic English vocabulary (e.g., clouds, water, crystals, etc.), as it was thought that people who required such terms to be defined lacked sufficient English fluency to perform the task of this experiment.

4.2.3 RESULTS

For each category, a line graph representing the mean ratings of all participants may be found in the Appendices, with excerpts rearranged in ascending order along that category's ratings. Additionally, scatterplot graphs show relations between the ratings of musicians and nonmusicians for each category.

4.2.3.1 *Fusion Ratings*

Ratings for sound mass fusion (see Appendix A) were consistent between blocks. For each group (all participants, musicians, nonmusicians), Fusion ratings in each block were strongly correlated with one another, suggesting that sound mass perception is consistent across multiple listenings of the same musical examples (at least in this experimental situation).

Table 9: Correlation matrices (correlation coefficients and p-values) for fusion ratings in Blocks 1, 2, and 3, Experiment 4.

(a) ALL PARTICIPANTS	Block 1	Block 2	Block 3
Block 1	1 —	.968 <.001	.980 <.001
Block 2	.968 <.001	1 —	.972 <.001
Block 3	.980 <.001	.972 <.001	1 —

(b) MUSICIANS	Block 1	Block 2	Block 3
Block 1	1 —	.953 <.001	.957 <.001
Block 2	.953 <.001	1 —	.969 <.001
Block 3	.957 <.001	.969 <.001	1 —

(c) NONMUSICIANS	Block 1	Block 2	Block 3
Block 1	1 —	.950 <.001	.963 <.001
Block 2	.950 <.001	1 —	.940 <.001
Block 3	.963 <.001	.940 <.001	1 —

Note: degrees of freedom = 38

Ratings of musicians and nonmusicians are also strongly correlated within each block, though the correlations are not as strong as those within groups. Paired-samples *t*-tests reveal that ratings are also significantly different between the two groups in Blocks 1 and 2, but not Block 3. This is interesting since the only difference is the grammatical form (adjectival or nominal) of the task for the other categories in the blocks.

Table 10: Correlation coefficients (*r*) and *t*-values with corresponding *p*-values for musicians' and nonmusicians' fusion ratings in each block in Experiment 4.

MUSICIANS vs. NONMUSICIANS	*r(38)* *p*	*t* *p*
Block 1	.877 <.001	2.89 .006
Block 2	.894 <.001	4.34 <.001
Block 3	.899 <.001	1.55 .13

While the musicians' and nonmusicians' ratings of the stimuli are statistically different for two blocks, the musical qualities underlying those ratings appear to be similar, as evidenced by the high correlation coefficients. Fusion ratings for both groups appear to relate most strongly to low rhythmic differentiation and timbral homogeneity. Low register also appears to be a contributing factor, as does low pitch salience. Density of activity alone does not seem to be sufficient for sound mass fusion in this group of stimuli, nor does overlapping gestural similarity. Large clusters, such as the opening sonority of *Atmosphères* and the final sonority of *Threnody*, were rated highly but not the highest, casting further doubt on the putative equivalence of pitch density and sound mass fusion.

4.2.3.2 *Block 1: Density, Complexity, Homogeneity*

Descriptions and definitions of sound mass in the literature frequently invoke the concepts of density, complexity, and homogeneity, and we had initially assumed that sound mass perception would correlate strongly with all three. The results from Block 1 (see Appendix B) confirm that ratings for homogeneity correlate robustly with sound mass perception. Density also correlates positively but accounts for much less of the variance, indicating that not even *perceived* density is the strongest factor in sound mass fusion.[379] But the biggest surprise was that complexity shows a strong *negative* correlation with sound mass fusion (and also with homogeneity). We interpret this as evidence that perceived complexity and acoustical complexity may be two different and even contradictory things: listeners are only able to make sense of relations between sound components up to a certain point, beyond which increasing the number or intricacy of relations between the components no longer results in increasing perception of complexity. On the contrary, it results in a simplifying assimilation of components into a global gestalt, at which point it begins to take on the character of a sound mass. The other pairings, density-complexity and density-homogeneity, did not correlate significantly. The strengths of the correlations were different between musicians and nonmusicians, but the trends were similar.

Table 11: Correlation matrices for Block 1 ratings, Experiment 4.

(a) ALL	Fusion	Density	Complexity	Homogeneity
Fusion	1 —	.491 .001	–.828 <.001	.865 <.001
Density	.491 .001	1 —	–.110 .500	.291 .069
Complexity	–.828 <.001	–.110 .500	1 —	–.765 <.001
Homogeneity	.865 <.001	.291 .069	–.765 <.001	1 —

(b) MUSICIANS	Fusion	Density	Complexity	Homogeneity
Fusion	1 —	.570 <.001	–.814 <.001	.830 <.001
Density	.570 <.001	1 —	–.288 .072	.279 .081
Complexity	–.814 <.001	–.288 .072	1 —	–.728 <.001
Homogeneity	.830 <.001	.279 .081	–.728 <.001	1 —

379 As discussed in chapter 2, density in the sense of pitch distribution did not emerge as a strong predictor of sound mass fusion in our first three experiments

(c) NON-MUSICIANS	Fusion	Density	Complexity	Homogeneity
Fusion	1 —	.328 .039	–.772 <.001	.852 <.001
Density	.328 .039	1 —	.136 .403	.257 .109
Complexity	–.772 <.001	.136 .403	1 —	–.696 <.001
Homogeneity	.852 <.001	.257 .109	–.696 <.001	1 —

Note: degrees of freedom = 38

Paired-samples *t*-tests revealed that although ratings by musicians and nonmusicians correlated strongly for all three categories, they also differed significantly for density and homogeneity.

Table 12: Correlation coefficients (*r*) and *t*-values with corresponding *p*-values for musicians' and nonmusicians' density, complexity, and homogeneity ratings in Experiment 4.

MUSICIANS & NON-MUSICIANS	*r(38)* *p*	*t* *p*
Density	.837 <.001	3.06 .004
Complexity	.843 <.001	–.93 .358
Homogeneity	.888 <.001	3.40 .002

Immediately after completing Block 1, participants were prompted to verbally describe their methods for rating complexity, density, and homogeneity (see Appendix C). This was to assess which sonic or musical parameters people associated with the three concepts. Some of the responses essentially reproduced the wording we provided, with participants using the words "compactness" or "compact" in reference to density, "intricacy" and "interconnectedness" in relation to complexity, and "similar" or "similarity" in relation to homogeneity. Other participants' choices of words were revealing of how they conceptualize these terms.

Participants' descriptions of density, which were qualitatively similar for musicians and nonmusicians, suggest that this term was interpreted both "vertically" and "horizontally": some responses referred to rhythmic organization (time or silence between the sounds; "how quickly the sounds change") and others to numbers of layers of sounds. Several participants referred to loudness or volume as a factor. Nobody specifically mentioned pitch, but related concepts of intervals and range were mentioned by two participants. Strikingly, many of the characterizations of density relied on metaphorical imagery, describing the sound as "opaque," "heavy" or "light," "busy," "chaotic" or "confused." Several participants invoked "space" or "closeness"; one associated density with a sense that there is "no room for any other instrument." Others used extended metaphors: the excerpt was perceived as dense if it was "more solid, like a wall of sound" or "if I felt like I could cut the sound with a knife." One might speculate that the polysemy of the term "density" might be a factor in the relatively low correlation between density and sound mass fusion ratings: if listeners associate density with different acoustical and metaphorical attributes, they may rate musical examples differently for density depending on selected attributes or connotations of the term.

There was a clear trend for participants to characterize complexity in terms of rhythm and/or texture, with a smaller number of references to other attributes including timbre, harmony, register, and number of parts. Several participants related perceived complexity back to their own agency in analyzing the auditory scene, describing it in terms of "my ability to actively follow what was happening" and "how difficult it was to identify the individual sounds." One participant referred to the composer's agency, describing complexity as "how deliberately the individual sounds seemed to be composed in relation to one another." It appears that complexity is an esteemed musical value for some participants, who described it in terms of "how well the sounds worked together as a single unit" and considered an excerpt complex if it was "intricate and well created."

Of the three categories, homogeneity was the most clearly related by participants to a single sonic parameter: timbre. Homogeneity was also the only term for which there was a clear difference in the responses of musicians and nonmusicians, with most nonmusicians opting to simply invoke similarity or difference between sounds and most musicians specifically mentioning timbre (or instrument, sound source, etc.): this is likely because the word "timbre" is less familiar to many nonmusicians and merely indicates a difference of vocabulary rather than a difference of intent. A few participants mentioned other parameters such as pitch, rhythm, form, patterns, and number of sounds, and two used cross-modal metaphorical descriptions: "smoothness of sound" and "if it feels (or sounds) 'liquidy' or 'fluid.'"

These subjective verbal accounts seem consistent with participants' ratings. High ratings for density seem to correlate with loudness, spectral saturation over a wide compass (either noise-based sounds or large pitch clusters), and the absence of rhythmic differentiation (though this seems to be more important for musicians). In some cases, there may also be a referential "density of information" with source-bonded sounds, as in the bee sounds from Wishart's *Vox* and the panoply of sound sources in Normandeau's "micro-montage" from *Clair de Terre*. For complexity, rhythmic differentiation and timbral segregation appear to be important factors. Lutosławski's excerpts, which typically employ aleatoric and asynchronous repetition of musical material, were rated highly for this category. Global gestural integration seems not to detract from the perception of complexity: several of the "Shepard tone"-like examples were rated highly in spite of relatively simple global gestures (*Jeux Vénitiens*, *Points de Fuite*, *Hyperion*). For homogeneity, timbral consistency was indeed an important factor, as was low register. Rhythmic differentiation seems not to interfere with perceived homogeneity, provided that it is metrical and regular (for example, *Gorécki Symphony No. 3* was rated highly by both musicians and nonmusicians). Pitch structure similarly seems not to be a determining factor. The lowest-rated clips are timbrally heterogeneous and have multiple discernible simultaneous strata.

4.2.3.3 *Block 2: Adjectival Metaphors*

In Block 2, participants rated the excerpts for metaphorical associations presented in adjectival form (see Appendix D). The following definitions were provided: Volatile (violently unstable), Atmospheric (creating an ambiance or environment), Busy (full of motion), Static (globally unchanging), Formless (lacking a coherent structure), Impenetrable (opaque, impossible to hear through), Voluminous (occupying physical space), Kaleidoscopic (having vivid, continuously changing colours and/or shapes). Once again, ratings by musicians and nonmusicians were strongly correlated for all categories, but were also significantly different in several of them (Atmospheric, Static, Formless, Voluminous, Kaleidoscopic), further justifying treating musicians and nonmusicians as separate populations in subsequent statistical analysis.

Table 13: Correlations coefficients, *t*-values and corresponding *p*-values for musicians' and nonmusicians' Block 2 ratings in Experiment 4.

MUSICIANS & NON-MUSICIANS	*r(38)* *p*	*t* *p*
Volatile	.908 <.001	1.63 .110
Atmospheric	.578 <.001	6.57 .000
Busy	.922 <.001	1.16 .255
Static	.865 <.001	2.73 .010
Formless	.766 <.001	2.53 .015
Impenetrable	.889 <.001	.26 .795
Voluminous	.771 <.001	5.47 .000
Kaleidoscopic	.898 <.001	–2.60 .013

In general, the adjectival categories in Block 2 mapped clearly onto identifiable musical attributes.

(1) 'Volatile' was associated with absence of stable pitch, emphasis on noisy or unstable timbres (i.e., electroacoustic sounds or instrumental extended techniques), kinetic and dynamic textures, and continuous and/or unpredictable change. There was a wide range of responses, indicating that participants perceived considerable variance between the excerpts along this category.

(2) For 'Atmospheric,' vocal pieces were rated highly (especially by nonmusicians), while electroacoustic and noise-based pieces were rated lowly. Stable pitch structure, continuous sound, and slow, regular rhythm emerged as important factors. *Trois Poèmes d'Henri Michaux* is a curious inclusion, full of shouting, but given that our description for this category was "creating an ambiance or environment," participants may have felt that the crowd created an atmosphere in the sense of a mental image or scene. Ratings for this category were fairly high overall with a relatively narrow range.

(3) For 'Busy,' density of rhythmic activity appeared to be the primary factor. Timbre was less of a concern, with both homogeneous and heterogeneous examples rated highly. The bee sounds in Wishart's *Vox* may have evoked the cultural trope of "busy bees," and this excerpt was rated very highly for this category, especially by nonmusicians. There was a wide range of responses.

(4) For 'Static,' the absence of rhythmic differentiation and global trajectory were determining factors, as was timbral homogeneity. Highly rated excerpts also tended to have little or no internal motion: an exception to this last condition is the high rating of *Mortuos Plango* by

nonmusicians. Perhaps in this case the slow and continuous change combined with timbral homogeneity overrode the perceptual impact of the sinusoidal glissandi. Again, there was a wide range of responses.

(5) For 'Formless,' perceptible harmonic structure and metrical rhythm were important negative factors (i.e., excerpts with clear harmonic and metrical structures tended to be rated lowly). The contour of the line graph for this category is distinct from most others, covering a fairly wide range with a moderate slope that drops off steeply for the bottom eight excerpts. This suggests that participants felt there were some standout examples of what formlessness is *not*.

(6) 'Impenetrable' was associated with loud dynamics and spectral saturation, especially with noise-based timbre or chromatic saturation over a wide range. Lowly rated excerpts had softer dynamics (and in the case of *Mimetismo*, a thin texture with rests), clear intervallic structure, and/or a narrow range. Global gesture seems not to be a major factor (e.g., *Metastaseis* was rated highly). There was a fairly wide range and steady slope for ratings along this category.

(7) For 'Voluminous,' there was a steeper slope for the bottom third, whose excerpts were characterized by short sound events, high degrees of internal motion, and/or soft dynamics. Ligeti's large clusters tended to be rated highly, especially by musicians, who notably rated *Volumina* highest in this category (raising the question of whether some of them may have known the piece and its title). There is fair variety among the attributes of excerpts rated highly on this category, and the slope is nearly flat for the top third, suggesting that participants were more resolved about what 'voluminous' is not than what it is.

(8) 'Kaleidoscopic' tended to be associated with timbral heterogeneity and internal dynamism or process, as well as with mid-high registers. Several "Shepard tone"-like examples were rated highly (*Hyperion*, *Points de Fuites*, *Lutosławski DC*), perhaps suggesting an affinity between two cross-modal types of circular or cyclical motion. Excerpts rated lowly for this category tended to be rhymthically static, timbrally homogeneous, and situated in a low register.

4.2.3.4 *Block 3: Nominal Metaphors*

In Block 3, participants rated the excerpts for metaphorical associations presented in nominal form (see Appendix E). No descriptions were provided for categories in this block (Gas, Liquid, Solid, Clouds, Wind, Water, Webs, Galaxies, Crystals, Machinery, Crowds/Herds/Swarms). As in Blocks 1 and 2, ratings by musicians and nonmusicians were strongly correlated for all categories, but were also significantly different in several of them (Gas, Liquid, Wind, Webs, Machinery).

Table 14: Correlation coefficients, *t*-values and *p*-values for musicians' and nonmusicians' Block 3 ratings in Experiment 4.

MUSICIANS & NON-MUSICIANS	*r(38)* *p*	*t* *p*
Gas	.653 <.000	2.73 .009
Liquid	.640 <.000	2.63 .012
Solid	.783 <.000	.19 .85
Clouds	.761 <.000	.49 .63
Wind	.727 <.000	–3.55 .001
Water	.717 <.000	–.46 .64
Webs	.635 <.000	2.35 .024
Galaxies	.787 <.000	–.66 .51
Crystals	.858 <.000	–1.18 .25
Machinery	.900 <.000	3.05 .004
Crowds/Herds/Swarms	.920 <.000	.39 .69

Block 3 ratings were generally lower, and were more difficult to relate consistently to musical features, than Block 2 ratings. In some cases, there was a direct mimetic relation between the category and the sounds, and in such cases ratings were very high: for instance, the bees in *Vox* and the shouting people in *Trois Poèmes d'Henri Michaux* were both rated highly for Crowds/Herds/Swarms, and the electroacoustic excerpts—especially the loud, noisy *Mycenae Alpha*—were rated highly for Machinery. Often it was possible to relate excerpts to ratings on a case-by-case basis, drawing on different musical attributes and also different attributes of the extramusical domain. For example, the filtered noise glissandi in *Sud*, which was rated highest for Wind, create a "rushing" sound, while the low registers of *Atmosphères (2)*, which was rated second-highest, is similar to the rumble caused by wind blowing in one's ears or in a microphone. *Pithoprakta* was rated highest for Water by nonmusicians but considerably lower by musicians: a likely explanation is that the dense pizzicato texture reminded nonmusicians of the sound of rain on the roof, while musicians, for whom the pizzicato sound is presumably more normalized, did not make this connection. Notably, although this excerpt from *Pithoprakta* was compositionally modeled on gas behavior at the molecular level, it was rated lowly in the Gas category (third from last by the musicians), suggesting that this non-sonic, conceptual homology was not perceived in this instance. *Riverrun*, which deliberately invokes water sounds using granular synthesis, was rated highest for Liquid and second-highest for Water by musicians, but much lower by nonmusicians, suggesting that the synthetic electroacoustic soundscape was more readily associated with its source model by musicians who are presumably more familiar with this musical idiom. Three examples—*Points de Fuites*, *Asterism (2)*, and *Crystal Music*—were all rated much higher for Crystals than other examples by both musicians and nonmusicians; all are characterized by short sounds in a mid-high register, with a rhythmically active but not "saturated" texture. Pieces by Ligeti, who described his compositional process metaphorically as a process of crystallization in a supersaturated solution, were not rated highly for Crystals. However, Ligeti also had a famous dream involving a room full of cobwebs, and his pieces were rated fairly highly for Webs (in an interesting coincidence, the four excerpts from his Double Concerto appear in order near the top of the ratings for Webs). In some cases, the ratings are easier to interpret in terms of presumed topical significance than homologies between attributes of musical and extramusical domains. For example, the highest rated example for Galaxies by both musicians and nonmusicians was *Mortuos Plango*, which is musically nothing like the kind of "galaxy" invoked by Xenakis in relation to his stochastic procedures, but is similar in its sinusoid-based timbres to soundtracks from early science fiction movies.

4.2.3.5 *Principal Component Analyses*

To examine the results for underlying factors that may have guided the ratings across categories, Principal Component Analyses (PCA; a statistical procedure that analyzes large numbers of factors for underlying correlational patterns, resulting in a simpler model), were conducted on the Block 2 and Block 3 categories for all participants, musicians, and nonmusicians (see Appendix F). The order and contributing factors in the Principal Components (PCs) differed marginally between these three groups, but the similarities between them are much more striking than the differences, and as such I will discuss only the PCA for all participants in this experiment. The semantic clusters revealed by this PCA are intuitive groupings, and also map consistently onto identifiable musical properties. For ease of reference, I will name the PCs after strong contributing factors that give a sense of the semantic cluster.

(1) Important musical attributes in PC1 ("Liquid-Crystal") included timbral heterogeneity and mid-high register. Most of the excerpts rated highly for this PC were "granular," composed of large quantities of short sound events; exceptions (*Hyperion*, *Mortuos Plango*) featured slow, continuous motion, reflecting different but intuitive connotations of "liquid" and "water."

(2) PC2 ("Busy-Crowd") was characterized by the uncoordinated activity of many parts. Lutosławski's pieces were rated highly along this PC, as were some source-bonded (*Vox*, *Trois Poèmes d'Henri Michaux*, *Clair de Terre*) and mimetic (*Polymorphia (2)*, *Ligeti DC (1)*) excerpts.

(3) In PC3 ("Formless-Machinery"), electroacoustic and noise-based excerpts were rated highly, while vocal excerpts were rated very lowly. This PC was characterized by loud dynamics and the absence of perceptible pitch structure or metrical rhythm.

(4) PC4 ("Voluminous-Solid") involved loud dynamics, spectral saturation, low register and broad compass. Large clusters and noise-based examples were rated highly along this PC.

(5) PC5 ("Wind-Gas") was characterized by glissandi, continuity of sound, timbral homogeneity, low register, and the absence of rhythmic differentiation.

4.2.3.6 *Questionable Relevance Selections*

As noted above, although participants were required to provide a rating for each category, they had the option to indicate "Questionable Relevance" if they found a category dubious with respect to a given excerpt in Block 2 and Block 3. Table 15 shows the frequency with which this option was selected for each category by all participants, musicians, and nonmusicians.

Table 15: Percentage of Questionable Relevance selections for Block 2 and 3, Experiment 4.

(a) Block 2 Category	All Participants	Musicians	Nonmusicians
Volatile	2.0%	4.0%	0.1%
Atmospheric	1.4%	2.4%	0.5%
Busy	0.3%	0.6%	0.0%
Static	0.9%	1.5%	0.4%
Formless	0.7%	1.4%	0.1%
Impenetrable	0.9%	1.7%	0.3%
Voluminous	1.4%	1.1%	1.8%
Kaleidoscopic	1.4%	2.9%	0.0%
Block 2 (Adjective) AVERAGE	**1.1%**	**2.0%**	**0.4%**

(b) Block 3 Category	All Participants	Musicians	Nonmusicians
Gas	6.1%	4.2%	7.8%
Liquid	6.6%	5.4%	7.8%
Solid	6.0%	4.9%	7.0%
Clouds	7.3%	6.7%	7.9%
Wind	5.4%	2.9%	7.6%
Water	7.5%	5.4%	9.4%
Webs	7.4%	4.4%	10.1%
Galaxies	6.8%	5.0 %	8.4%
Crystals	8.6%	7.9%	9.1%
Machinery	6.6%	4.0%	9.0%
Herds/Crowds/Swarms	4.2%	2.9%	5.4%
Block 3 (Noun) AVERAGE	**6.6%**	**4.9%**	**8.1%**

These results point to two interesting asymmetries: between adjectival and nominal categories, and between musicians and nonmusicians. Overall, skepticism towards nominal categories is greater than skepticism towards adjectival categories. Musicians appear to be more skeptical about adjectival categories, and less skeptical about nominal categories, than nonmusicians.

4.2.3.7 *Participant-Added Categories*

Participants also had the option to add categories of their own for each excerpt in Block 2 (see Appendix G) and Block 3 (see Appendix H). In Block 2 (Adjectives), participants took this option 42 times, and in Block 3 (Nouns) they took it 90 times. However, one participant added a new category for nearly every excerpt, so if they are considered an outlier and removed from the tally, the difference is even more stark: 3 added categories for Block 2, and 50 for Block 3. The content of some of these added categories sometimes reflected literal sound source identification ("busy bees," "voices," "church organ," "orchestra," "flute," "brass," "string pizzicato," "computers"), while the content of others drew plausible comparisons with other, similar sound sources ("busy street," "welding," "just white noise," "background noise," "radio station not tuning in," "race cars," "steam," "guns," "trains or helicopters," "motorbike," "insects," "wind chimey," "a plane flying above," "religious chants"). A number of others described affects ("scary," "excitement," "confusing," "playful," "anxiety creating," "impending doom," "eery," "cheerful," "creepy,"), cross-modal associations ("darkness," "heavy"), and types of motion ("flight," "drifting"). Some added categories named specific objects or events ("dark souls," "death," "aliens," "lasers," "children playing," "blowing glass," "prayer," "church," "monastery," "something lurking in the background," "something crazy," "birds," "dogs, foxes, wolves," "animals in pain," "blood," "sunlight," "mist," "stairs"), and some referenced very specific tropes from film and popular culture ("taking you to the promised land," "Cinderella's evil stepmother," "Alice in wonderland's confusion," "falling down the rabbit hole").

4.2.4 Discussion

These results leave little doubt that listeners can and do experience metaphorical, extramusical associations with sound mass music, and that the selected set of semantic categories from composers' and theorists' discourse are germane to their experiences. The results further demonstrate that extramusical associations are often statistically consistent across listeners (at least in an experimental context) and that they relate to identifiable musical attributes, providing a strong counter-argument to the charge of arbitrariness often leveled at accounts of extramusical meaning. That the same excerpts may be rated highly along different categories may be explained in terms of attribute selection: the same musical attributes may be homologous with attributes of different extramusical domains, or different musical attributes may provide the basis for different cross-domain mappings. Extramusical meaning thus emerges not as a "content" delivered by the music, but as a dynamical, selective, many-to-many mapping that arises in the act of interpretation. Extramusical meaning so conceived is complex and variable, but not arbitrary, as the statistically significant correlations observed in Experiment 4 demonstrate. In some cases, such as the Block 2 categories and the PCA, the mappings were consistent enough to draw generalized associations beyond the individual excerpts (Kaleidoscopic with timbral heterogeneity and kinetic textures, "Formless-Machinery" with loud dynamics and noise-based timbres, etc.), while in others, such as many of the Block 3 categories, the mappings appeared more idiosyncratic to the individual musical excerpts and were more difficult to explain in terms of generalizable properties.

These results also demonstrate that not all extramusical meaning can be accounted for in terms of cross-domain homologies. Topical associations, which may arise from the context in which music is experienced rather than from inherent properties of the music itself, also provide a basis for extramusical meaning. This was demonstrated in the categories added by participants: many of the free associations reported by participants suggest the imagery of movies, especially science fiction, fantasy, horror, and fairy-tale movies, which are likely the only contexts in which many of them (especially nonmusicians) have experienced sound mass music (or contemporary music in general).

An unanticipated observation from these results is that there may be categorical differences between adjectival and nominal categories: the nouns were rated lower overall and were more likely to be selected for Questionable Relevance, indicating greater skepticism. This may or may not be a coincidence: when people wish to cast doubt on extramusical meaning, the examples they use to discredit it frequently involve comparison with nouns. For example, Tecumseh Fitch writes, "neither 'A#' nor a sequence of notes 'means anything' in the same way that 'dog' does."[380] But would it be equally problematic to think of a musical passage as "dog-like" or "affectionate" or "frisky" or "playful"? It may be that the qualitative generality and abstractness of adjectives are more amenable to musical meaning than the object specificity of nouns. Of course, it may also be that the results observed in Experiment 4 result from this particular set of categories rather than from their grammatical forms. We wondered how the results might be affected if the grammatical forms of the categories were switched.

4.3 Experiment 5

4.3.1 INTRODUCTION

A follow-up experiment was conducted to assess whether the differences between adjectival and nominal forms that we had observed in Experiment 4 were peculiarities of the categories we had chosen, or if they were generalizable to adjectival and nominal forms *eo ipso*. To that end, the adjectival categories from Experiment 4 (e.g., Volatile) were now presented as nouns (e.g., Volatility) and vice-versa. A consequence of this is that some of the new categories were worded more awkwardly or less idiomatically in English: for example, it seems more natural to ask if something seems busy than to ask if it reminds you of busyness. Nevertheless, we preserved the original roots of the words rather than seeking idiomatic substitutions. If nouns in general tend to be rated lower and adjectives higher, we would expect the Block 2 (adjectival → nominal) ratings to go down and the Block 3 (nominal → adjectival) results to go up as a result of this change. Furthermore, we would expect to see the skepticism participants showed towards Block 3

[380] Tecumseh Fitch, "The Biology and Evolution of Music: A Comparative Perspective," *Cognition* 100 (January 2006): 177.

categories, as demonstrated in their Questionable Relevance selections, to decrease, while their skepticism towards Block 2 categories would increase. We would expect the asymmetries between musicians and nonmusicians observed in Experiment 4 to appear again in Experiment 5, but redirected as per the grammatical change in the ratings categories. If these tendencies were not observed, it would support the conclusion that the observed asymmetries in results arose from the associations of particular categories, and not from their grammatical forms.

4.3.2 Method

The experimental design and stimuli of Experiment 5 were identical to those of Experiment 4, except that the grammatical forms of the ratings categories were reversed. As such, Block 2 was now the nominal block and Block 3 the adjectival block, with the wording of the questions adjusted accordingly. Twenty participants completed this follow-up experiment, ten of whom self-identified as professional musicians and the remainder of whom self-identified as amateurs or nonmusicians. All participants were fluent in English. Prior to completing the experiment, all participants passed a pure-tone audiometric test using a MAICO MA 39 (MAICO Diagnostic GmbH, Berlin, Germany) audiometer at octave-spaced frequencies from 125 Hz to 8 kHz (ISO 389-8, 2004; Martin & Champlin, 2000) and were required to have thresholds at or below 20 dB HL to proceed. All participants completed the same task and each was paid $15 CAD as compensation. They all signed informed consent forms prior to participating in the experiment.

4.3.3 Results

Visual comparison of ratings from the corresponding Block 2 (see Appendix I) and Block 3 (see Appendix J) categories suggested that the results were similar, but diverged fairly often. These tendencies appeared to be especially marked in nonmusicians' ratings for Block 3 categories, which often appeared considerably higher in Experiment 5 (adjectival form). Paired-samples *t*-tests revealed that while ratings for all of the corresponding categories were significantly correlated, most of them were also significantly different.

Table 16: Correlations coefficients, *t*-values, and corresponding *p*-values comparing results from Experiments 4 & 5 for Block 2 and Block 3 categories.

(a) Block 2 Category Pairs	*r(38)* *p*	*t* *p*
Volatile-Volatility	.923 <.000	–1.02 .32
Atmospheric-Atmosphere	.683 <.000	–2.83 .007
Busy-Busyness	.967 <.000	1.01 .32
Static-Stasis	.874 <.000	–3.75 .001
Formless-Formlessness	.845 <.000	5.53 <.000
Impenetrable-Impenetrability	.906 <.000	–1.24 .22
Voluminous-Volume	.908 <.000	–2.77 .009
Kaleidoscopic-Kaleidoscope	.913 <.000	–2.08 .044

(b) Block 3 Category Pairs	*r(38)* *p*	*t* *p*
Gas-Gaseous	.727 <.000	7.93 <.000
Liquid (n) – Liquid (adj)	.658 <.000	5.16 <.000
Solid (n) – Solid (adj)	.769 <.000	5.87 <.000
Clouds-Cloudy	.714 <.000	8.52 <.000
Wind-Windy	.743 <.000	-2.59 .013
Water – Water-like	.656 <.000	1.57 .124
Webs – Web-like	.761 <.000	5.72 <.000
Galaxies-Glactic	.695 <.000	1.88 .068
Crystals-Crystalline	.881 <.000	3.35** .002
Machinery-Mechanistic	.921 <.000	2.30* .027
Crowds/Herds/Swarms – Crowding/Herding/Swarming	.836 <.000	3.93 <.000

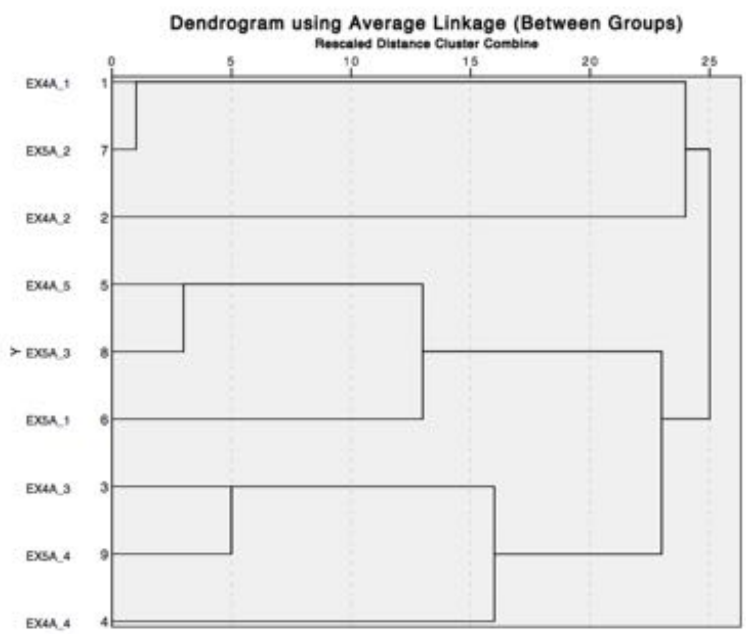
4.3.3.1 *Principal Component and Hierarchical Cluster Analyses*

We therefore conducted PCAs on the Block 2 and Block 3 categories from Experiment 5 (see Appendix K), in order to compare them to the PCAs from Experiment 4. There was somewhat more difference between the PCAs for all participants, musicians, and nonmusicians than for the Experiment 4 data. In the data for all partipants, only four principal components explained enough of the variance to register in the analysis, compared with five for each of the musicians and non-musicians treated as separate populations. The contributing factors for the third and fourth components are considerably different between musicians and nonmusicians, and the fifth component for each is driven primarily by a single category (Windy for musicians and Web-like for nonmusicians).

Some of the PCs in these analyses appear similar to PCs from the analyses from Experiment 4. But the first PC, the one that explains the most variance in Experiment 5, which we might call "Cloudy-Stasis," has no equivalent in Experiment 4. To verify that the PCAs from the two experiments were significantly different from one another, hierarchical cluster analyses were performed on the PCs from Experiments 4 and 5 for all participants, for musicians, and for nonmusicians. The results are represented in the dendrograms in Figures 51-53.

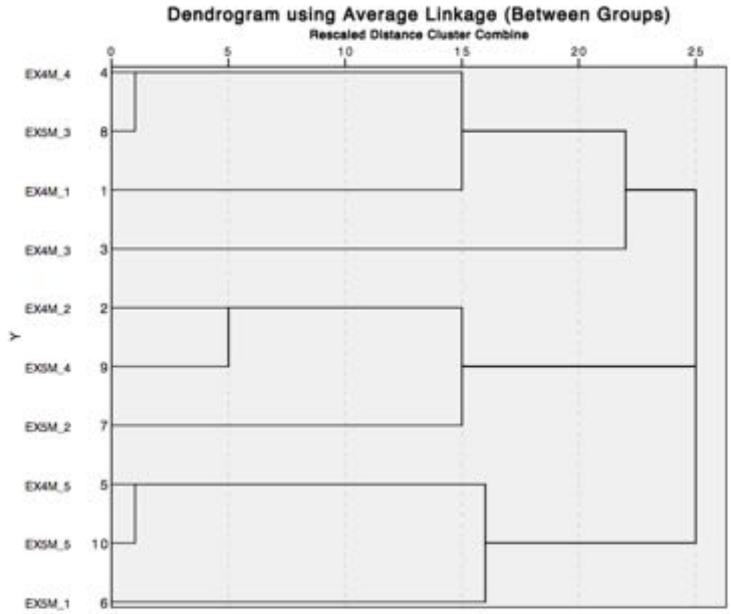
For all participants, Exp4 PC1 ("Liquid-Crystal") and Exp5 PC2 ("Water-like – Liquid"), Exp4 PC 5 ("Wind-Gas") and Exp5 PC3 ("Windy-Formlessness"), and Exp4 PC3 ("Formless-Machinery") and Exp5 PC4 ("Galactic-Mechanistic") were closely grouped with one another, while the remaining PCs from Experiment 4 were not closely grouped with any PC from Experiment 5.

Figure 51: Hierarchical cluster analysis of PCs from Block 2 & 3 categories for all participants.



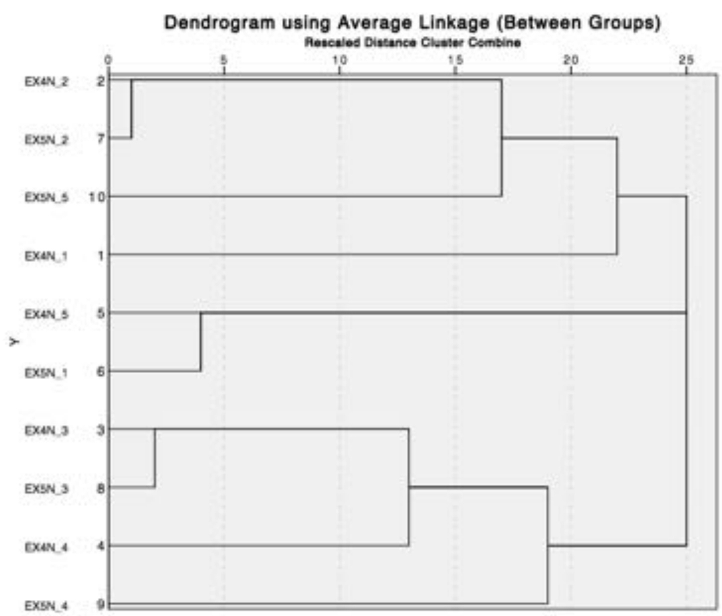
For musicians, Exp 4 PC4 ("Formless-Machinery") and Exp 5 PC3 ("Formlessness-Crowding"), Exp 4 PC2 ("Liquid-Crystal") and Exp5 PC4 ("Galactic-Mechanistic"), Exp4 PC5 ("Wind-Gas") and Exp5 PC5 ("Windy") were closely grouped with one another, while the remaining PCs from Experiment 4 were not closely grouped with any PC from Experiment 5.

Figure 52: Hierarchical cluster analysis of PCs from Block 2 & 3 categories for musicians.



For nonmusicians, Exp4 PC2 (“Liquid-Crystal”) and Exp5 PC2 (“Water-like – Liquid”), Exp4 PC5 (“Wind-Gas”) and Exp5 PC1 (“Cloudy-Stasis”), Exp4 PC3 (“Voluminous-Solid”) and Exp5 PC3 (“Formlessness-Mechanistic”) were closely grouped with one another, while the remaining PCs from Experiment 4 were not closely grouped with any PC from Experiment 5.

Figure 53: Hierarchical cluster analysis of PCs from Block 2 & 3 categories for nonmusicians.



4.3.3.2 *Questionable Relevance Selections*

Recall that participants in Experiment 4 were generally more skeptical about the Block 3 nominal categories than Block 2 adjectival ones, as evidenced by the frequency of their selection of the 'Questionable Relevance' option. If the grammatical form was the driving factor behind this trend, we would expect more Questionable Relevance selections in Block 2 than in Block 3 in Experiment 5. As shown in Table 18, this was not the case, so at least some of the skepticism must be due to the particular categories, and/or their relation to the particular musical excerpts. However, the *changes* between the frequency of Questionable Relevance selections between Experiment 4 and Experiment 5 do provide qualified support for the hypothesis that participants are more accepting of adjectival metaphors (Table 19). The Block 2 ratings in Experiment 5 (see Appendix O) are higher for all participants, for musicians, and for nonmusicians than their counterparts in Experiment 4. For Block 3 (see Appendix P), the ratings were actually higher in the adjectival form for musicians, but for nonmusicians the reduction was dramatic, reduced nearly by half, resulting in a lower percentage overall.

Table 17: Percentages of Questionable Relevance selections for Blocks 2 and 3, Experiment 5.

Block 2 Category	All Participants	Musicians	Non-Musicians
Volatility	6.4%	10.0%	2.8%
Atmosphere	2.4%	4.8%	0%
Busyness	1.9%	3.3%	0.5%
Stasis	5.9%	8.5%	3.3%
Formlessness	1.4%	2.3%	0.5%
Impenetrability	1.0%	0.8%	1.3%
Volume	0.4%	0.8%	0%
Kaleidoscope	2.9%	5.8%	0%
Block 2 (Noun) TOTAL	**2.8%**	**4.5%**	**1.1%**

Block 3 Category	All Participants	Musicians	Non-Musicians
Gaseous	5.5%	7.0%	4.0%
Liquid	6.2%	7.0%	5.3%
Solid	3.8%	2.0%	5.5%
Cloudy	8.5%	7.8%	9.9%
Windy	7.0%	6.8%	7.3%
Water-like	5.4%	7.0%	3.8%
Web-like	6.6%	4.0%	9.3%
Galactic	3.1%	5.8%	0.5%
Crystalline	5.9%	11.0%	0.8%
Mechanistic	2.4%	4.5%	0.3%
Herding/Crowding/Swarming	0.3%	0.5%	0%
Block 3 (Adjective) TOTAL	**5.0%**	**5.8%**	**4.2%**

Table 18: Comparison of Questionable Relevance ratings for Experiments 4 and 5.

	Block 2		Block 3	
	Adjective (Exp 4)	Noun (Exp 5)	Noun (Exp 4)	Adjective (Exp 5)
All	1.1%	2.8%	6.6%	5.0%
Musicians	2.0%	4.5%	4.9%	5.8%
Nonmusicians	0.4%	1.1%	8.1%	4.2%

4.3.4 DISCUSSION

The results of Experiment 5 indicate that changing the grammatical form of categories of extramusical associations affects both the robustness of participants' ratings (as shown in individual category ratings) and the way those ratings group together across categories (as shown in PCA and hierarchical cluster analysis). For all three groups, the PCAs between Experiment 4 and Experiment 5 were significantly different, with only three PCs closely aligning in hierarchical cluster analysis. The strongest effect was observed in nonmusicians, for whom the switch from nominal to adjectival metaphors in Block 3 corresponded with higher ratings and lower Questionable Relevance selections; and this in spite of the fact that, as noted above, changing the grammatical form sometimes led to less idiomatic English expressions.

4.4 GENERAL DISCUSSION AND CONCLUSIONS

The results of Experiments 4 and 5 generally support the theoretical account of extramusical meaning described in Chapter 3. The plurality of associations that led to formalist skepticism towards extramusical meaning is no longer problematic if extramusical meaning is conceived as homologous and topical cross-domain mapping that arises dynamically in the act of interpretation, rather than as fixed content delivered by the music. As the results reported in this chapter suggest, extramusical associations are pervasive aspects of musical experience, particularly in this case of the experience of sound mass music. The findings of other studies, such as Margulis (in press) and Huovinen and Kaila (2015), suggest that this is true of other types of music as well. The complications of intersubjective variation in extramusical associations should not be taken as grounds to trivialize or dismiss this aspect of musical experience as arbitrary or unimportant, nor to avoid its scholarly study.

A limitation of this study is that the musical analysis used to compare the excerpts with the ratings is based on my own subjective analysis, which of course is determined by my perception of attributes in the music which may or may not cohere with the perceptions of others. A more precise or systematic analysis of the stimuli, for example spectral analysis using audio descriptors, may provide a more incisive analysis, potentially revealing mappings between attributes and associations that I may have overlooked.

Perennially fraught comparisons between linguistic and musical meaning may begin to be addressed by reconsidering the role of grammatical form. In particular, it may be productive to avoid defaulting to the noun as the exemplar of linguistic denotation and the standard by which to measure music's referentiality, and consider other parts of speech such as adjectives, whose abstract qualitative generality may be more amenable to our experiences of extramusical meaning. The results of Experiments 4 and 5 provide qualified support for this hypothesis, but much further research should be done to corroborate it. The ratings categories in Experiment 4 were chosen based on their inclusion in discourse by composers and theorists in the sound mass literature, and not for their ability to convert idiomatically between adjectival and nominal forms. Future studies could more carefully select categories that make for a smooth grammatical transition. Also, examples from other styles should be studied with similar experiments, to determine the extent to which the observations from these experiments may be generalized beyond sound mass music to questions of musical meaning in general.

Chapter 5: Compositional Application of Sound Mass: *biome* (2017)

5.1 Introduction

My composition *biome* (score in volume II of this dissertation; recording available at https://soundcloud.com/jasonnoble-1/biome), a concerto for trombone and wind orchestra, demonstrates many ideas about perceptual and semantic dimensions of sound mass that are the subject of this dissertation. What follows is an analysis of the piece with respect to these ideas.

biome uses sound masses constructed in a variety of ways, motivated in part by their rich semiotic potential. The piece is based on a complex biological system viewed from different perspectives, from very zoomed-in to very zoomed-out. The abiding idea is that the perceptual and conceptual significance of things is a function of the perspective from which they are viewed, with levels of order depending on other levels beneath and at the same time providing foundations for levels above. As described in the Introduction, this is true in music and also in many other areas, including—to name just a few—logic, language, mathematics, physics, architecture, cosmology, and of course biology; it thus provides a plausible schema through which music may relate meaningfully to other domains. *biome* takes as precedents the third movement of Grisey's *Vortex Temporum* (1996), which is formally based on three different zoom levels of temporal perspectives (the time of humans, the time of whales, and the time of birds or insects), and films such as *Powers of Ten* (1977) that use zoom perspective to present radically different depictions of the same physical system. It also shares some conceptual affinities with Ives' *Universe Symphony*.[381]

biome is conceptually divided into seven sections: *I. Organism, II. Organs, III. Organism, IV. Cells, V. Ecosystem, VI. Organism, VII. Biome.* Each level involves the metaphorical grouping of many parts into coherently behaving units: biomolecules into cells, cells into organs, organs into organisms, organisms into ecosystems, ecosystems into biome. While we may understand a kind of recursive organization here that may make each level seem abstractly equivalent, their temporal and spatial scales differ by orders of magnitude, and we thus perceive them in qualitatively different ways. The middle levels—organs, organism, ecosystem —correspond to things

[381] See, for example, Ives' extended description quoted in Erickson, 193.

we can perceive without the aid of instruments such as microscopes or satellites, and in some cases, they produce sounds that we can recognize and imitate with musical instruments. Activity in the more peripheral levels—cells, biome—is far-removed from the scales of space and time inhabited in our quotidian experience; as such, these levels cannot be easily represented by direct sonic imitation and require more abstract homologies.

The analysis that follows will discuss each section individually, focusing on the different types of masses and how they were constructed, as well as the types of image schemata that were chosen to potentially map onto extramusical images and concepts. It is entirely possible that these same schemata may equally map onto domains other than the ones offered here, that some listeners may perceive schemata and mappings other than those described here, or that they may "just listen" and not map the music onto any other domains; as such, no assertion is made that this interpretation is "correct" to the exclusion of others. Nevertheless, to the extent that it relates identifiable properties of the music to identifiable properties of other domains, the presented analysis is not arbitrary or "merely" subjective but is grounded in claims that may be intersubjectively evaluated.

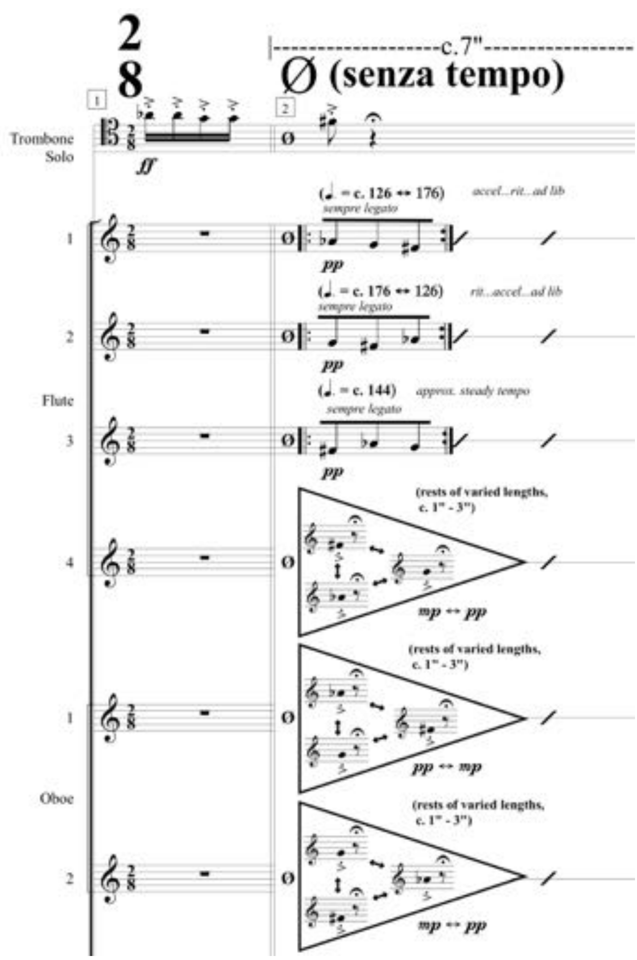
5.2 "I. ORGANISM"

The piece opens at the level of "organism," presumed to cohere most closely with "normal" daily experience, and returns to it several times over the course of the piece. A number of different ensemble textures occur in these sections, along with a variety of gestures from the soloist: the common thread is a strong distinction between foreground (soloist) and background (ensemble), created by the distinct dynamic, timbral, rhythmic, articulative, and dynamic profiles of the soloist's part, starkly juxtaposed with the predominantly homogeneous, indistinct, overlapping, and mutually assimilating parts in the ensemble. This texture provides a clear example of what Nussbaum calls "object motion" (discussed in Chapter 3), in which one instrument is in motion while others remain relatively motionless.[382] The ensemble parts are not literally motionless here, but the aggregate effect of their overlapping patterns is one of relative global stasis. The "figure-ground" organization required for object motion is typical of concerti, implied in their very form and instrumentation. The physical presence of the concerto soloist, brought to the front of the stage in order to be heard more clearly and to interact with the audience more directly,

[382] Nussbaum, 49-50.

differentiates him or her as the figure, and also as an “agent,” a protagonist or character. In the “Organism” sections of *biome*, as in concerto settings, the individual characters of ensemble instruments are attenuated with the goal of assimilating them into a background or “environment” through with which the agent (soloist) may traverse, or with which he or she may interact. The agent-environment distinction is the primary sense in which these sections attempt to embody the concept of “organism,” as agency (or the apparent experience thereof) is a fundamental characteristic of our own interactions with the world, and also of our observations of other organisms insofar as the appearance or illusion of agency, or perhaps of “purposiveness” in Kantian terms,[383] is what distinguishes the organism from its environment in our perception. The soloist’s part in this section is articulate and gestural. It opens with a declamatory 3-note descending motif, identifying a chromatic trichord that is then prolonged by the ensemble.

Figure 54: Opening of “I. Organism.”



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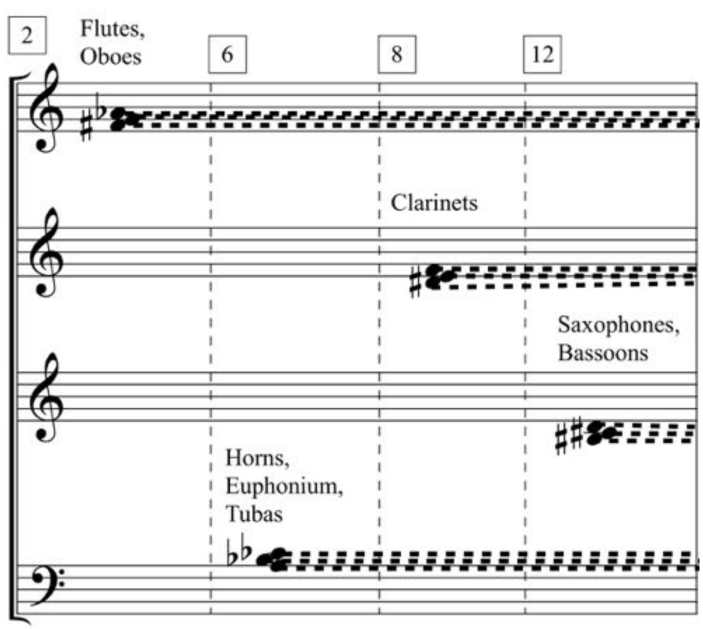
383 Immanuel Kant, *Critique of the Power of Judgment*, ed. Paul Guyer, trans. Paul Guyer & Eric Matthews (New York: Cambridge University Press, 2000), 249-52.

While the soloist's gesture and the ensemble's "shadow" of it share the same pitch content, they are very different in several ways. Flutes 1-3 cycle in continuous legato motion between the pitches in the same descending order, but each begins at a different position in the cycle. Flute 3 maintains an approximately steady tempo, but flutes 1 and 2 accel and rit freely within defined ranges, creating constantly changing 3-way phase relationships. Flute 4 and the two oboes interject freely with staccato articulations of the three pitches, adding intermittent colouristic accents to the continuous wash of the legato flutes. Since note order is unspecified for these instruments, their music is presented in polygon notation, a spatialized depiction of the instruction "play in any order." While it would have been possible to present material of this nature in a more conventional way—on a single staff with text instructions—I believe polygon notation better portrays the logic of the musical construction, is more visually interesting, and circumvents the strongly ingrained tendency to read from left to right (in conventional musical notation and also for printed text in English and most western languages). The overall effect of this first sound mass is one of continuous timbral and textural modulation in spite of simple and relatively spare pitch content: always the same but never the same. This mass is expanded at m. 6 with the addition of a similar construction a major sixth lower in the horns, euphonium, and tubas, creating a gap that is then filled in by the clarinets at m. 8 and the saxophones and bassoons at m. 12.

Figure 55: Pitch structure of first sound mass in "I. Organism."



This continuing chromatic aggregate provides a background "buzz" that persists throughout the section. Notated dynamics are initially soft for each trichord, but after the trichords have all been introduced, they are highlighted one a time by changes in the dynamics and textures. When a trichordal group is highlighted, instruments that had been playing legato sustain the pitches of the trichord and execute a dynamic hairpin, and the instruments that have been playing staccato continue to do so but with increased density and dynamic intensity. The instruments then resume their previous patterns, re-assimilating into the background mass, out of which another trichordal group may emerge (Figure 53). Each of the trichords is highlighted in this way before the end of the section, with some instruments octave-displaced in order to be heard more easily.

Figure 56: Highlighted trichord in first sound mass of "I. Organism."

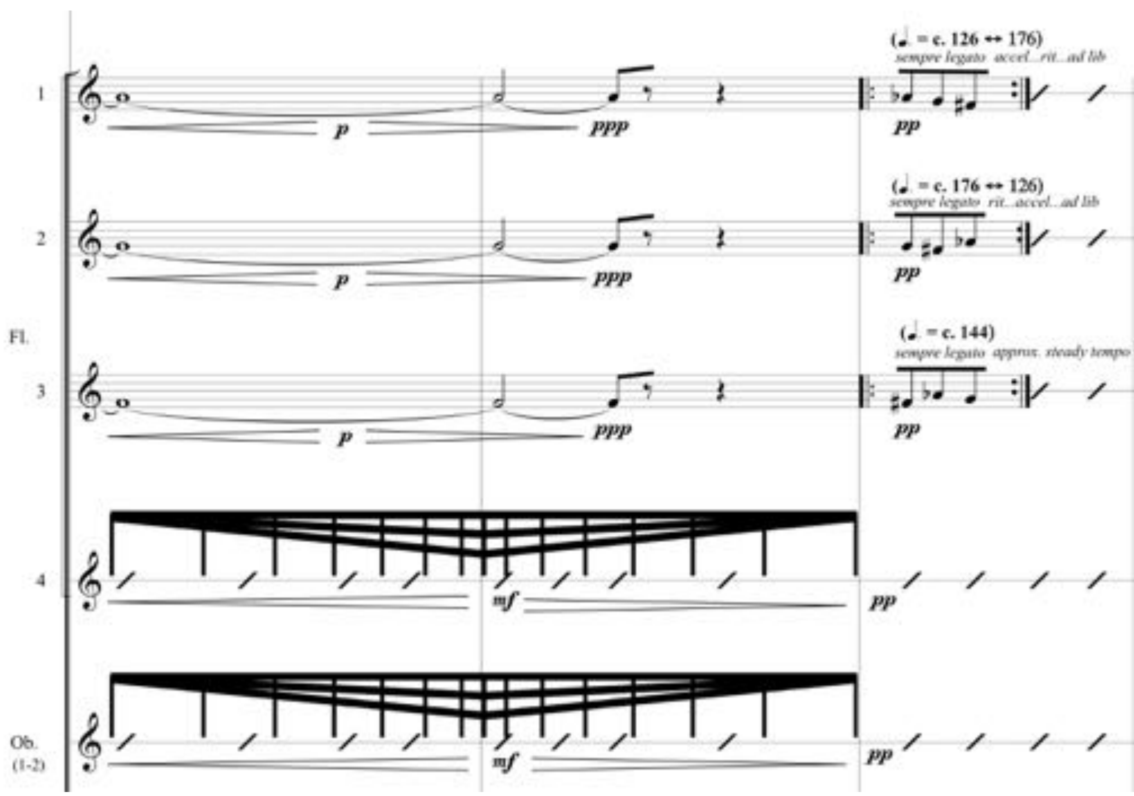
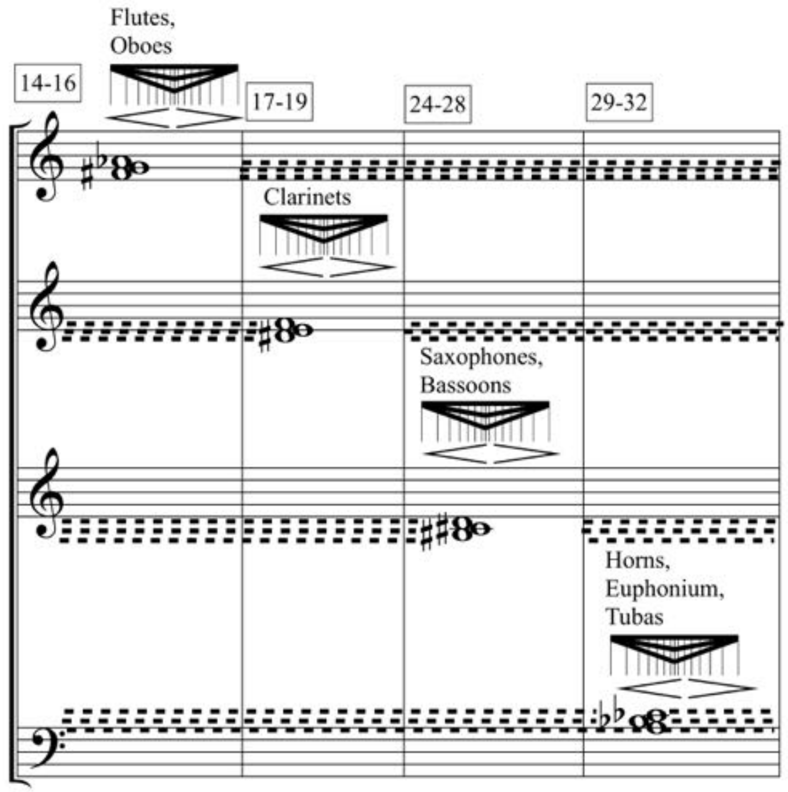
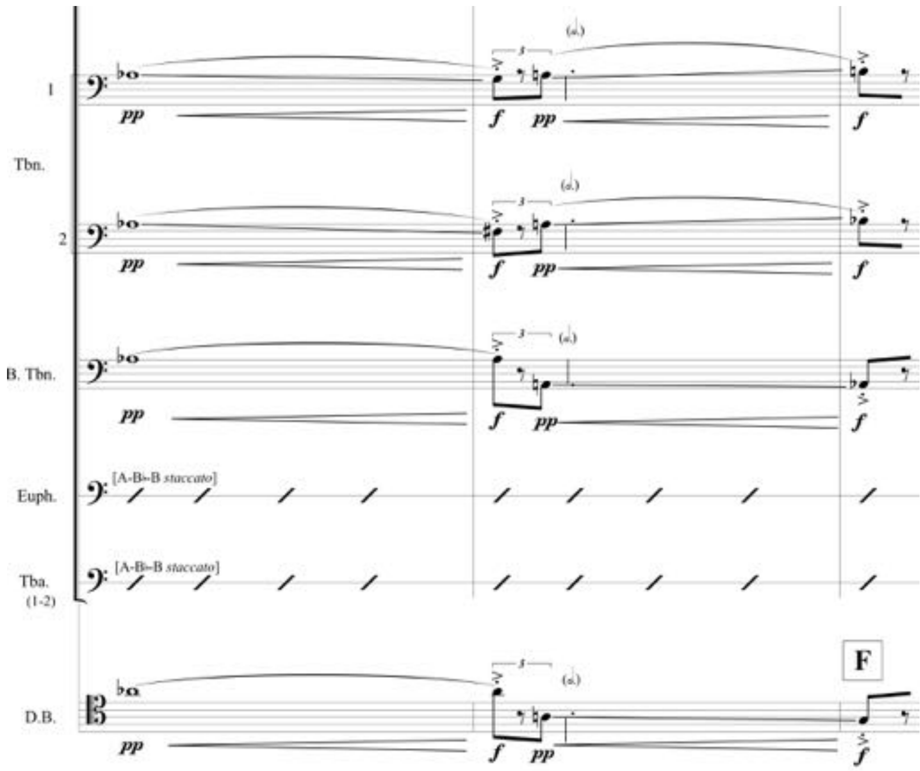


Figure 57: Highlighted trichords in "I. Organism."



Another type of sound mass used in this section also originates with the soloist and is shadowed by ensemble instruments, this time in a middle-ground rather than background layer. A number of times, the solo trombone identifies and rearticulates a pitch, sometimes with melodic embellishment, initiating a gesture in the orchestral trombones and double bass. Each of these instruments begins on the identified pitch and either sustains it or executes a slow, narrow gliss to a pitch a maximum of a major second away (either above or below). The slight differences in their trajectories cause pitch unity to gradually cede to beating that becomes increasingly intense as the pitches slide further apart, eventually splitting into perceptibly separate pitches at the termination of the gesture.

Figure 58: Second type of sound mass in "I. Organism."



The section ends, as do several others in the piece, with an abrupt "scene change" demarcated by a sharp hit from the bass drum.

5.3 "II. ORGANS"

An organism, which from one perspective may be regarded as a single thing and represented gesturally by a single musical line, is of course composed of a number of organ systems which each exhibit somewhat independent behaviour in spite of their interconnectedness. Some of these systems, notably cardiac and pulmonary, exhibit periodic activity within tempo ranges that we can readily and directly perceive. The activities of other systems, such as neural and endocrine, may be too fast or two slow for us to perceive and may consist in physical changes whose microscopic scale make them impossible to observe directly, though of course we are affected by these activities at macro levels. In the section labeled "II. Organs," there are four musical layers that unfold simultaneously, each modeled in some way on the activity of an organ system. Two of these (cardiac, pulmonary) have rhythmic features that approximate the real temporal characteristics of human organ systems. The other two (equilibrium-transformation, tension-release) are more abstract representations of processes of change that are important in organ-level biological functioning.

5.3.1 "Equilibrium-Transformation" Layer

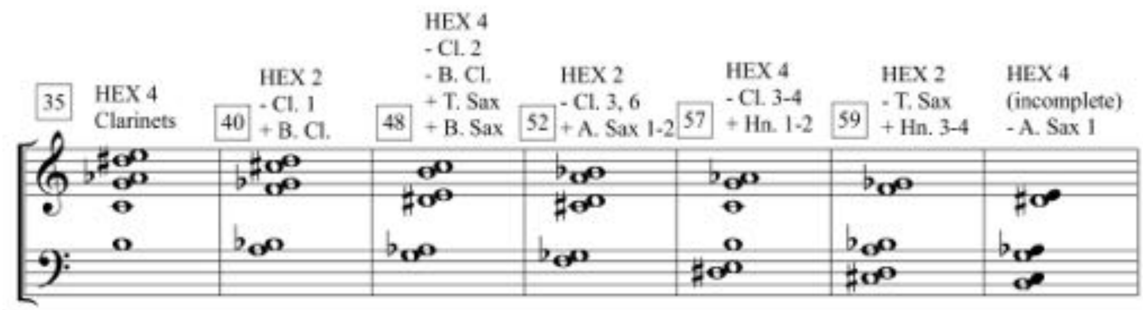
Following the abrupt cut-off triggered by the bass drum, "II. Organs" begins with sustained notes a semitone apart in clarinets 1 and 2, marked "*absolutely still*." These initiate the "equilibrium-transformation" layer, which continues throughout the section. The other four clarinets enter in mm. 35 – 36, completing an open voicing of a hexatonic collection.[384] Although the pitch content remains static for several measures, each instrument executes staggered hairpin dynamics following an independent path of durations, rests, and peak dynamic level, resulting in a texture that is, once again, always the same and never the same. The values of these independent parameters were determined by random number generation. Occasionally instruments may have coincidentally synchronous onsets and/or dynamic envelopes, causing them to group perceptually. These groupings produce a variety of harmonic emphases in spite of the overall stasis of pitch content, in which the denoted "equilibrium" is represented.

Figure 59: "Equilibrium-Transformation" layer in "II. Organs."

[384] The hexatonic collection (considered as a pitch class set) exists in four non-redundant transpositions, here labeled HEX 1 (C, C#, E, F, G#, A), HEX 2 (C#, D, F, Gb, A, Bb), HEX 3 (D, Eb, F#, G, A#, B), and HEX 4 (D#, E, G, Ab, B, C).

The “transformation” is both registral and timbral, and is very gradual. One hexatonic collection is gradually and overlappingly replaced by another a whole step lower, and then another, and so forth, resulting in an alternation between HEX 4 and HEX 2 over the course of the section that gradually descends from a medium-high to a medium-low register. As the entries and exits of pitch classes are staggered (both within and across hexachords), the appearances of pure hexatonic collections are temporary and transitional.

Figure 60: Register and instrumentation of hexatonic collections in “Equilibrium-Transformation” layer in “II. Organs.”



The timbre also continuously changes, as the clarinets are gradually replaced by bass clarinet, saxophones, and horns, which were chosen due to affinities of construction (the saxophone is also single reed) and timbre (the “mellow” horn is classed both as a brass and a woodwind) so the transformation would be gradual and smooth. It is a sort of Klangfarbenmelodie, but since – here as in works by many composers including Schoenberg and Ligeti – the focus is on continuous, vertically fused timbral combinations and not on a succession that is in any clear sense “melodic” apart from the fact that it unfolds in time, one wonders if the term “Klangfarbenharmonie” might be more apt. The “equilibrium-transformation” layer is ever-present throughout the section, but due to its soft dynamics and relative stasis, it fades easily into the perceptual background when other layers are present. It nevertheless contributes to an impression of continuous change through apparent surface-level repetition.

5.3.2 “PULMONARY” LAYER

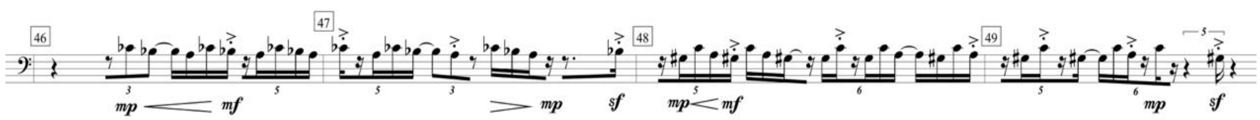
At m. 42, the second layer in this section, “pulmonary,” makes its first appearance. Gestures in this layer are composite between instruments, following a staggered crescendo-decrescendo contour in a much lower register than the "equilibrium-transformation" layer. The gestures are also temporally discontinuous (i.e., separated by silences) and are characterized by sustained intervals in a consistent, relatively narrow range, deeper, brassier, and more consistent timbre with some noise components. In keeping with the fairly high amount of variation there may be in the durations of consecutive human breaths, both the pulmonary gestures and the silences between them are somewhat unequal in duration, varying according to random number generation within a prescribed range that corresponds approximately with an average breathing rate for resting humans. Each gesture consists of a dyad, the lower note of which enters first in the double bass and tuba 2, and the upper of which enters after in the double bass and tuba 1. Although these intervals are clearly projected, their position in the low register nevertheless imparts to them a mass-like quality due to reduced pitch salience in this range of human hearing (see Chapter 1). The pitches are doubled an octave above in the bassoons, which enter slightly after the tubas, creating, along with the hairpin dynamics, a progressive sense of enriching or filling out of the timbre. The euphonium reinforces the gestures with actual breath sounds, and the undampened suspended cymbal continues the resonance of the "exhalation" phase of the gesture after the pitch has terminated, progressively and naturally diminishing. These qualities impart to the pulmonary gestures elements of iconic imitation.

Figure 61: "Pulmonary" layer in "II. Organs."

5.3.3 “Cardiac” Layer

Whereas in the first section the soloist was strongly foregrounded against a mostly homogeneous background texture, in the second section he or she presents one layer among others, the “cardiac” layer, unique only in that it is the only layer created by a single instrument. When the soloist enters at m. 46, it presents repeated three-note figures in the trombone’s mid-high register at a fairly rapid rate, with strong accents causing some of the notes to pop out of the texture. The accents are calculated to approximate the tempo of a resting human heart rate, but like the pulmonary gestures, they are not timed to be exactly periodic but to admit of random variation within a pre-determined range of rhythmic values.

Figure 62: cardiac layer in “II. Organs.”



The cardiac layer is not continuous throughout the section, but weaves in and out; this is partly to allow the soloist to participate in the onsets of the “tension-release” gestures, and partly to reflect the fact that we are not aware of our heartbeats as constantly as we are aware of our breathing.

5.3.4 “Tension-Release” Layer

Since the build-up of tension followed by its release is a feature of the functioning of many biological (and non-biological) systems, this layer maps not onto a particular organ system but to a familiar type of process. In keeping with the traditional musical analogy between higher register and higher tension,[385] the build-up phases of this layer’s gestures branch into the highest register visited in this section. The soloist arpeggiates a chord in an ascending gesture, the pitches of which are then taken up by piccolos, flutes, and oboes one or two octaves higher. These woodwinds crossfade above the soloist and crescendo to a local climax, whose breaking point is signaled by a loud crotales strike followed by a descending “shatter” gesture in the flutes, oboes, piano, glockenspiel, crotales, and vibraphone. Some of these parts are notated precisely to avoid synchrony

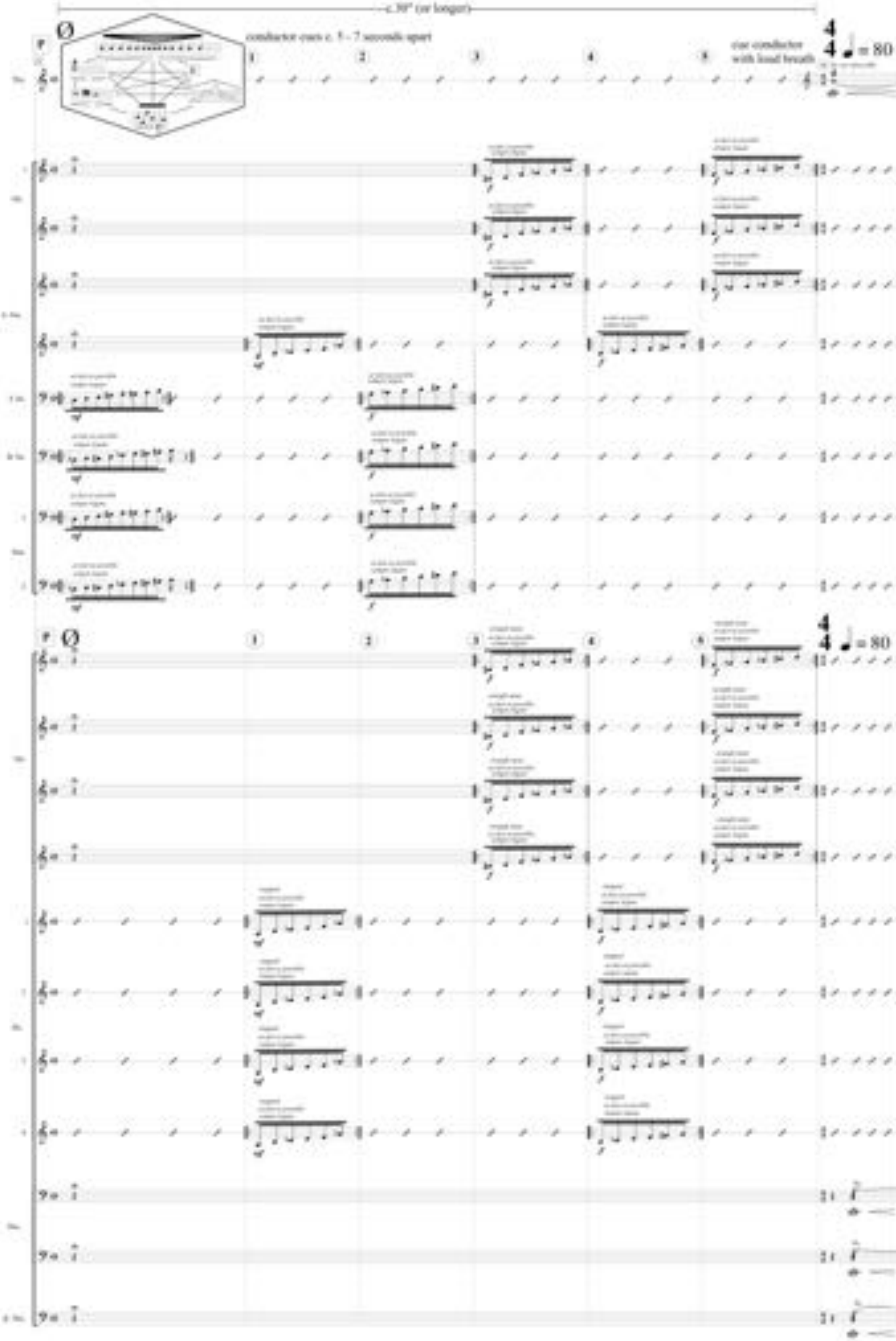
[385] Cox, 85-108.

while others are left to aleatoric decelerating rhythm (with specified pitches). Tension-release gestures occur twice in this section, at mm. 50-53 and at mm. 58-60.

5.4 "III. ORGANISM"

This third section reprises the "agent-environment" texture that characterized the first "organism" section and resumes some of the features of sound-mass construction exploited there: in particular, the use of legato repeat-cells at free tempi for some instruments and staccato notes in polygon notation for others. The timbre is brighter, the direction of the repeat cells is inverted to ascending, and the pitch collections are expanded to wider compass intervals and larger collections of notes, allowing for a sense of kinetic, directional thrust that was largely absent from the "environment" of the first section. That the ensemble is considerably more brass-heavy now diminishes the material distinction between agent and environment. There is also less distance between the soloist and ensemble in temporal organization: whereas the solo trombone part in the opening was mostly precisely notated in measured time while the ensemble was mostly in free time, here the soloist and the ensemble are all in free time, and even those gestures that occur in the context of a notated meter are rhythmically aleatoric (for example, with feathered beams indicating freely-interpreted accel and rit). In several places in this section, the soloist is given a number of choices in polygon notation that do not specify pitch but do specify gesture type, contour, and articulation. These consist of fragments taken from other places in the solo line, and it is up to the performer to piece them together into a coherent musical statement. At the same time the dynamics in the ensemble swell for the first sustained *forte* in the piece (there have been other loud moments earlier, but always brief and punctuating), in the register of best projection for the trombone. The combination of these factors – registral overlap, timbral similarity, loud dynamics, dense kinetic activity – create a context in which the soloist is "swarmed" and must fight to be heard. If we continue to interpret the section in terms of a dichotomy of agent and environment, the environment has become more hostile and more difficult for the agent to navigate.

Figure 63: Excerpt from "III. Organism."

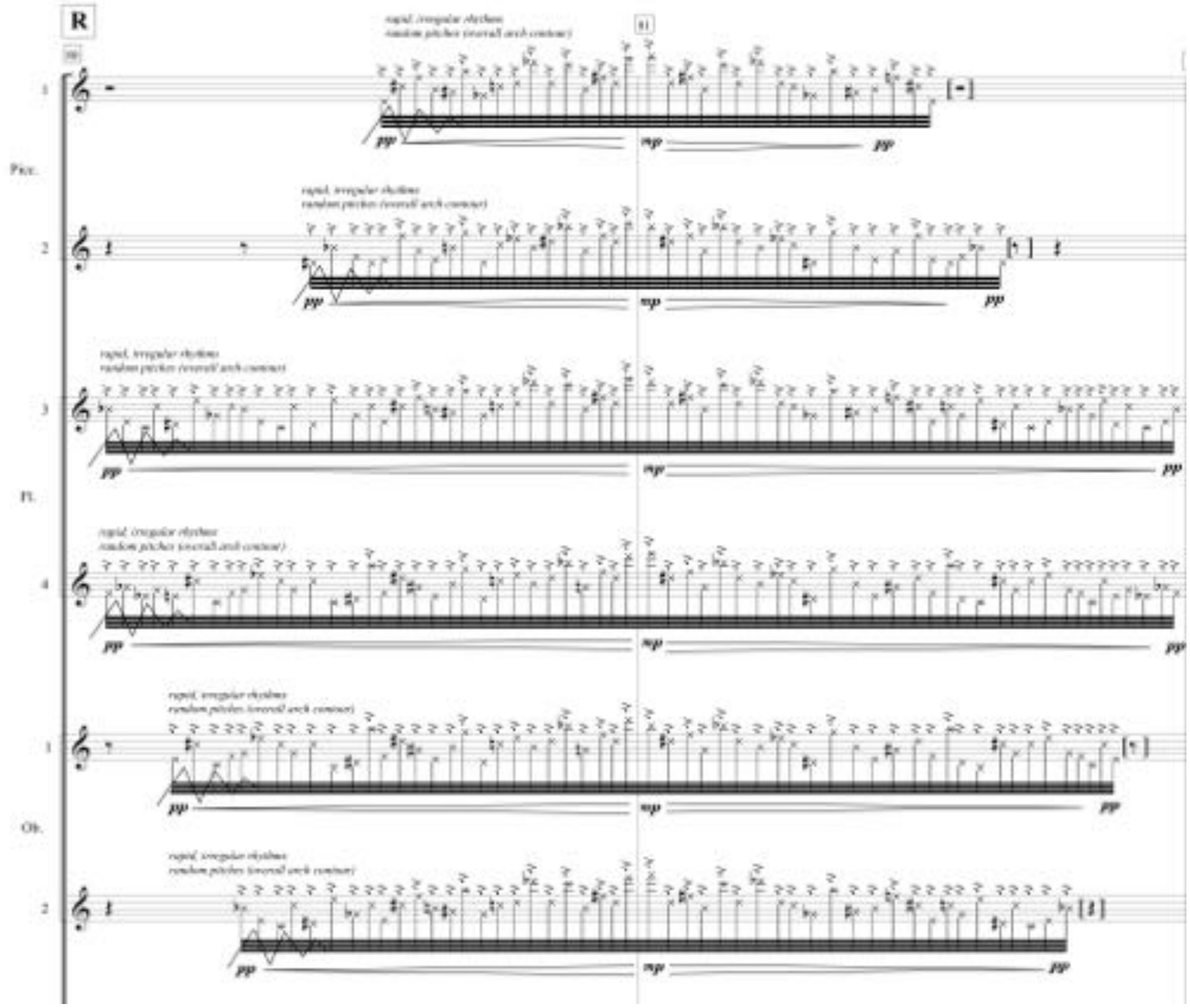


5.5 "IV. CELLS"

This section explores a level of order for which there is no recognizable sonic analogue: we may imagine what cellular activity is like, but there is no such thing as the "sound of a metabolism" in any normal listening situation. When we study the cellular world, we are introduced to objects and relations in a spatiotemporal scale radically contracted relative to our normal sensation, such that we can only picture it to ourselves by artificially magnifying its image to a scale to which we are accustomed. The experience of zooming in to this world— looking at a sliver of apparently homogeneous and inert organ tissue under a microscope and discovering that it is actually an aggregation of thousands of compartments coordinated in a bloom and buzz of activity too fast, tiny, and intricate for us to grasp with our naked eyes—is at first blush a revelation. It also lends itself almost perfectly to analogy with sound mass, especially sound mass achieved by granular synthesis and similar textures: the coming together of a large number of parts that are perceptually trivial as individuals but that amass to an aggregate perceptual gestalt.

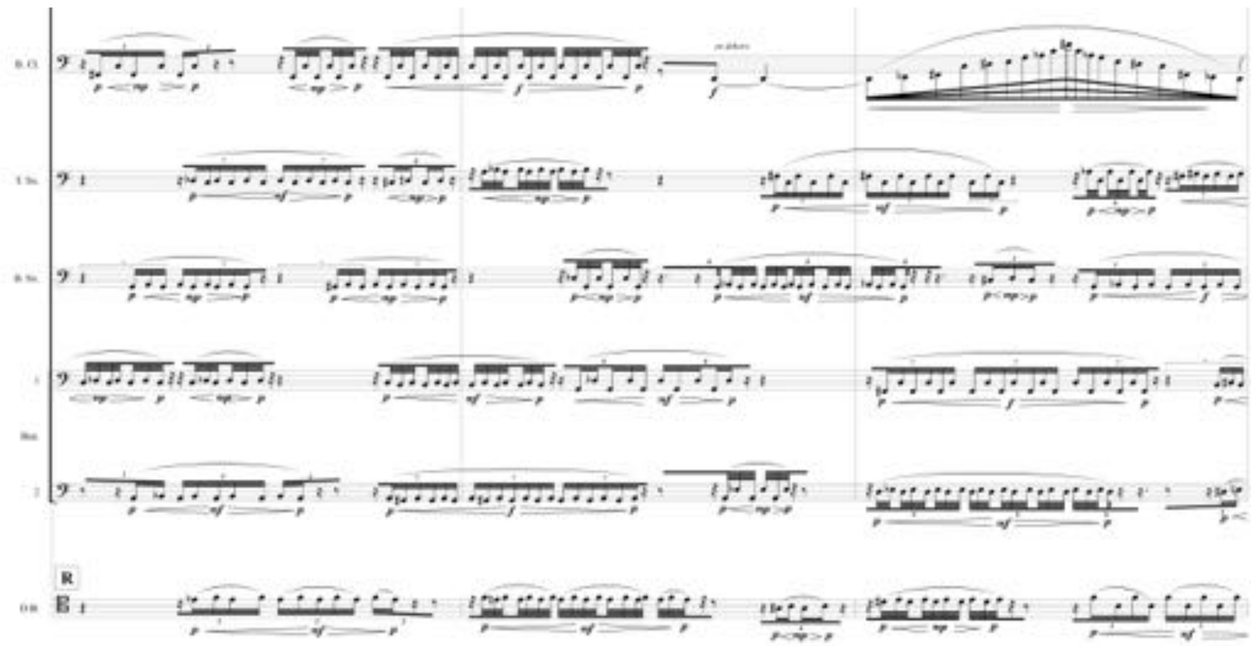
The "Cells" section opens with an expanded reprise of the "shatter" gesture from the "tension-release" gestures in "II. Organs," with a downward-sweeping cascade of indeterminate pitches in rapid, irregular, staccato rhythms in the piccolos, flutes, oboes, harp, piano, and mallet percussion instruments. Modified versions of this gesture return at m. 80 with the woodwinds only in an arch contour, and at m. 83 with the percussion, piano, and harp only in an ascending contour. The spectromorphologies of staccato articulations and percussive notes—rapid flecks of sound-colour that emphasize attack and minimize sustain—are well-suited in large numbers to create a pointilistic "cloud."

Figure 64: Pointillistic cloud in “IV. Cells.”



Another way this section expands on material introduced in “II. Organs” is by revisiting the low register, which was first presented in stable dyads in the “pulmonary” layer. Here it is presented in a busier, more complex and granular texture, but the individual gestures are still dyadic: the bass instruments of the wind orchestra play measured, overlapping, and interlocking trills or tremoli. Several aspects of the gestures—pitches, rhythmic subdivision (ranging from sixteenth-note quintuplets to thirty-second-note nonuplets), figure duration, rest duration, and peak dynamic of hairpin—were selected through weighted random number generation, yielding a consistent but continuously changing texture that is somewhat mechanical in nature—an abstracted iconic reference to the “cellular mechanics” of metabolism. In a musical texture in which everything is moving, long notes will tend to pop out of the texture, and this is exploited in drawing attention to onset of a few soloistic gestures in the ensemble, such as that of the bass clarinet in m. 81-82. The proliferation of notes and larger ambitus also contribute to the perceptual salience of this gesture (attention having already been established by the long note):

Figure 65: "Metabolism" in "IV. Cells."



In mm. 86-7 the texture and timbre change, but the sense of kinetic momentum is carried on. For the first time in the piece, all wind instruments drop out and the harp, piano, and mallet percussion instruments (vibraphone and marimba) are heard alone, with rapid scale patterns that are initially measured but then desynchronized as they accel and rit ad lib. These continue in free time and are later joined by punctuating sforzandi in the euphonium and tubas, pitchless fluttertonguing in the orchestral trombones, and the resumption of the trills and tremoli in the bass winds: a superposition of layers that are materially, timbrally, and organizationally stratified, but all are characterized by dense kinetic activity. Throughout this section, the soloist interjects with relatively brief gestures sharing some characteristics with other layers – brief notes, staccato articulation, fluttertongue – but as was the case in "II. Organs," here it is treated not as a foreground or protagonist but as one layer among others.

Figure 66: Excerpt from “IV. Cells.”

5.5 "V. ECOSYSTEM"

Whereas most changes of spatiotemporal perspective in this piece are abrupt and punctuated, the transition to "V. Ecosystem" occurs by way of a more deliberate and extended dilation: diverging scales in various instruments paired with a descending tremolo gliss in the bass serve to "open up" the texture, and to underscore the dramatic difference of scale between the zoom-in of the preceding "cells" and the zoom-out of the ensuing "ecosystem." Although at least some ecosystems have recognizable sounds that may be possible to imitate – the sound of the forest, for instance – the musical analogy here is based not on sonic imitation but on organization over time. Ecosystems (in my rudimentary and impressionistic understanding) ideally maintain global stability through local change, as individual organisms or species temporarily flourish or wane and then return to a state of ecological balance. Global stability here takes the form of invariant pitch structure and relative rhythmic stasis, while local ebbs and flows take the form of timbral evolution and perceptual "pop-outs."

The section is rather like an elaborated version of the "equilibrium-transformation" layer from "II. Organs." Rather than a series of hexatonic collections descending in register, the pitch content here is a full chromatic aggregate voiced to emphasize semitones and minor thirds, ranging from F#4 to C#6 initially and expanding downward to A3 with the entry of the trombones and double bass in m. 105. After this initial expansion, the pitch content and register remain constant throughout the section. However, after after m. 103 the pitches are traded around between various instruments, dovetailed so that each pitch is sounded continuously. Internal dynamism is created by staggered breaths and dynamic envelopes—as was the case in "equilibrium-transformation"—and by repeated marcato notes in free, decelerating rhythm and decrescendo dynamics that pop out of the texture before quickly resubmerging into it. Here the soloist is barely discernible within the texture: one part among many, subsumed within the global texture, differentiated from other instruments only by small dynamic variations.

Figure 67: Excerpt from "V. Ecosystem."

5.7 "VI. ORGANISM"

This second reprise of the "Organism" section is the most anthropomorphic section of the piece. Once again, there is a clear distinction between agent and environment (soloist and ensemble), but whereas section I exhibited a more-or-less comfortable coexistence with the environment and section III featured a more crowded, encroaching environment, the environment in section VI is both more vacuous and more volatile. For the first time in the piece, the soloist is occasionally unaccompanied, and there a number of long silences or spaces filled only with soft breath sounds. The accompaniment, when it is present, is provided almost exclusively by brass instruments, and to a greater degree than anywhere else in the piece is "reactive," with gestures from the soloist "triggering" responses from the ensemble instruments. For instance, in m. 125 the soloist's arrival at the low B-flat is followed by low clusters in the euphonium and tubas in the same register, the soloist's flared crescendo on F in m. 127 initiates first a reprise of the "pulling apart" gesture in the trombones and euphonium, and the soloist's loud upward rip in m. 128 sets off a succession of similar gestures in the trumpets. Dynamic contrasts are stark, ranging from complete silence to *fortissimo* outbursts. The full range of the brass choir is exploited, from high, indeterminate upward sweeps in the trumpets to the very lowest notes of the tubas (see Figure 65).

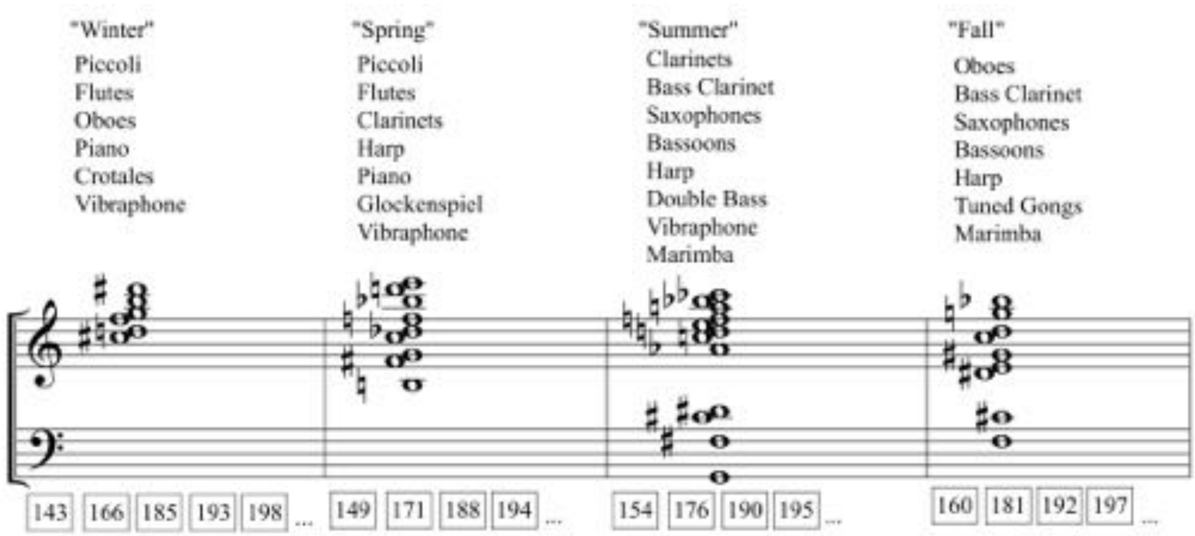
The soloist sets off a frenzy in one minute, and in the next finds himself or herself utterly alone. It is hoped that material and affinities between the agent and environment, the erratic nature of the gestures, and the uncomfortable spaces between them may suggest psychological tendencies such as obsessiveness, overreaction, and emotional instability, inviting an interpretation of an internal, psychological environment instead of (or in addition to) an external, physical environment. It is subjective, free-associative writing, not especially systematic in its construction, attempting to express in music something of a "before the abyss" rumination on mortality. There are several features of the composition that may allow for a plausible cross-domain mapping to this concept. The soloist's gestures are heterogeneous and frequently changing, transitorily recalling fragments of gestures from earlier sections such as the staccato articulations in mm. 121-122 that invoke the "cardiac" layer of "II. Organs" and the accented energetic solo at m. 124 that invokes "I. Organism." This is in contradistinction to earlier sections which were much more sustained in tone and character, had fewer jarring contrasts and no silences, and a more stable, less reactive environment. If these short-lived gestures are interpreted in tandem with the agent-environment distinction then it may suggest a wandering, restless agent, passing itinerantly from aggressive declamations to ‘dolcissima’ pitch bends separated by long pauses, panicked one moment and deflated the next. Finally, if a sense of a living system has been conveyed at all, then the idea of death is never very far away. The upward-sweeping rips that appear throughout the section culminate in a pseudo-tutti gesture in mm. 141-142, in which the soloist executes an irregular and free gliss while the rest of the ensemble sweeps inexorably upward, ushering in the next and final section.

Figure 68: Excerpt from “VI. Organism.”

5.8 "VII. Biome"

Zoom out far enough and the ecological totality begins to appear in some ways like an organism: this is a loose paraphrase of James Lovelock's Gaia hypothesis.[386] The "Biome" section of this piece is more differentiated than the "Ecosystem" section, for the same reason that a satellite image of the earth is more differentiated than an aerial view of a forest. The section cycles continuously through four phases, defined by harmonic structure, instrumentation, and degree and type of motion. The scale of this cycle is initially quite long, with each phase lasting four to six measures, but progressively contracts over the course of the section, until after m. 203 each phase lasts less than one measure. This is to indicate the cyclical passage of time, analogous to years which seem to pass faster as we age; the four phases may be considered proxies for the four seasons. The pitches notated in Figure 66 indicate starting positions: octave displacement may occur thereafter as instruments pass melodically through subsets of these harmonic structures. The phases are not always clearly delineated but often overlap.

Figure 69: Sectional organization of "VII. Biome."



The "winter" phase contains six pitch classes, and is harmonically, texturally, and timbrally the most austere. The piccoli, flutes, and oboes play senza vibrato in a fairly high register while the piano and bowed percussion highlight notes selected from the harmonic structure. The "spring" phase expands the harmonic background to nine pitch classes, enriches the tone colour with

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386 James Lovelock, *Gaia: A New Look at Life on Earth* (New York: Oxford University Press, 2000).

clarinets, and begins to enliven the texture with upward arpeggio gestures in the harp and occasional tremoli in the winds. The "summer" phase employs the complete chromatic aggregate, the rich timbres of saxophones, bassoons, bass clarinet, and double bass, and preponderant tremoli in the winds and upward arpeggios in the harp and mallet percussion. The "fall" phase diminishes the pitch-class content to nine notes, inverts the arpeggio figures to descending, re-introduces the decelerando-decrescendo repeating-note gestures that were first heard in "V. Ecosystem," and begins to thin out the timbre by dropping out the clarinets, double bass, and vibraphone.

Although particular instruments pop out intermittently throughout the section, there is no particular melodic line—including in the soloist's part—that provides a continuous thread, the emphasis being instead on the global changes. It is therefore closer to the situation identified by Nussbaum for "observer motion" rather than "object motion," but if the recurring cyclical pattern maps onto the passage of time, then so too does the listener's sense of motion: the music conveys the observer's motion not through space, but through time, at an ever-accelerating pace indicated by the progressive contraction of the duration of each cycle.

For large stretches of this final section, the solo trombone is silent. When the soloist does play, it is at first to rip through the inexorable cycle established by the ensemble and attempt to re-initiate textures from earlier sections: "I. Organism" in mm. 173-177, "IV. Cells" in mm. 181-185, and "II. Organs" in mm. 198-201. Each time, the ensemble texture is momentarily disrupted and follows suit by recapitulating the material initiated by the soloist, but after a couple of measures it "heals back over" and resumes its cyclical process. At m. 204, the soloist recapitulates the plaintive, dolcissima pitch bends from "VI. Organism," which fade to niente in m. 209. At this point, one by one, the wind instruments begin mixing their tone with air while still fingering the notes of the chords they have been cycling through, gradually hollowing out the sound: the increased breath content in the sound joins a soft shadow of noise that has been introduced in the background by tremoli on the suspended cymbal, double bass, and inside the piano. By the final iteration of the repeated measures 215-217, all pitch has disappeared and only breath remains. The soloist's final gesture is an exhalation at m. 218, which initiates a gradual diminuendo al niente in all parts. As indicated in the program notes, "it is not clear whether it is the organism, or the biome, or both, that expire."

Figure 70: Final measures of “VII. Biome.”

Conclusion

Part of my motivation for conducting this study is my sheer admiration for sound mass music. It has captivated me from the first hearing, and I have never needed deliberate study or acclimatization to appreciate it (as I have with some other strains of contemporary music). The sounds themselves; the ways they play off features of our auditory system to create illusions of fusion and fission; the ways they circumvent esoteric combinatorial constructions and syntaxes and promote a global listening perspective in which, if I may be allowed a cliché, the whole is greater than the sum of its parts; all of these aspects of sound mass perception are inherently fascinating. The many rich and varied associations that sound masses inspire, as detailed by composers and theorists and as I have also anecdotally experienced; the ways cross-domain mappings between this music and other modes of experience (auditory, cross-modal, conceptual) lessen the great divide between the musical and the extramusical, with the twin consequences that music embraces other domains and other domains assume something of the character of music; these aspects of sound mass semantics are fascinating as well. I find this music to be throroughly rewarding, and even after studying it at great length, its rewards persist.

Another part of my motivation for this study is my conviction that music is a vehicle for meaningful expression, and my consequent dissatisfaction with the formalist position, which, by needlessly confining music to the solipsistic prison of "purely musical meaning," leads to an impoverished understanding of musical signification. Perceptual and semantic dimensions of musical experience are complicated, plural, intersubjectively variable, sometimes apparently inconsistent or contradictory: the formalist position is right to point out these problems. But I believe the strategy of excluding difficult but pervasive and important aspects of musical experience from analysis in order to focus exclusively on those parameters that are easiest to quantify and notate is wrong-headed. My sense is that the field of music theory is coming around to agree with this position in these early years of the 21st century, and I hope that its erstwhile monolithic focus on pitch structures (even when these have yielded little explanatory power in terms of how the music is experienced by listeners) will gradually be supplanted by more holistic analytical methods, perhaps incorporating some of the insights of cognitive semiotics and music perception and cognition research. Sound mass almost *de facto* challenges the supremacy of the score as a representation of the work, as well as those analytical methods that focus on the score as the supreme source of information about the work: the music as heard bears only an abstract and strained relation to the score, especially to conventionally notated scores. To confront the challenges posed by sound mass music is almost of necessity to look away from the score and to seek out other ways to conceptualize the music.

In this dissertation, I have attempted to account for some of the perceptual and semantic aspects of sound mass. Chapter 1 detailed some of the many ways that complex musical entities comprised of many parts can exploit features of human auditory perception to attenuate the individual identities of those parts and assimilate them into a massed totality. This discussion was structured around the perceptual principles identified by David Huron as grounding the traditional rules of voice-leading, whose aesthetic aim—preserving the identities of contrapuntal lines—is the diametric opposite of the aesthetic aim of sound mass. But as Huron notes,

> ...even if the 'rules of voice-leading' were shown to be somehow immutable, their musical relevance depends entirely on the acceptance of the underlying perceptual goals ... different genres might manifest different perceptual goals that evoke pleasure in other ways.[387]

My argument is that sound mass depends on the very same features of auditory perception as polyphonic voice leading (toneness principle, principle of limited density, etc.), but applied inversely, to bring about an opposite perceptual goal: exceeding or subverting the auditory system's ability to parse the incoming sound into distinct auditory streams.

Chapter 2 explored some perceptual dimensions of sound mass through three experiments and a supplementary pilot study. Experiment 1 asked participants to rate three versions of Ligeti's *Continuum* (harpsichord, piano, and organ) for perceptual fusion in real-time, to assess how musical organization and timbre affect sound mass perception. Experiment 2 selected three excerpts from *Continuum*, modified their tempos and octave transpositions, and assessed how these parameters affected participants' sound mass ratings. Experiment 3 isolated harmonic structures from *Continuum* and neutralized the rhythmic dimension, in order to assess the extent to which pitch density and referential pitch structures influence sound mass perception outside of an ecological musical context. The supplementary pilot study asked participants to rate pitch structures, including many of the same ones from Experiment 3, for perceived brightness, pitchedness, and density.

[387] Huron, 'Tone and Voice,' 56-8.

Findings contradicted the assumption that high pitch density correlates with high sound mass perception: whether in or out of musical context, the distribution of notes in pitch space was consistently overridden as a predictor of sound mass perception by other factors such as emergent rhythm, register, rate of attack, number of notes, and number of pitch classes. Pitch distribution was nevertheless found to be aesthetically relevant with respect to other perceptual and semantic categories, such as those evaluated in the pilot study.

Chapter 3 addressed cultural attitudes towards musical meaning in the 1950s and 1960s when sound mass music came of age, and discussed various ways in which it defined itself in contradiction to the serialist orthodoxy and ideology of absolute music that prevailed at that time. It then addressed general problems of musical meaning through a review of several contemporary semiotic and philosophical approaches, and argued for the rejection of the structural metaphor MEANING IS CONTENT and the adoption of a dynamical model of musical meaning based on homologous or topical relations between musical attributes and the attributes of extramusical domains. In the last section of this chapter, metaphorical associations of sound mass music extracted from the writings and interviews of composers and theorists were compiled, organized into seven categories: *spatial*, *material*, *behavioural*, *cross-modal*, *naturalistic*, *technological,* and *surreal*.

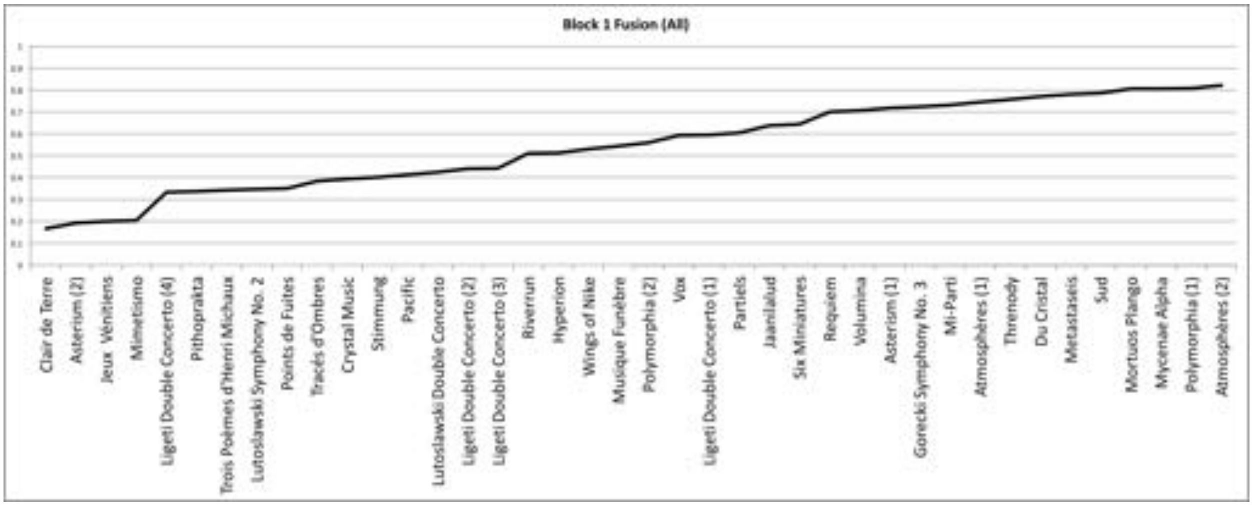
Chapter 4 reported two empirical studies on listeners' semantic associations with sound mass music, in which participants were presented with 40 excerpts from the sound mass repertoire and asked to rate each along batteries of scales selected from the metaphors listed in Chapter 3. Experiment 4 established that listeners were statistically consistent with one another in their ratings along many of these categories, and that attributes of the rating categories could often be related meaningfully to musical attributes of the excerpts. It also gave participants the opportunity to offer categories of their own, and the results revealed potential topical associations with sound mass music based on the imagery of movies, especially the imagery of science fiction, horror, fantasy, and fairy-tale. This experiment also revealed that participants were more skeptical in general towards metaphorical categories presented in nominal form than towards categories presented in adjectival form. To probe this unexpected observation further, Experiment 5 repeated the conditions of Experiment 4 but with the grammatical forms of the metaphorical categories reversed, such that categories that had been adjectival were now nominal and vice versa. Results suggest that while much of the variance in the data is attributable to the particular semantic categories, grammatical form is a significant factor, especially for nonmusicians, with adjectival forms tending to be rated higher and met with less skepticism.

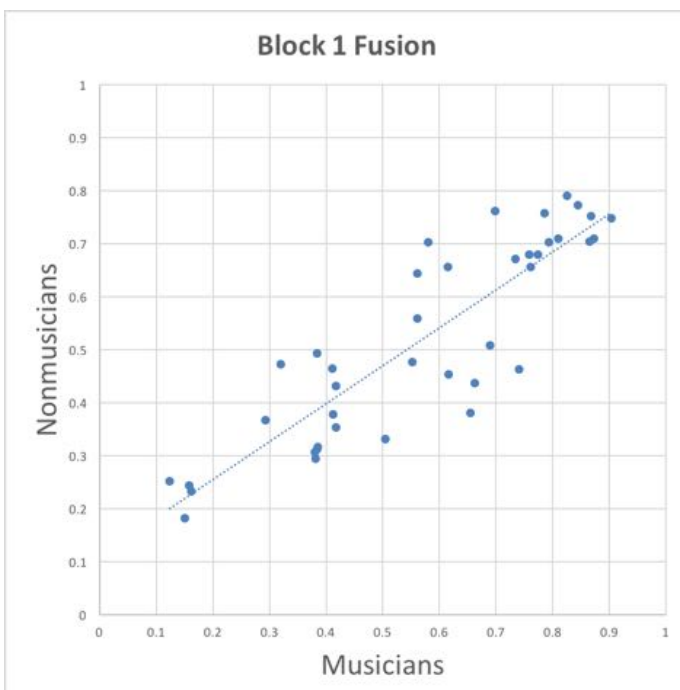
Chapter 5 presented an analysis of my composition *biome* for solo trombone and wind orchestra, which applies some of the methods of sound mass fusion studied in Chapters 1 & 2, and some of the insights into sound mass semantics studied in Chapters 3 & 4. The analysis reflects my own goals for, and interpretations of the work, on which of course I have a unique perspective as its composer and which I cannot expect to cohere exactly with the experiences of other listeners. Plurality of interpretations is a running theme in this dissertation, and I understand that many other intepretations of my piece are possible, and that they may differ starkly from, or even contradict, the interpretation I offer here. Nevertheless, I hope that lessons learned in researching this dissertation have allowed me to compose with a more refined understanding of relations between musical attributes and metaphorical associations, and to create a work that is both musically interesting and extramusically meaningful.

Concert music, at the time of this writing, stands before an uncertain future. While it may have been acceptable in the past to treat music as a field of pure experimentation, I believe that today a concerted effort is needed to reconnect contemporary music with an alienated general public. Given the ubiquity and individual privatization of media in general and musical media in particular, this is no mean feat. But believing as I do in the conceptual, expressive, aesthetic, and moral value of concert music as a serious art form, I feel a pointed urgency to try to find a way forward. I hope that this dissertation has been conducted in the spirit of seeking such a way, focusing on a branch of contemporary music that I believe holds great potential to communicate with non-specialist audiences (as demonstrated by its effective inclusion in classic films, as well as by anecdotal personal experience). I have aimed to study this music from the listener's point of view, specifically focusing on perceptual and semantic dimensions. I believe that we as composers stand a greater chance of connecting with broad audiences if we deeply consider their experiences, using all the tools of research and creation that we have. I hope that future work will continue to explore these subjects, convoluted and arcane though they may be, in the interest of both the audience and the art.

Appendix A: Experiment 4 Fusion Ratings

A.1 BLOCK 1 FUSION





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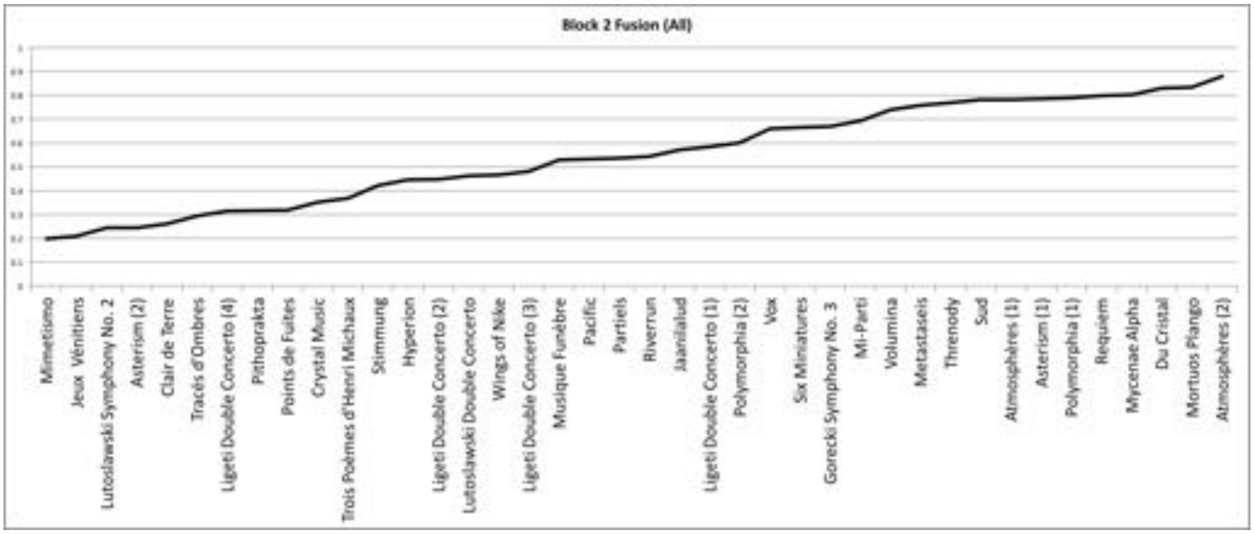

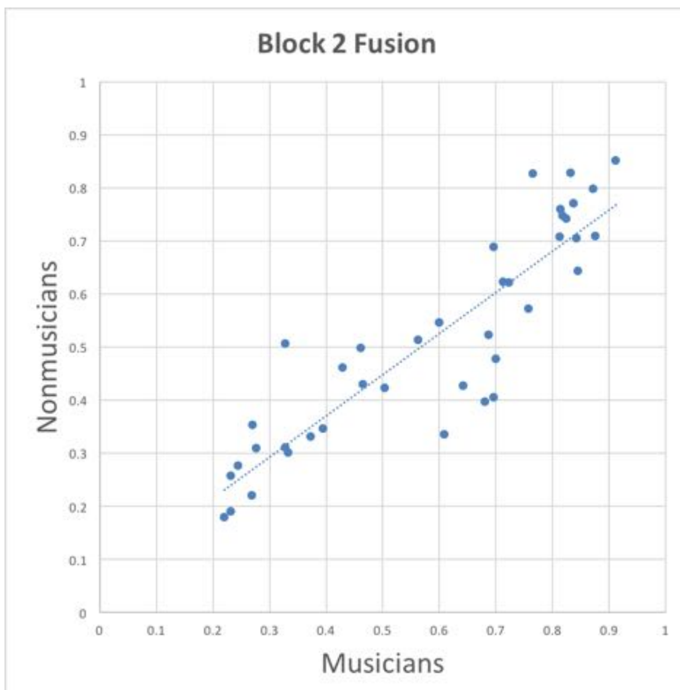

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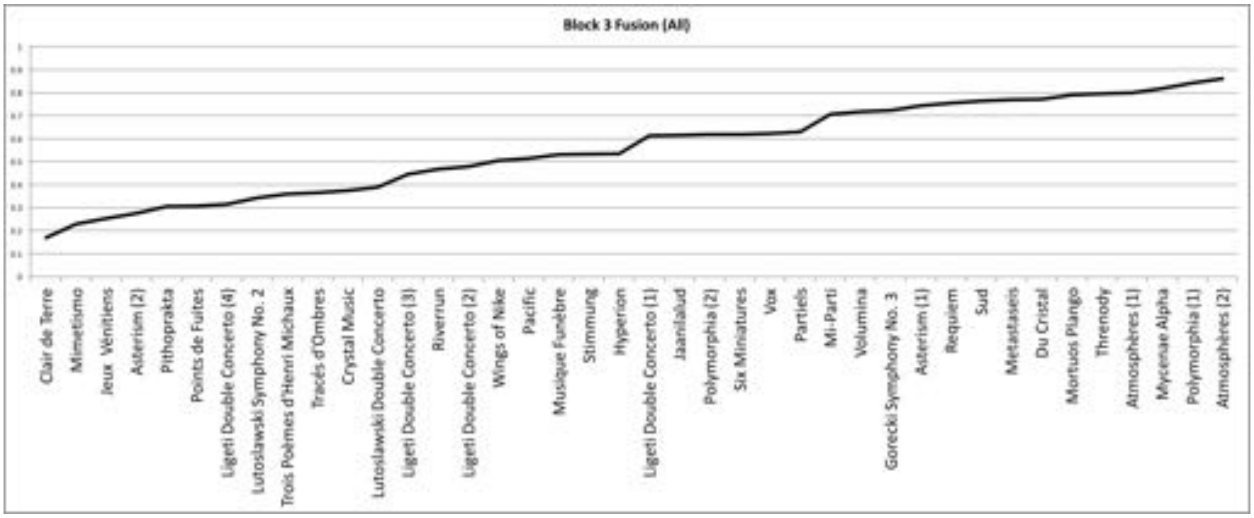
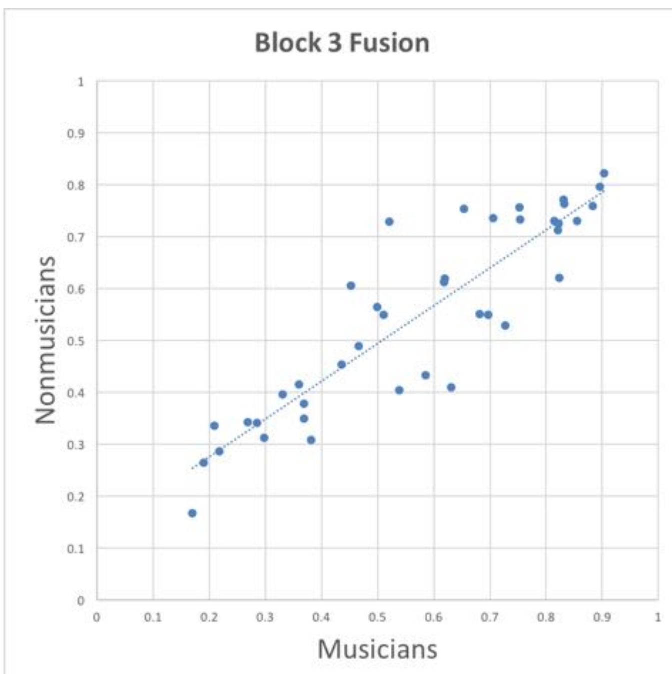
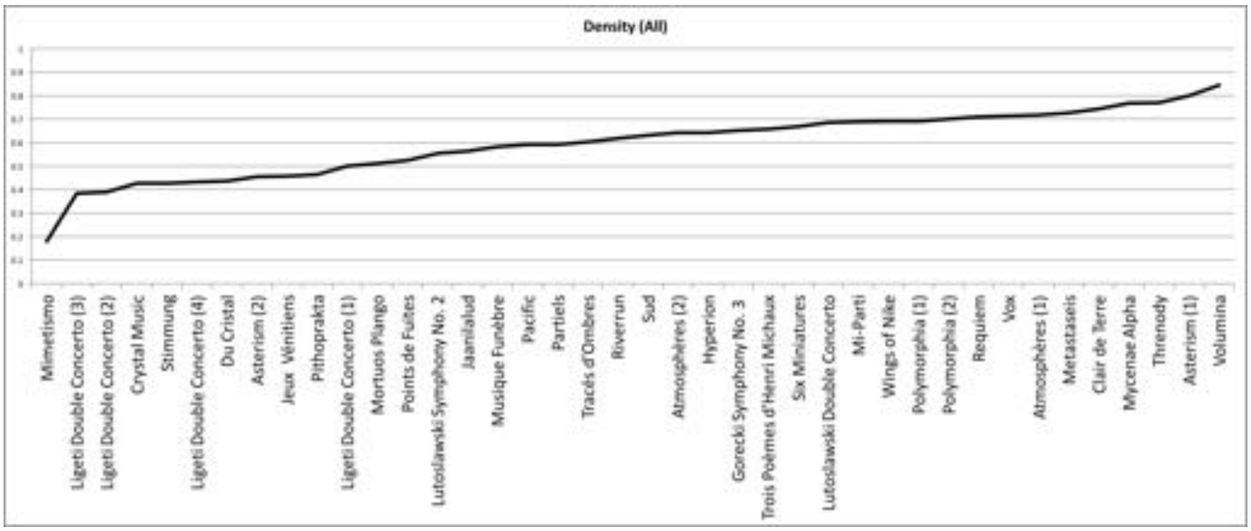
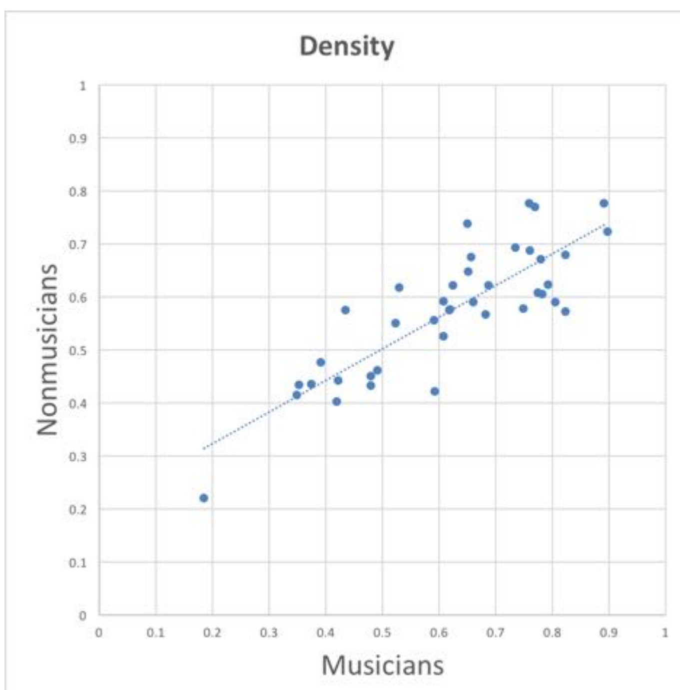




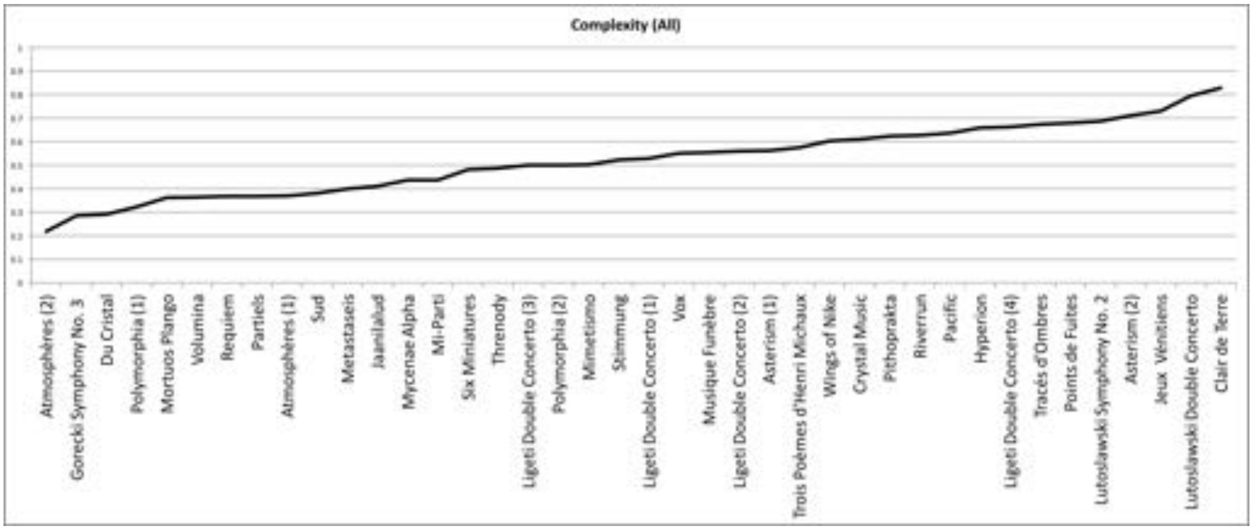
Appendix B: Experiment 4 Block 1 Ratings (Density, Complexity, Homogeneity)

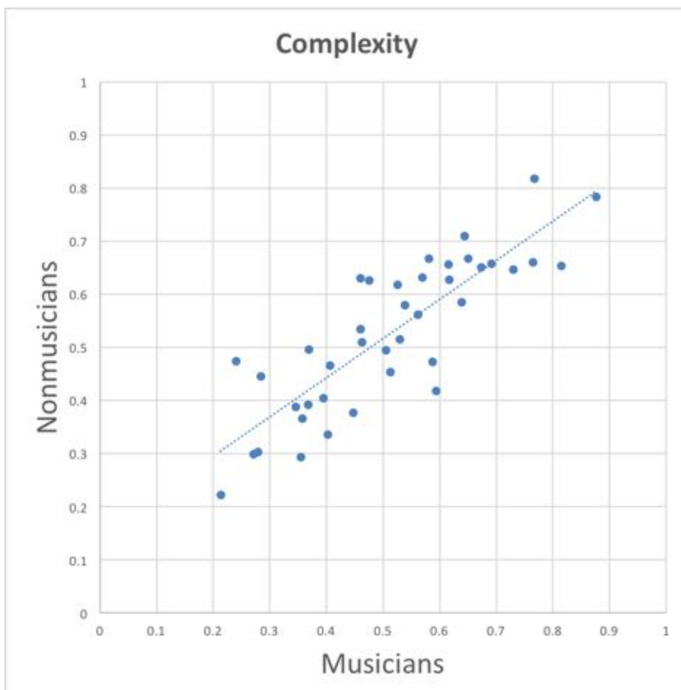
B.1 DENSITY



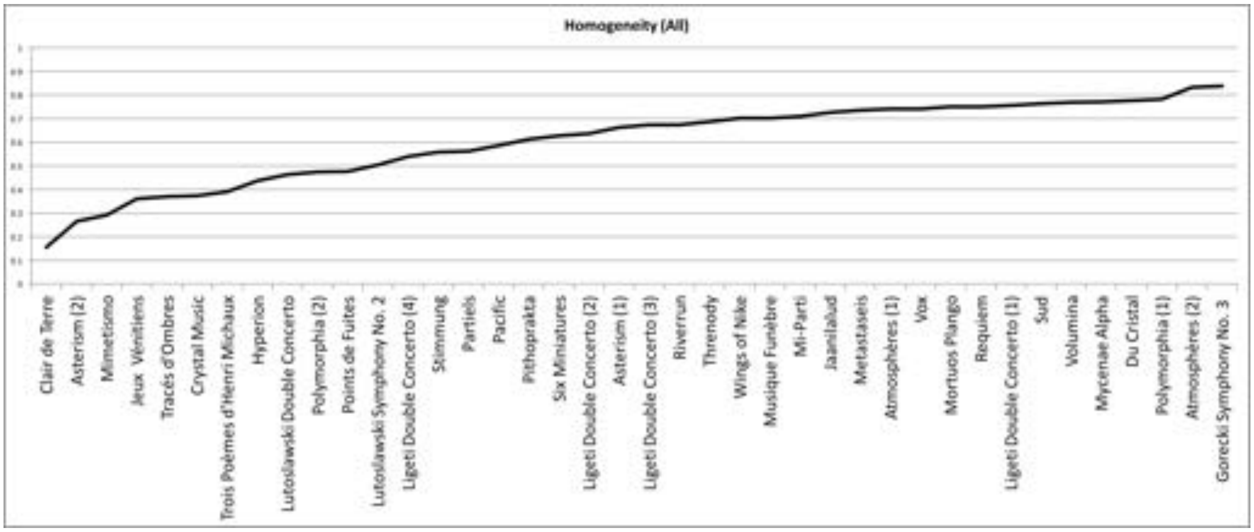


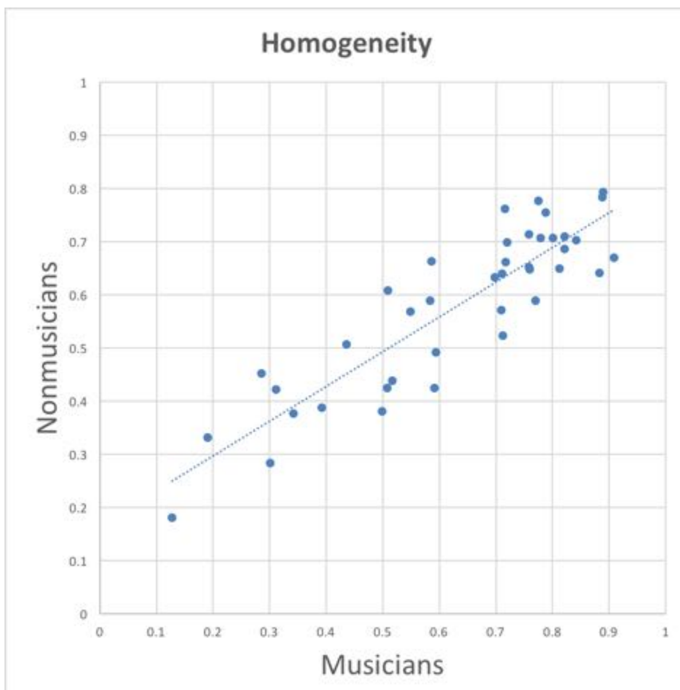
B.2 COMPLEXITY





B.3 HOMOGENEITY





Appendix C: Verbal Descriptions of Strategies for Rating Density, Complexity, and Homogeneity

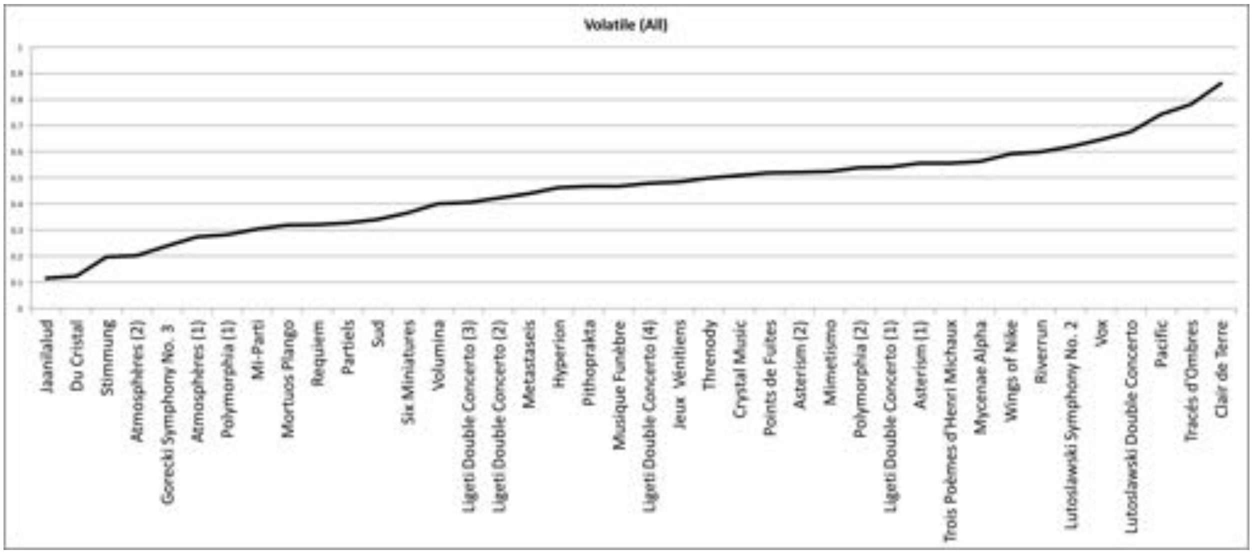
Subject	*Description of Strategies*
S1	Density--tried to listen for how many layers" were in an excerpt Complexity--tried to listen for things like recurring patterns or a sense that individual sound sources were interacting with one another as opposed to just being layered on top of each other Homogeneity--tried to compare sound sources--human-like voices instrument families timbres"
S2	unsure
S3	a) if I could identify somewhere say between 1-4 individual sounds, whether similar or different in timbre, I considered this low-moderately dense. If the sounds created a sense of a very large amount of performers, or many different electronic sounds, or many bees buzzing... it was higher in density b) long sustains and gestures that were less busy seem more simple" to me. Anything that was busy or had complex rhythms seemed more complex c) sounds with similar timbre (bees, crowds, string pizzicatos, organ chords) seem homogenous. Sometimes I could tell there was maybe brass and strings simultaneously, or a couple different sound sources, but they still seemed homogenous. If many different layers and timbres are instantly identifiable, then it was more hetergenous to me. "
S4	[Part 1] a) I listened for the degree of silence between sound events. b) I reflected on my ability to actively follow what was happening with the sound c) I listened to the degree of similarity between different sounds [Part 2] a) I tried to measure the amount of space around the sounds b) I responded to the amount of interaction I felt between individual sounds c) I responded to weather the timbre felt singular or contrasting
S5	For density, I rated sounds as more dense if they sounded more solid, like a wall of sound. For complexity, I rated sounds as more complex if they seemed to fit together in a complicated/intricate way. For homogeneity, I rated sounds are more homogeneous if each component of the sound seemed very similar to the others.
S6	a.) Density was seen how packed the clip that was being played, like how many same sounds came in at the same time , so if it was too dense it was rated to be as such and so on . b.) Complexity was based on how difficult it was to identify the individual sounds in the clips being played . c.) Homogeneity was on the basis of how similar the different sounds in the clip were , some of them were too similar that the sounds were in fact very much homogenous in other case I could hear the differnt sound without much effort so they were hetrogeneous in that sense.
S7	-
S8	a) to me dense meant that there was not time/space between sounds b)i rated something as complex if there was a lot" going on OR if multiple sounds created a melody c) i rated a piece as being high on homogeneity when the sounds used were similar to one another"
S10	A) density: how full the excertpt was. How heavy and deep it sounded. B) complexity: how intricate the componenets were. Could have been the number of voices or the speed at which they changed notes or rhythm C) Homogeneity: How similar the different sounds were
S12	a. whether the mood was calm (less dense) or heavy (more dense) b. the number of different voices/how different the colors were c. how different each individual voice sounded
S13	a) most were relatively dense but there were still subtle difference i could note between different sounds in most cases b) there wasnt really a correlation between complexity and density in most cases c) most were quite homogenous, again little link between homogeneity and density although the more heterogenous the easier it was to spot complexity and less dense
S14	a. If there are more rythmic attacks, it is more dense. Also stronger dynamics b. unsure c. Similar timbres
S15	[Part 1] a) Range of the different sounds b) How simple or complex the rhytmn and/or the the music is c)how similar the sounds are to each other [Part 2] a)how close the sounds are to each other (ex: range) b) How complicated musically the piece felt c) how similar the sounds were to each other in terms of timbre

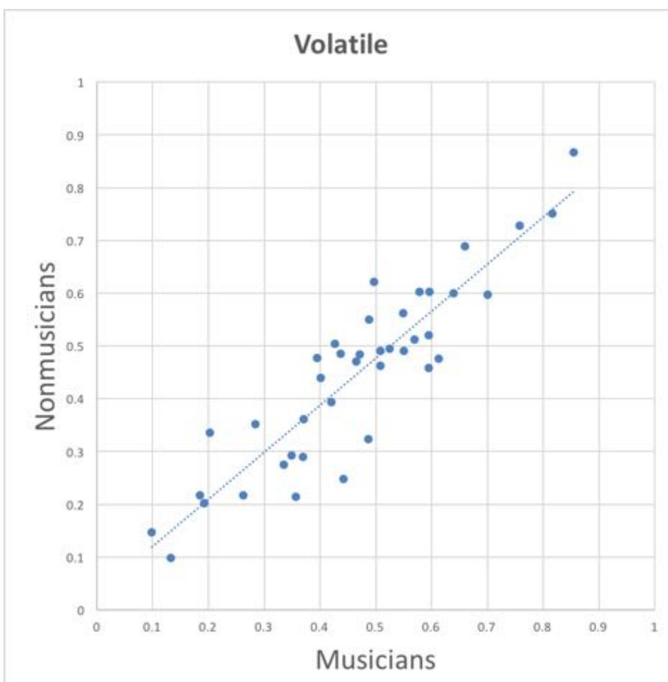
S17	a) I rated the sounds based off how loud they were, ie. how dense sounding they were b) I rated the complexity based off how many sounds I heard and how they were put together, ie. if the sounds were in all over the place or in melody c) I rated the homogenity based off how the sounds sounded, ie. if the sounds were similar to one another or not
S18	a) I listened for how many sounds there were and how compact they were when played together.I guess volume and opaqueness of overall sound were definitely factors here. b) I was looking for how well the sounds worked together as a single unit. c) I was listening for similarities based on timbre, rhythm, melody and patterns between the sound components.
S19	-
S20	a) the degree of compactness of sound components within the audio. How compact do they sound? b) the degree of how intricate the sounds are within the audio c) the degree of similarity of sound components. Are the sounds from the audio similar or do they vary a lot?
S22	(a) based on the volume, frequency, strong or weak (b) based on the extend of change of the sounds, whether it is static or volatile (c) based on the similarity of different components
S23	a) how heavy (dense)or light does the sound feel to me b) how detailed the sound is and how many parts there are to the sound make it complex c) if the sound is homogenous, it feels (or sounds) liquidy" or fluid"
S24	a) I listened for the amount of overlap between the sounds of each component. b) I listened to how busy the music sounded between different sound components c) I listened for distinguishable timbres in the music, the less distinguishable, the more homogenous
S25	a)density- how compact the sounds are when compared with others b)complexity- how difficult it to seperate the interconnected noise c)homogeneity- how similar the interconnected noises are.
S26	[Part 1] (a) by the volume the sound occupied (no. of layers in the musical piece). Higher the no. of layers, denser the sound. (b) by the structure the piece of sound followed. If simple to follow (expected), less complex. If difficult to follow (unexpected sudden changes), it's complex. (c) by the way the sound mass sounds, ie. how many instruments are played together or individually. It's done on the basis of (a) and (b) combined. Homogeneous songs have similar instruments and beats throughout. [Part 2] (a) was based on the 'volume' of music occupied in the earphones. If I felt there could be another instrument added, it was less dense, and if I felt that there was no room for any other instrument, it was highly dense. (b) was based on the structure of the sound piece. If the pattern was followable, it was not complex but if the pattern was weird and not-followable, it had high complexity. (c) was based on the variety of instruments used. If that's high, the piece is heterogeneous, else homogeneous.
S27	-
S28	a) if it was loud & overbearing, a lot was going on. b) If it seemed intricate and well created, rather than just noise. c) If all the sounds were the same or similar, no different noises over each other.
S29	(a)how much it seemed like other sounds could break through, how opaque it sounded (b)harmonic complexity, rhythmic complexity, how deliberately the instrument seemed to be composed in relation to one another (c)how much instrumentation, timbre, and pitch matched
S30	a) When the sound is played slowly, it is less dense. b) When the range of the tone is larger, it is more complex. c) When the sound does not change a lot, it is more similar.
S31	a) density: how close the sounds were together and how little space there was between them b) complexity: how difficult it was to produce the sounds, how elaborate they were c) homogeneity: whether all the sounds produced were similar to each other or not
S32	a) j ai pris en compte les nuances, s il y avait des silences ou non b) la difference de timbres, registres c) la ressemblance entre les son, l unisson
S33	[Part 1] A. how filling the noise was, how much sound b. how many different sounds c. how simple they are [Part 2] a. thick sounds, so lots of noise b. how many sounds, are being played together c. how similar all the sounds sounded
S34	a) weight, impact, confusion of the music or sound b)presence of complex patterns, does interplay fuse together or is the sound monotonous or simple tones c) are the sound elements similiar or varied

S36	a) I rated sounds for density based on how compact the noises were. The more they were fused together the more dense they were. b) I rated sounds for complexity based on how well they connected. I tried to piece the different sounds in my head and listen to the sound as a whole to see how they connected with each other. c) I rated sounds for homogeneity based on how similar the sounds were to each other. Again, I tried to separate the different sounds in my head. If I could hear a big difference in pitch or in the form, I rated them towards the heterogenous side.
S37	a. I listened to how busy or chaotic the music was, I also looked for an overwhelming feeling, usually meaning it was dense b. I listened to see if the sounds were following a similar pattern or it their melody was completely unrelated to the rest of the audio c. For homogeneity, I judged the similarity of the instruments (ie, if the track used multiple string instruments I said it was high in homeogeneity) vs a collection of random sounds, it was low in homogeneity.
S38	A) Lightness of sound and whether there were spaces between sounds B) Business of different sounds C) Smoothness of sound and whether the sounds connected easily together
S39	a- Dancing b- How the sound made c- How the sound is similar
S40	a) the airiness between sound components, and weight of the sounds. b) the number of layers and predictability of relation between them c) the uniformity of sounds,timbres and sound textures
S41	a) How close together sounds were in intervals & beats b) How many different sounds there were c) How similar the sounds were to one another in pitch and rhythm
S42	[Part 1] Density was based on the level of homogeneity. Homogeneity was based on the complexity or differences between sounds. Complexity was based on how or if different sounds blended together [Part 2] a. density: density was based on how thick" the sound sounded. If I felt like I could cut the sound with a knife, it was high density. b. complexity: this was based on how "busy" the sound sounded and how often the sound changed. If it sounded like there were a lot of different noises, or a lot of textures that were constantly changing it was complex c. homogeneity: this was based on the number of different sounds within the song. "
S43	a) how quickly the sounds changed in a segment b) how many different sounds there were c) how similar the sounds were

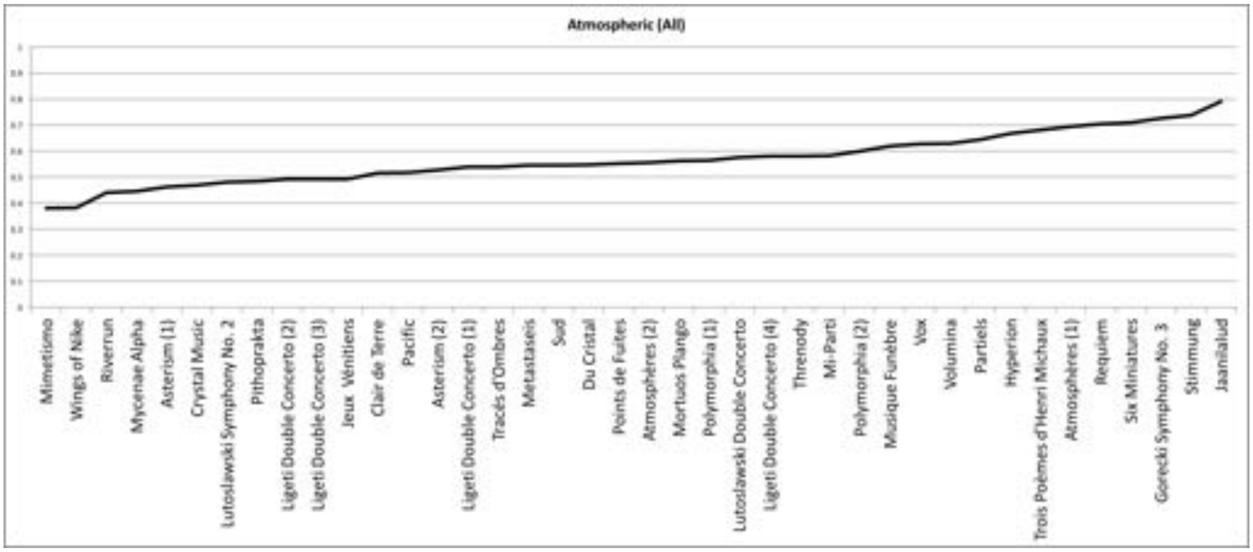
Appendix D: Experiment 4, Block 2 Ratings (Adjectival Categories)

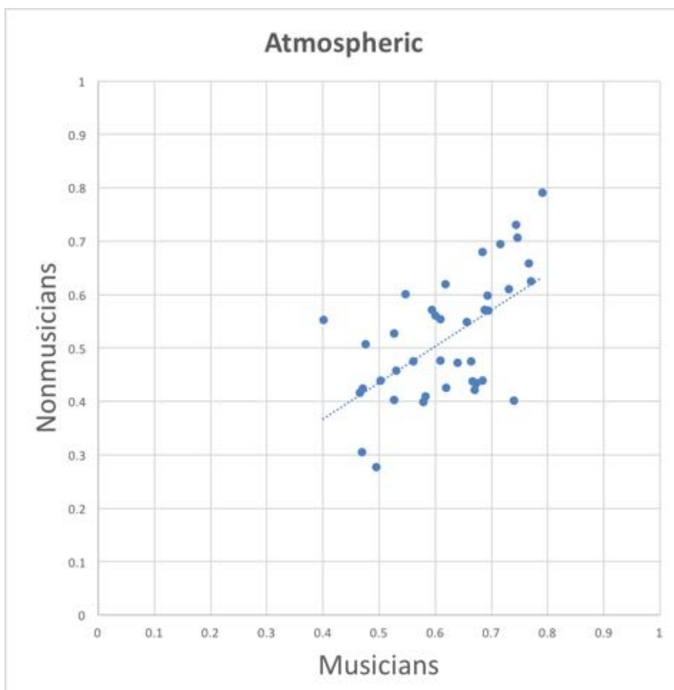
D.1 VOLATILE

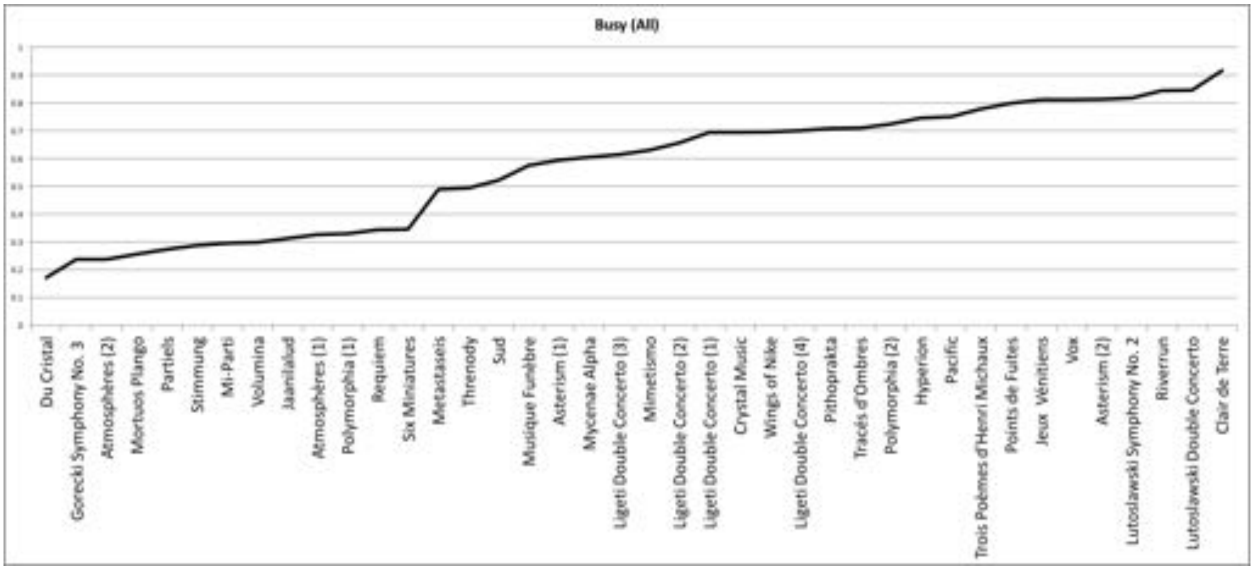


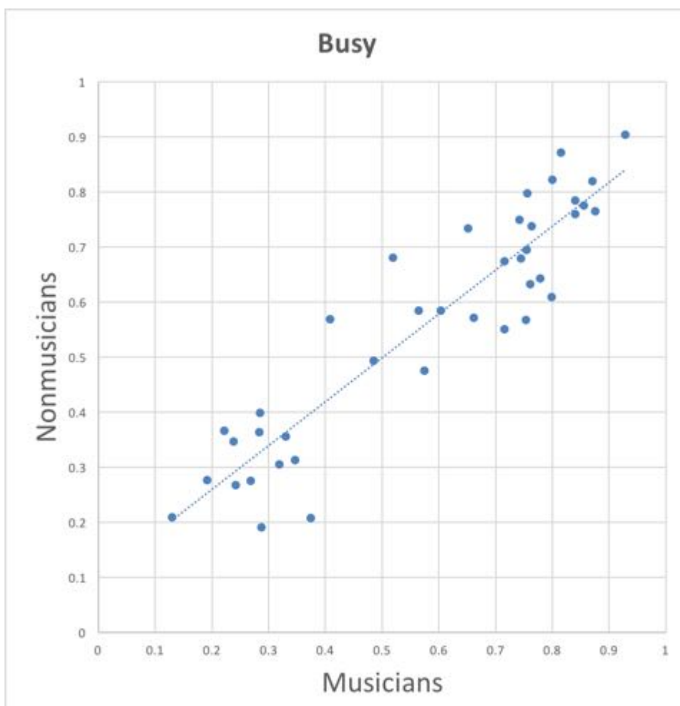


D.2 ATMOSPHERIC

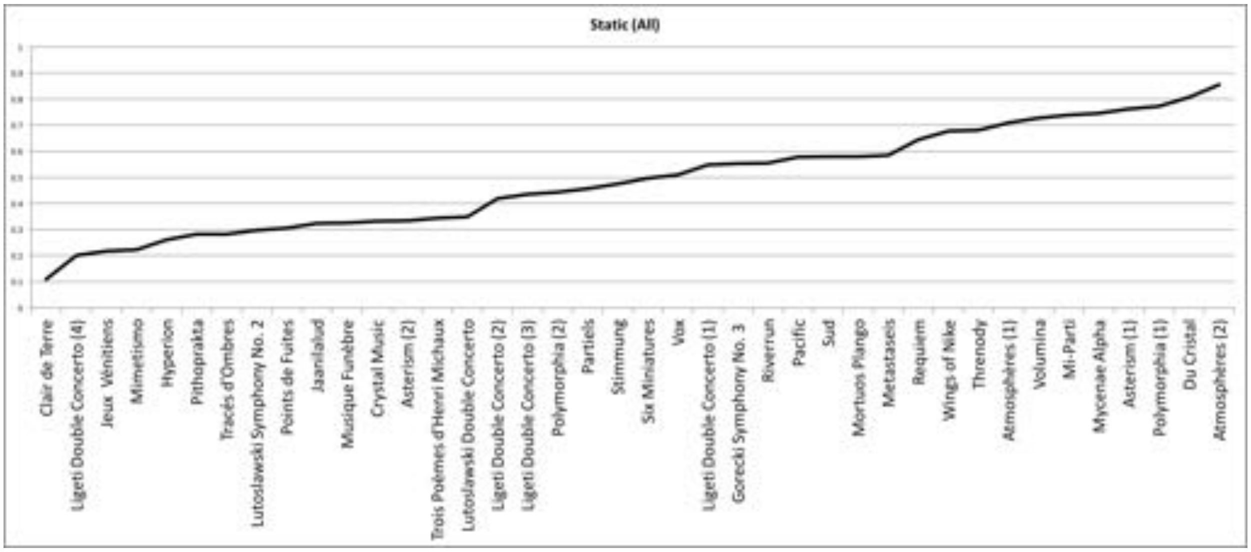




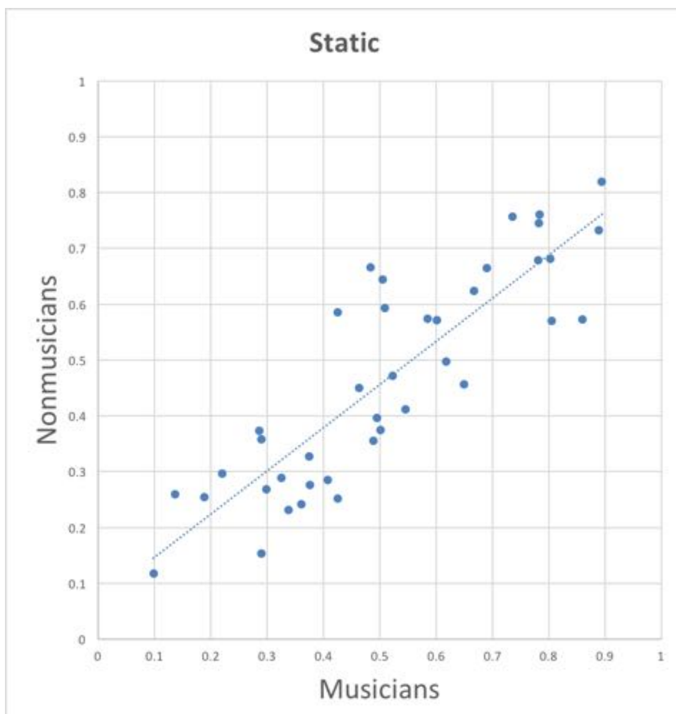

Busy (All)
Du Cristal
Gorecki Symphony No. 3
Atmosphères (2)
Mortuos Plango
Partiels
Stimmung
Mi-Parti
Volumina
Jaanilalud
Atmosphères (1)
Polymorphia (1)
Requiem
Six Miniatures
Metastaseis
Threnody
Sud
Musique Funèbre
Asterism (1)
Mycenae Alpha
Ligeti Double Concerto (3)
Mimetismo
Ligeti Double Concerto (2)
Ligeti Double Concerto (1)
Crystal Music
Wings of Nike
Ligeti Double Concerto (4)
Pithoprakta
Tracés d'Ombres
Polymorphia (2)
Hyperion
Pacific
Trois Poèmes d'Henri Michaux
Points de Fuites
Jeux Vénitiens
Vox
Asterism (2)
Lutoslawski Symphony No. 2
Riverrun
Lutoslawski Double Concerto
Clair de Terre


Busy
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Nonmusicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Musicians

D.4 **STATIC**

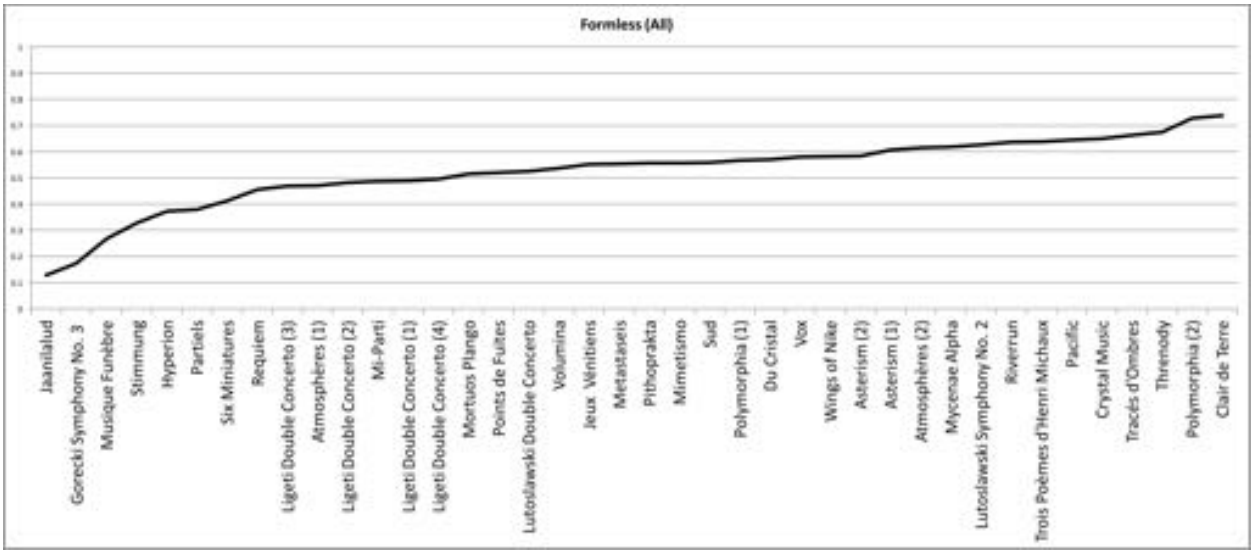


Static (All)
Clair de Terre
Ligeti Double Concerto (4)
Jeux Vénitiens
Mimetismo
Hyperion
Pithoprakta
Tracés d'Ombres
Lutoslawski Symphony No. 2
Points de Fuites
Jaanilalud
Musique Funèbre
Crystal Music
Asterism (2)
Trois Poèmes d'Henri Michaux
Lutoslawski Double Concerto
Ligeti Double Concerto (2)
Ligeti Double Concerto (3)
Polymorphia (2)
Partiels
Stimmung
Six Miniatures
Vox
Ligeti Double Concerto (1)
Gorecki Symphony No. 3
Riverrun
Pacific
Sud
Mortuos Plango
Metastaseis
Requiem
Wings of Nike
Threnody
Atmosphères (1)
Volumina
Mi-Parti
Mycenae Alpha
Asterism (1)
Polymorphia (1)
Du Cristal
Atmosphères (2)

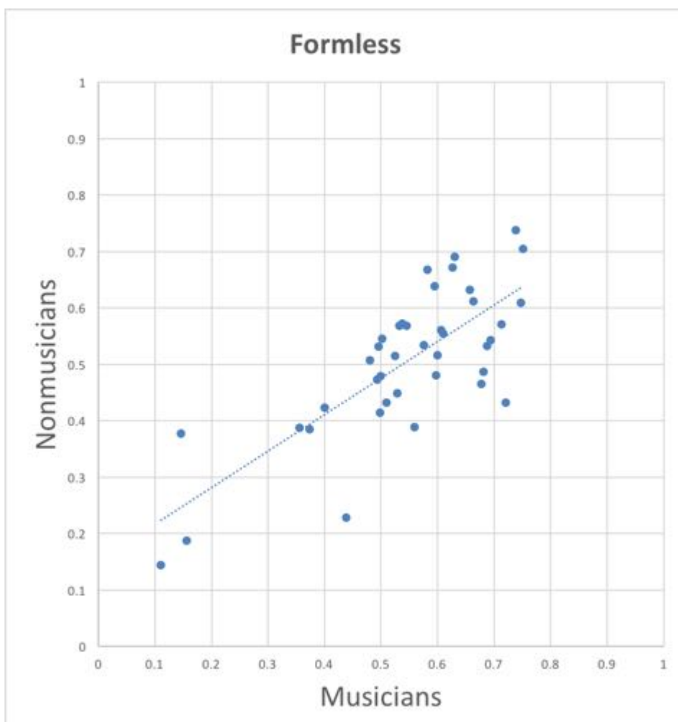


Static
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

D.5 **FORMLESS**

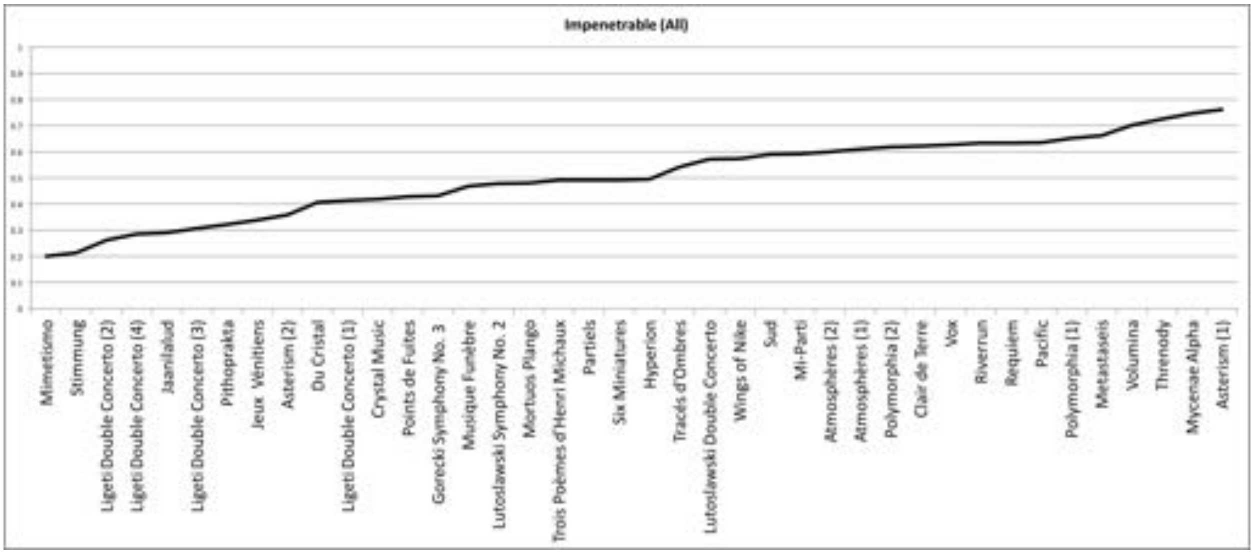


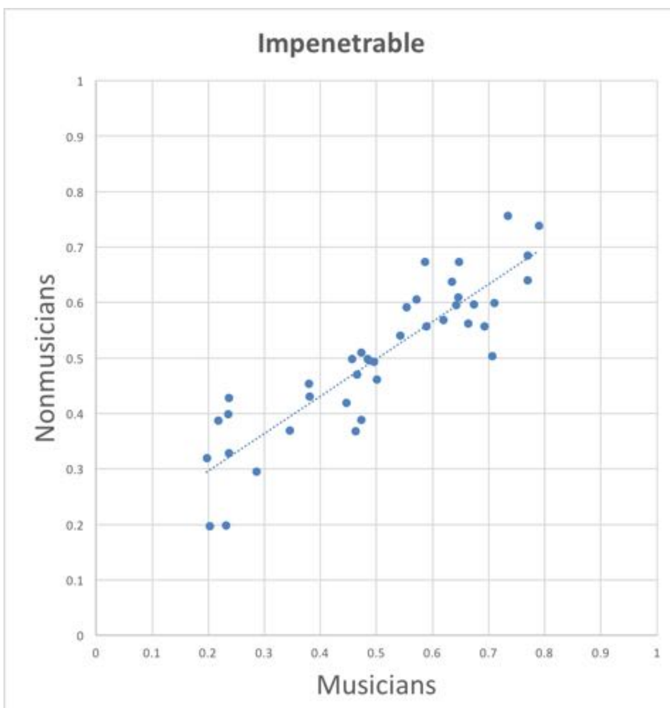
Formless (All)
Jaanilalud
Gorecki Symphony No. 3
Musique Funèbre
Stimmung
Hyperion
Partiels
Six Miniatures
Requiem
Ligeti Double Concerto (3)
Atmosphères (1)
Ligeti Double Concerto (2)
Mi-Parti
Ligeti Double Concerto (1)
Ligeti Double Concerto (4)
Mortuos Plango
Points de Fuites
Lutoslawski Double Concerto
Volumina
Jeux Vénitiens
Metastaseis
Pithoprakta
Mimetismo
Sud
Polymorphia (1)
Du Cristal
Vox
Wings of Nike
Asterism (2)
Asterism (1)
Atmosphères (2)
Mycenae Alpha
Lutoslawski Symphony No. 2
Riverrun
Trois Poèmes d'Henri Michaux
Pacific
Crystal Music
Tracés d'Ombres
Threnody
Polymorphia (2)
Clair de Terre



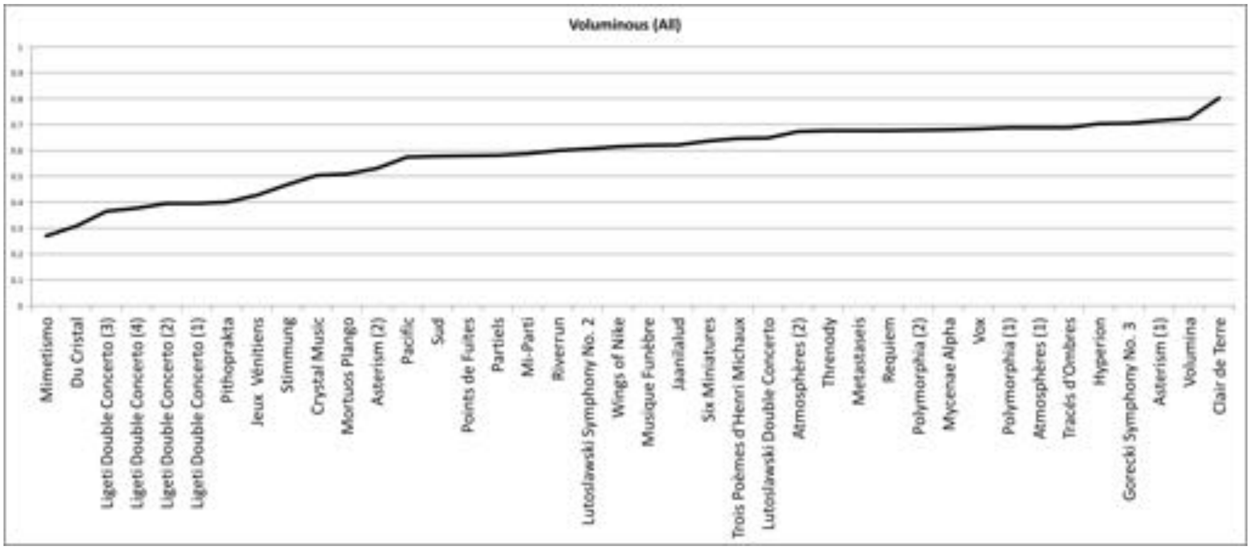
Formless
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

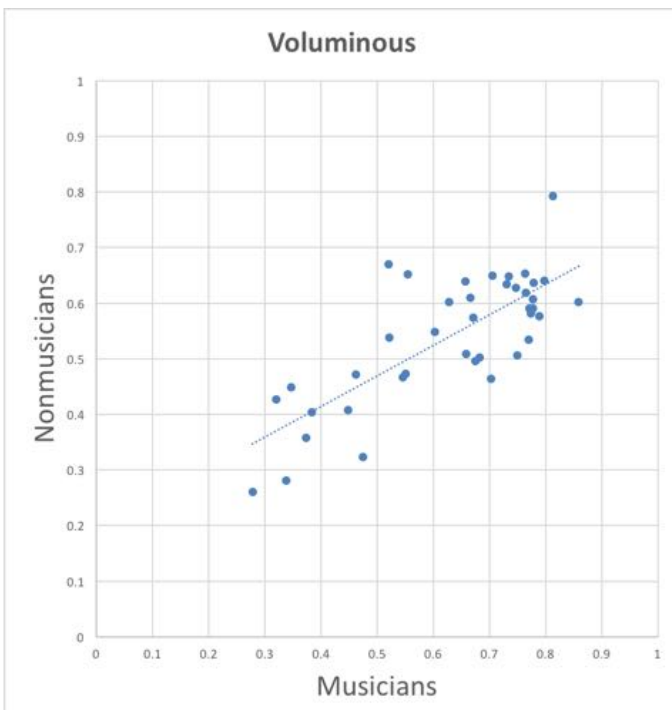
D.6 **IMPENETRABLE**



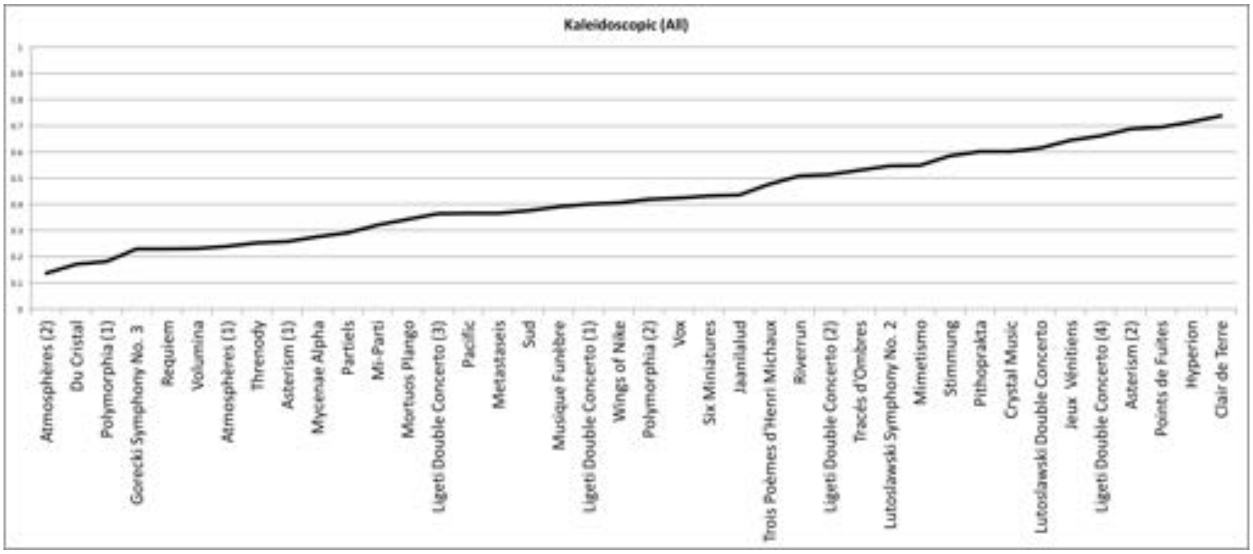


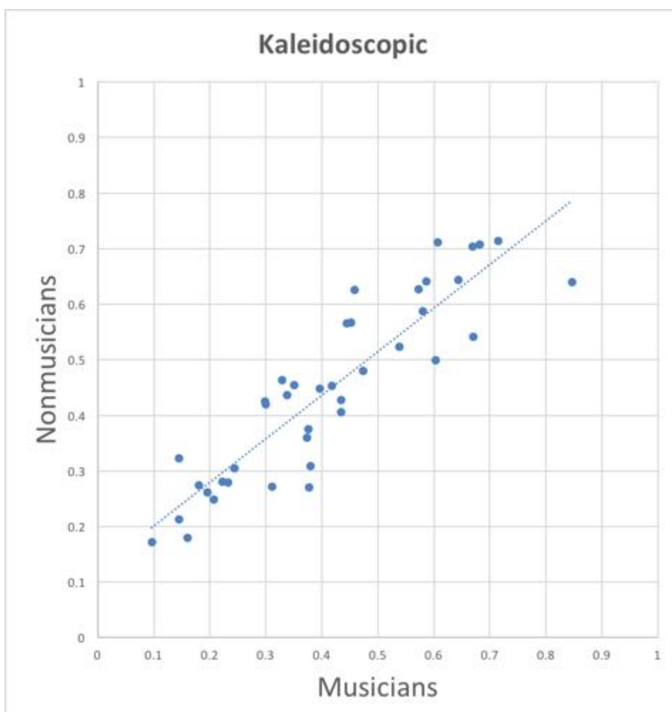
D.7 VOLUMINOUS





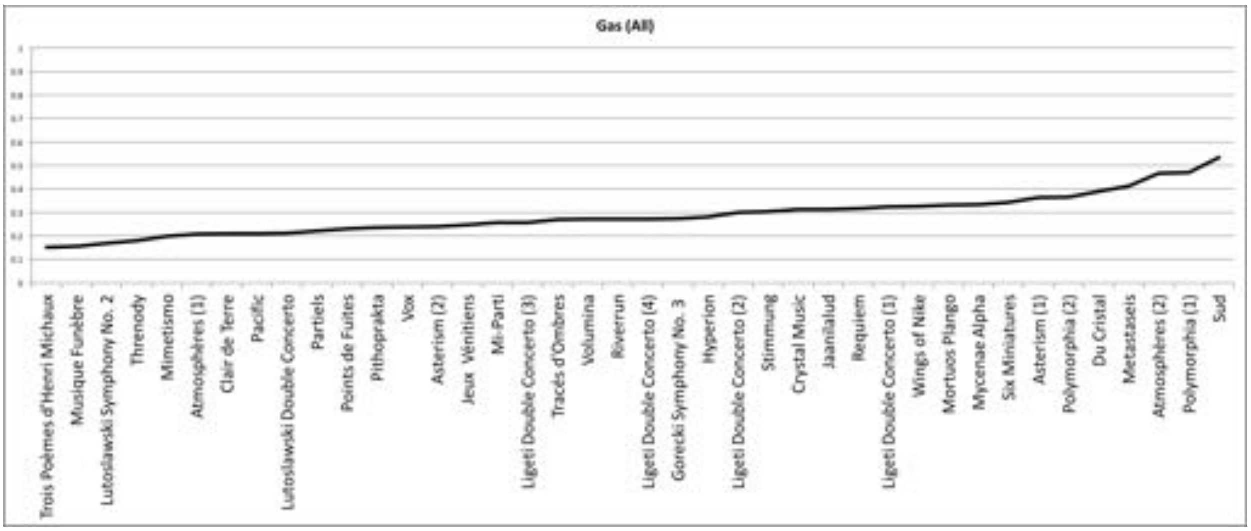
D.8 KALEIDOSCOPIC

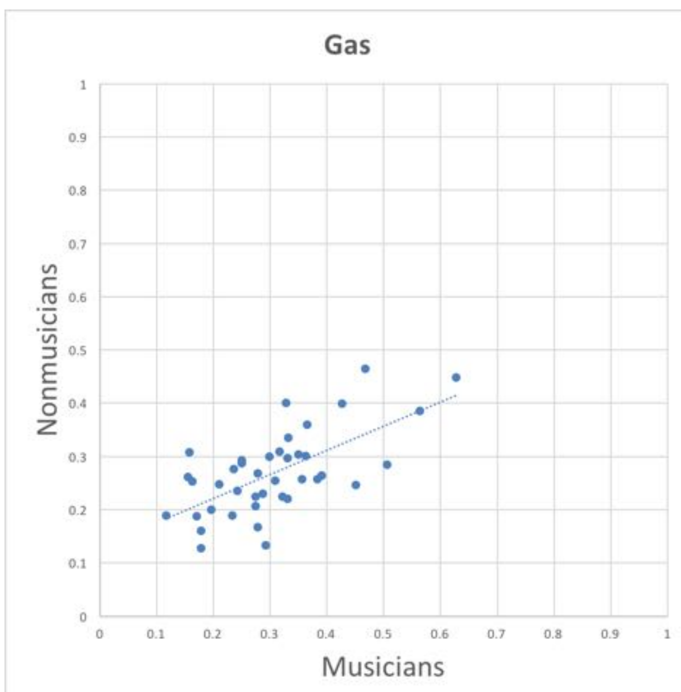




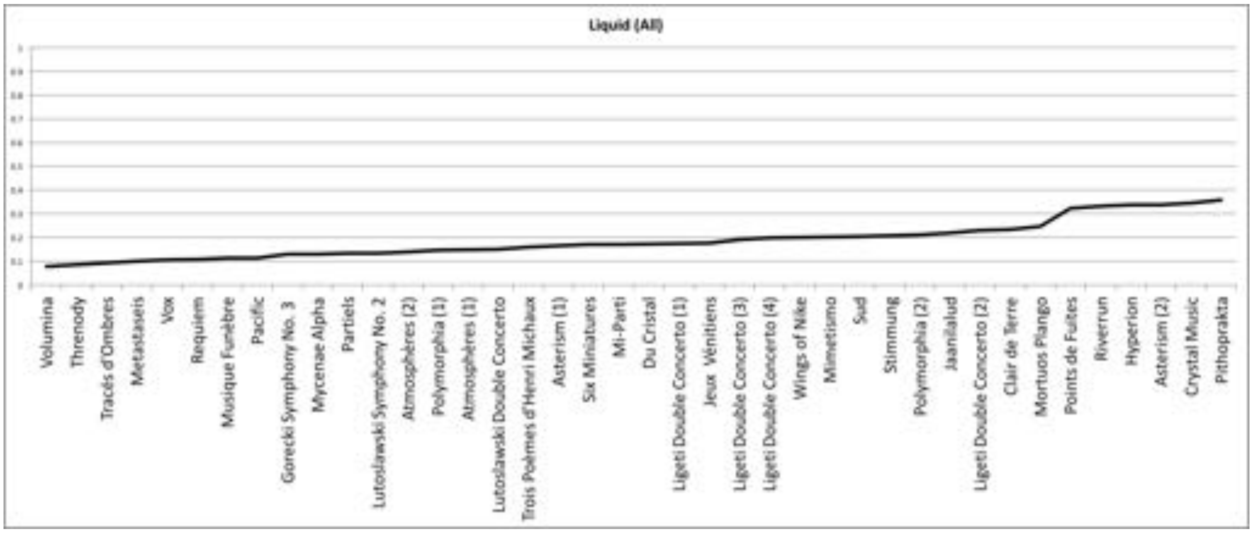
Appendix E: Experiment 4, Block 3 Ratings (Nominal Categories)

E.1 GAS

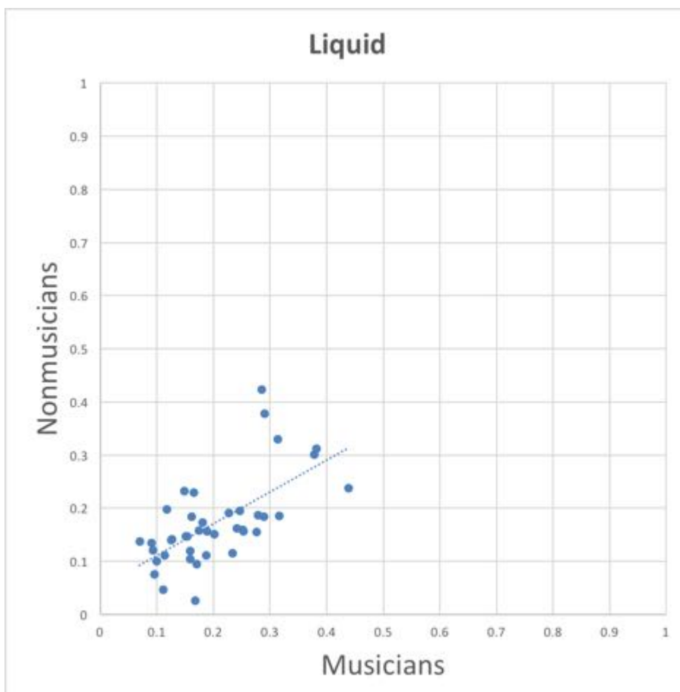




E.2 LIQUID

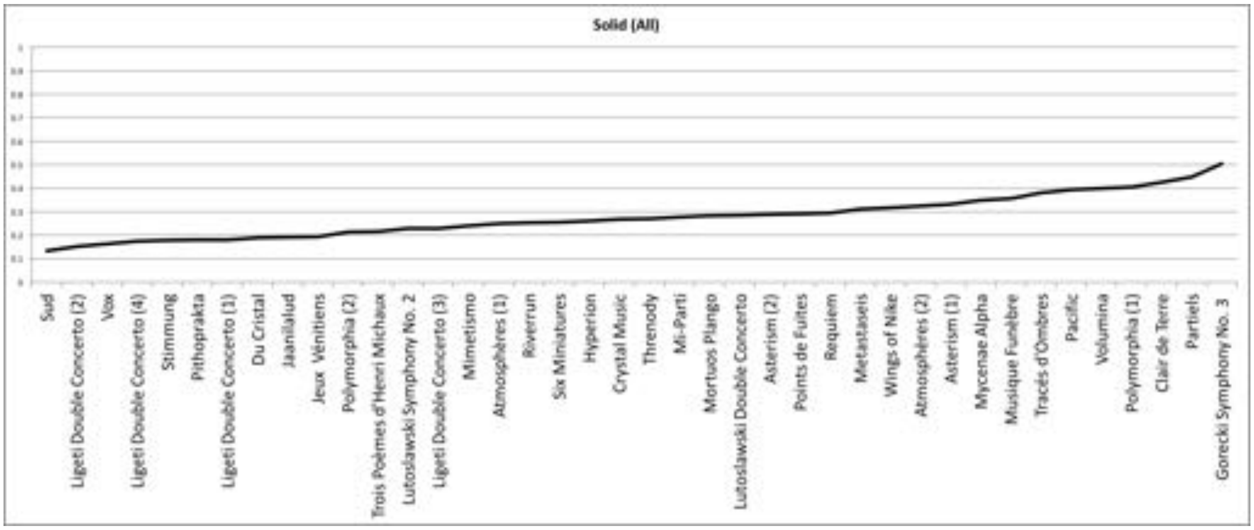


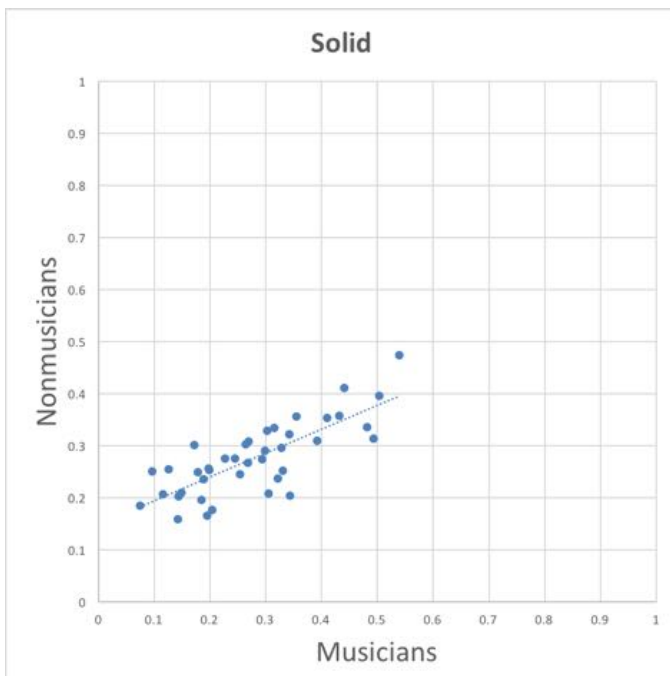
Liquid (All)
Volumina
Threnody
Tracés d'Ombres
Metastaseis
Vox
Requiem
Musique Funèbre
Pacific
Gorecki Symphony No. 3
Mycenae Alpha
Partiels
Lutoslawski Symphony No. 2
Atmosphères (2)
Polymorphia (1)
Atmosphères (1)
Lutoslawski Double Concerto
Trois Poèmes d'Henri Michaux
Asterism (1)
Six Miniatures
Mi-Parti
Du Cristal
Ligeti Double Concerto (1)
Jeux Vénitiens
Ligeti Double Concerto (3)
Ligeti Double Concerto (4)
Wings of Nike
Mimetismo
Sud
Stimmung
Polymorphia (2)
Jaanilalud
Ligeti Double Concerto (2)
Clair de Terre
Mortuos Plango
Points de Fuites
Riverrun
Hyperion
Asterism (2)
Crystal Music
Pithoprakta



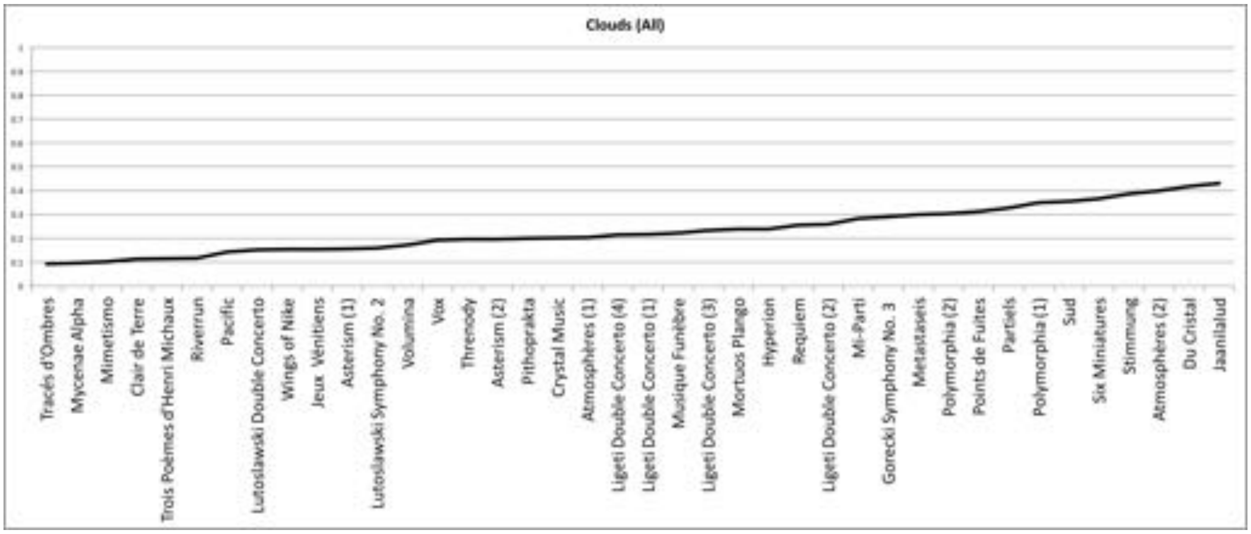
Liquid
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

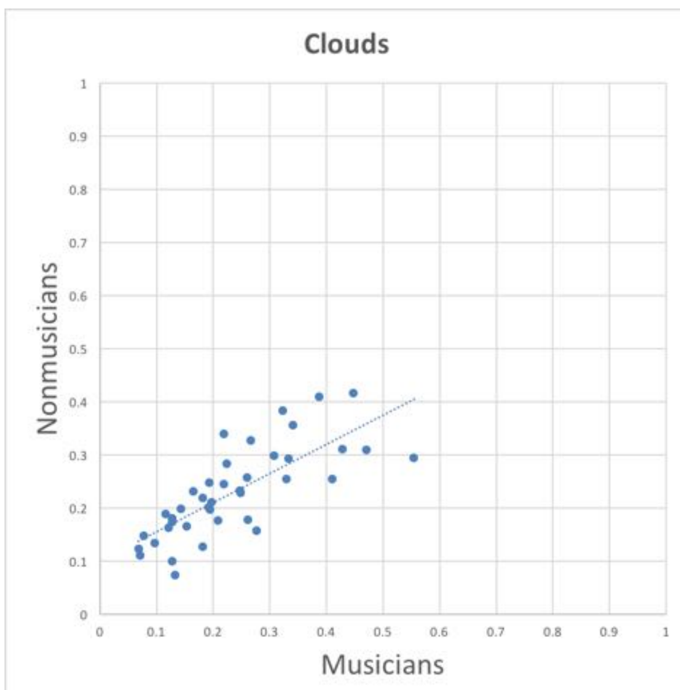
E.3 SOLID


Solid (All)
Sud
Ligeti Double Concerto (2)
Vox
Ligeti Double Concerto (4)
Stimmung
Pithoprakta
Ligeti Double Concerto (1)
Du Cristal
Jaanilalud
Jeux Vénitiens
Polymorphia (2)
Trois Poèmes d'Henri Michaux
Lutoslawski Symphony No. 2
Ligeti Double Concerto (3)
Mimetismo
Atmosphères (1)
Riverrun
Six Miniatures
Hyperion
Crystal Music
Threnody
Mi-Parti
Mortuos Plango
Lutoslawski Double Concerto
Asterism (2)
Points de Fuites
Requiem
Metastaseis
Wings of Nike
Atmosphères (2)
Asterism (1)
Mycenae Alpha
Musique Funèbre
Tracés d'Ombres
Pacific
Volumina
Polymorphia (1)
Clair de Terre
Partiels
Gorecki Symphony No. 3

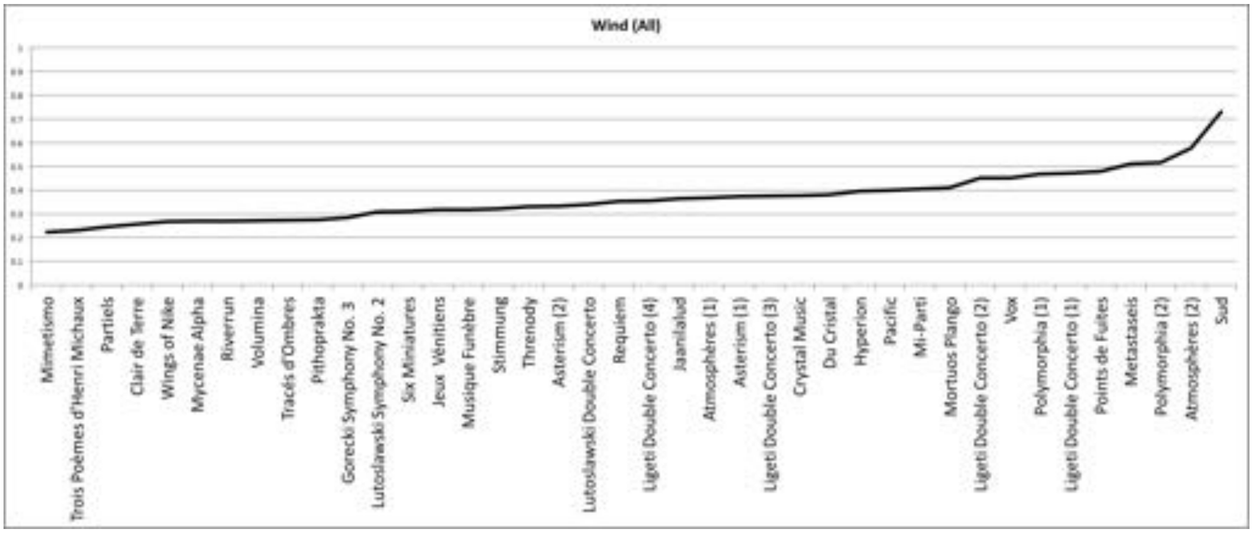

Solid
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

E.4 CLOUDS

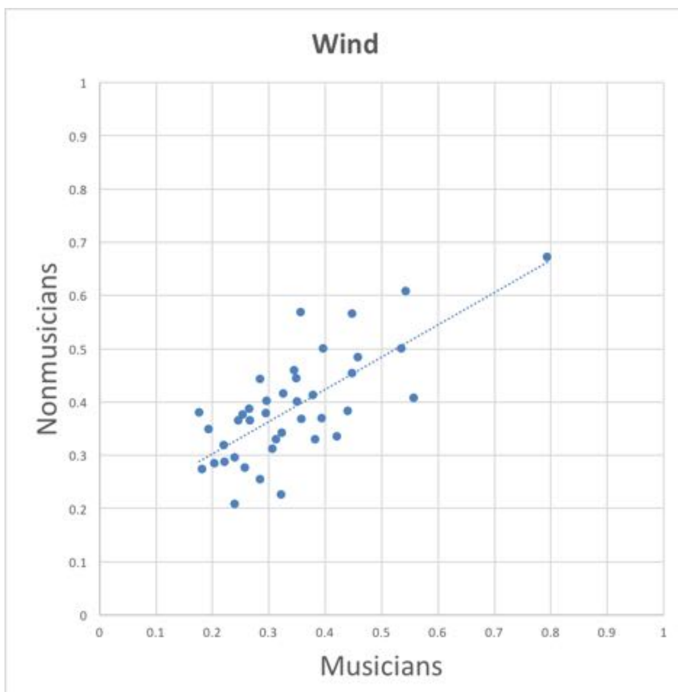

Clouds (All)
Tracés d'Ombres
Mycenae Alpha
Mimetismo
Clair de Terre
Trois Poèmes d'Henri Michaux
Riverrun
Pacific
Lutoslawski Double Concerto
Wings of Nike
Jeux Vénitiens
Asterism (1)
Lutoslawski Symphony No. 2
Volumina
Vox
Threnody
Asterism (2)
Pithoprakta
Crystal Music
Atmosphères (1)
Ligeti Double Concerto (4)
Ligeti Double Concerto (1)
Musique Funèbre
Ligeti Double Concerto (3)
Mortuos Plango
Hyperion
Requiem
Ligeti Double Concerto (2)
Mi-Parti
Gorecki Symphony No. 3
Metastaseis
Polymorphia (2)
Points de Fuites
Partiels
Polymorphia (1)
Sud
Six Miniatures
Stimmung
Atmosphères (2)
Du Cristal
Jaanilalud


Clouds
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

E.5 **WIND**

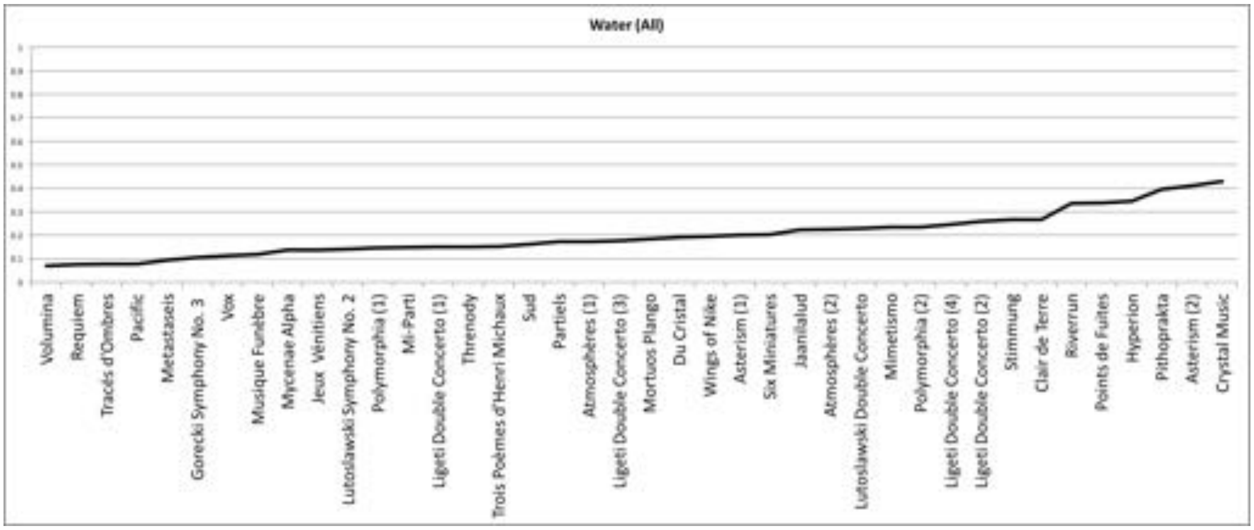


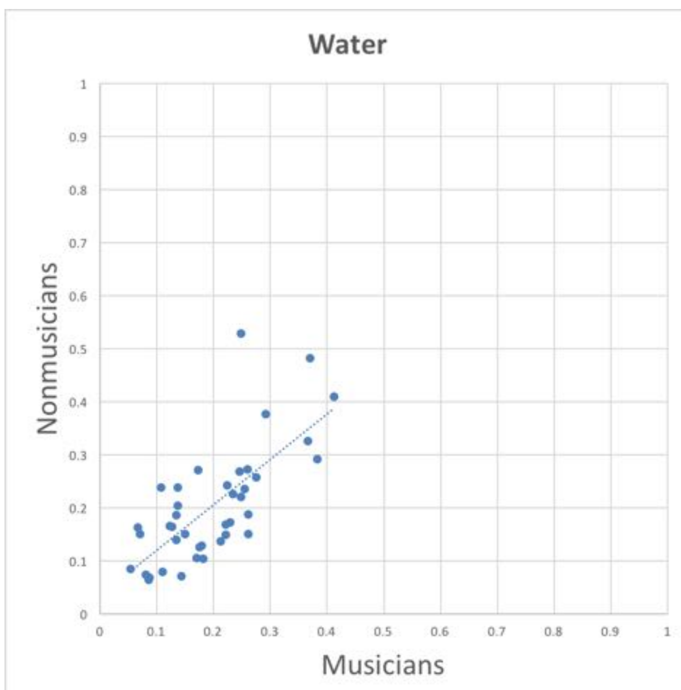
Wind (All)
Mimetismo
Trois Poèmes d'Henri Michaux
Partiels
Clair de Terre
Wings of Nike
Mycenae Alpha
Riverrun
Volumina
Tracés d'Ombres
Pithoprakta
Gorecki Symphony No. 3
Lutoslawski Symphony No. 2
Six Miniatures
Jeux Vénitiens
Musique Funèbre
Stimmung
Threnody
Asterism (2)
Lutoslawski Double Concerto
Requiem
Ligeti Double Concerto (4)
Jaanilalud
Atmosphères (1)
Asterism (1)
Ligeti Double Concerto (3)
Crystal Music
Du Cristal
Hyperion
Pacific
Mi-Parti
Mortuos Plango
Ligeti Double Concerto (2)
Vox
Polymorphia (1)
Ligeti Double Concerto (1)
Points de Fuites
Metastaseis
Polymorphia (2)
Atmosphères (2)
Sud



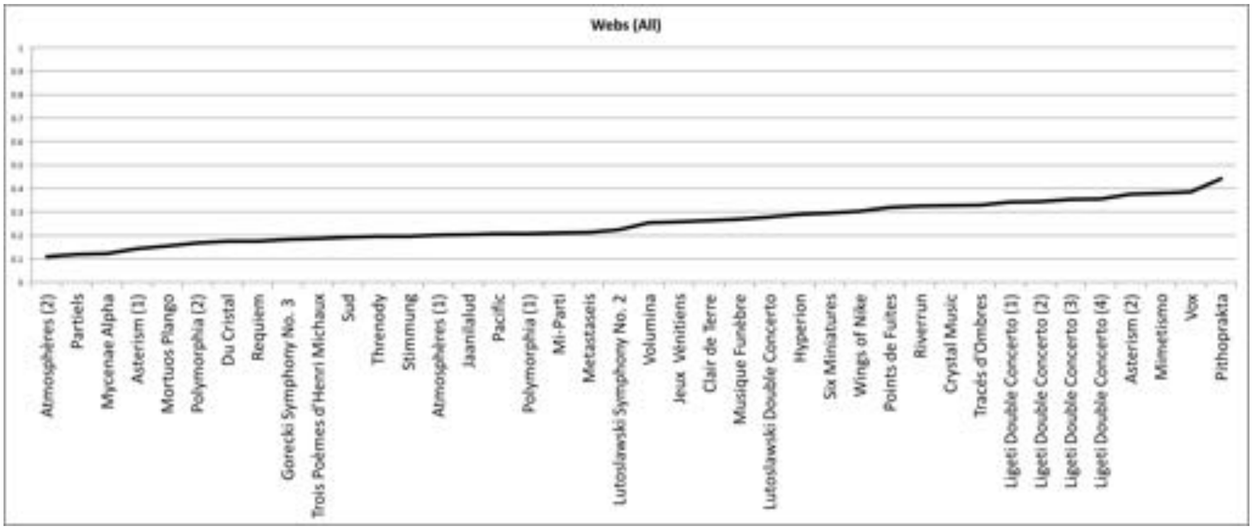
Wind
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

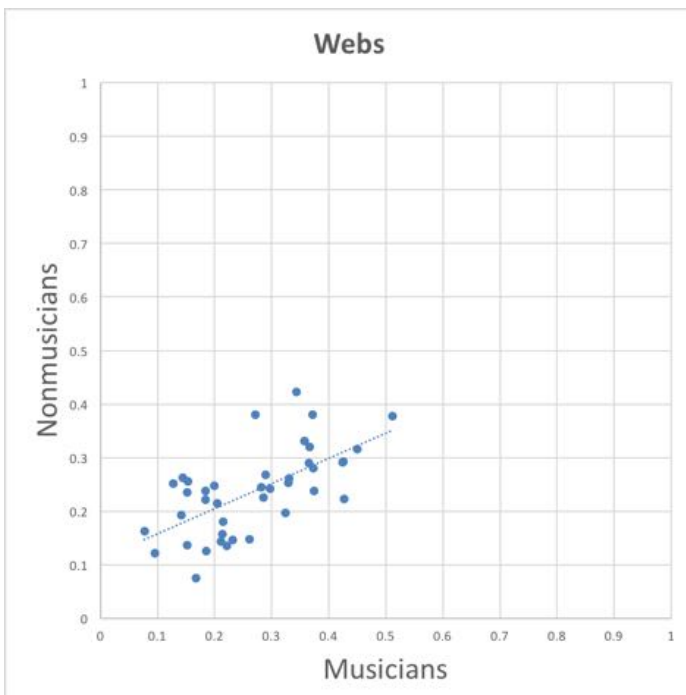
E.6 **WATER**


Water (All)
Volumina
Requiem
Tracés d'Ombres
Pacific
Metastaseis
Gorecki Symphony No. 3
Vox
Musique Funèbre
Mycenae Alpha
Jeux Vénitiens
Lutoslawski Symphony No. 2
Polymorphia (1)
Mi-Parti
Ligeti Double Concerto (1)
Threnody
Trois Poèmes d'Henri Michaux
Sud
Partiels
Atmosphères (1)
Ligeti Double Concerto (3)
Mortuos Plango
Du Cristal
Wings of Nike
Asterism (1)
Six Miniatures
Jaanilalud
Atmosphères (2)
Lutoslawski Double Concerto
Mimetismo
Polymorphia (2)
Ligeti Double Concerto (4)
Ligeti Double Concerto (2)
Stimmung
Clair de Terre
Riverrun
Points de Fuites
Hyperion
Pithoprakta
Asterism (2)
Crystal Music

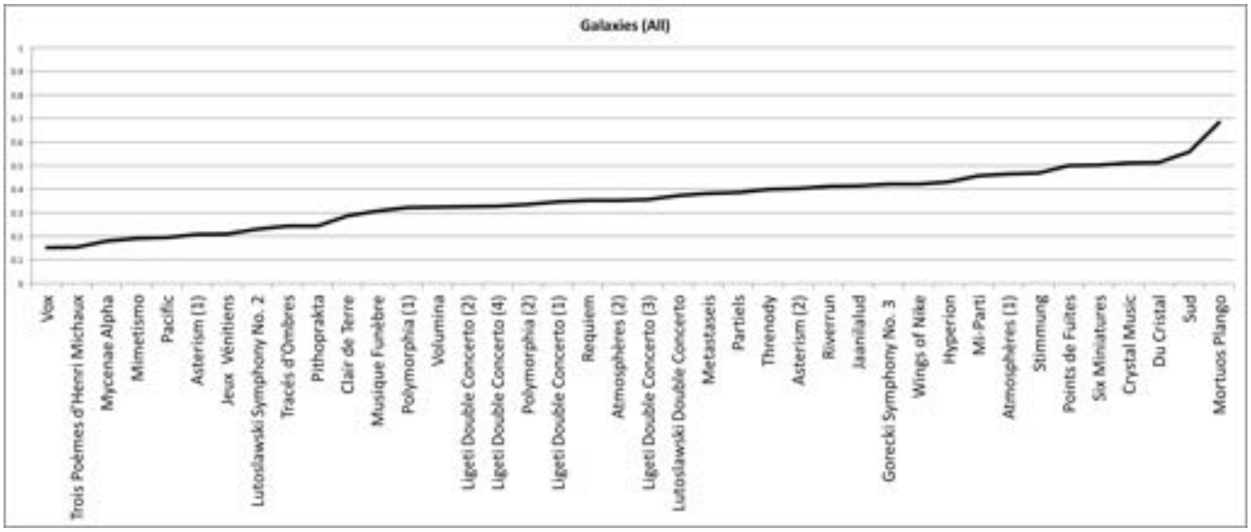

Water
Nonmusicians
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Musicians

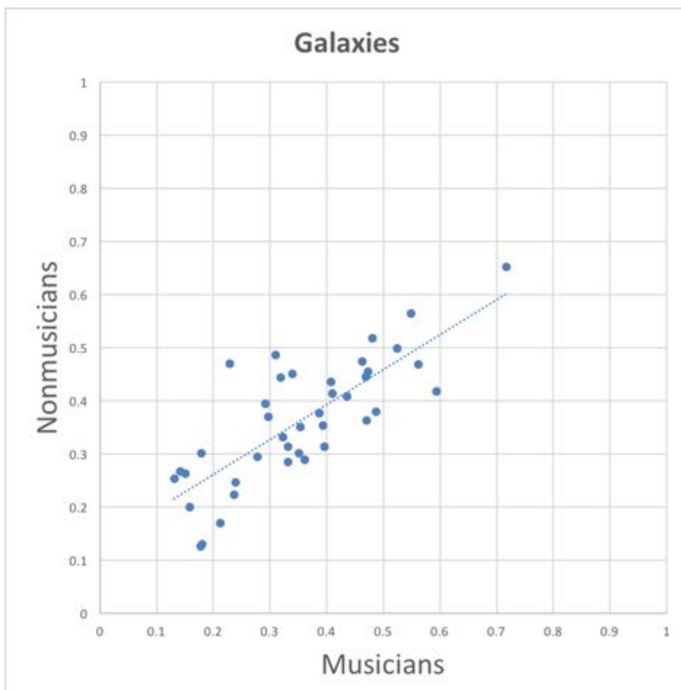
E.7 WEBS


Webs (All)
Atmosphères (2)
Partiels
Mycenae Alpha
Asterism (1)
Mortuos Plango
Polymorphia (2)
Du Cristal
Requiem
Gorecki Symphony No. 3
Trois Poèmes d'Henri Michaux
Sud
Threnody
Stimmung
Atmosphères (1)
Jaanilalud
Pacific
Polymorphia (1)
Mi-Parti
Metastaseis
Lutoslawski Symphony No. 2
Volumina
Jeux Vénitiens
Clair de Terre
Musique Funèbre
Lutoslawski Double Concerto
Hyperion
Six Miniatures
Wings of Nike
Points de Fuites
Riverrun
Crystal Music
Tracés d'Ombres
Ligeti Double Concerto (1)
Ligeti Double Concerto (2)
Ligeti Double Concerto (3)
Ligeti Double Concerto (4)
Asterism (2)
Mimetismo
Vox
Pithoprakta

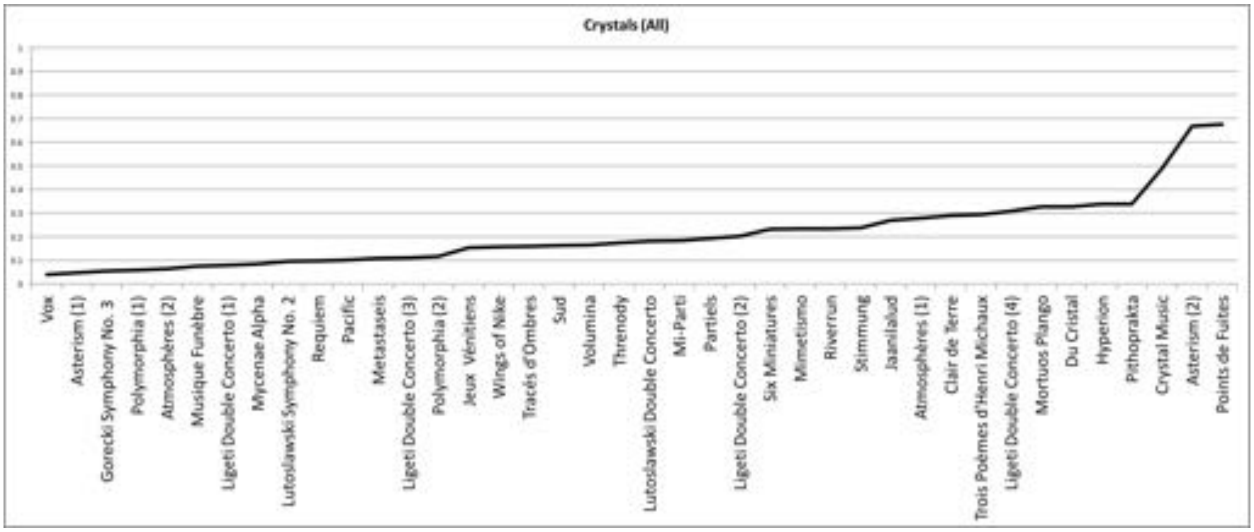

Webs
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

E.8 GALAXIES

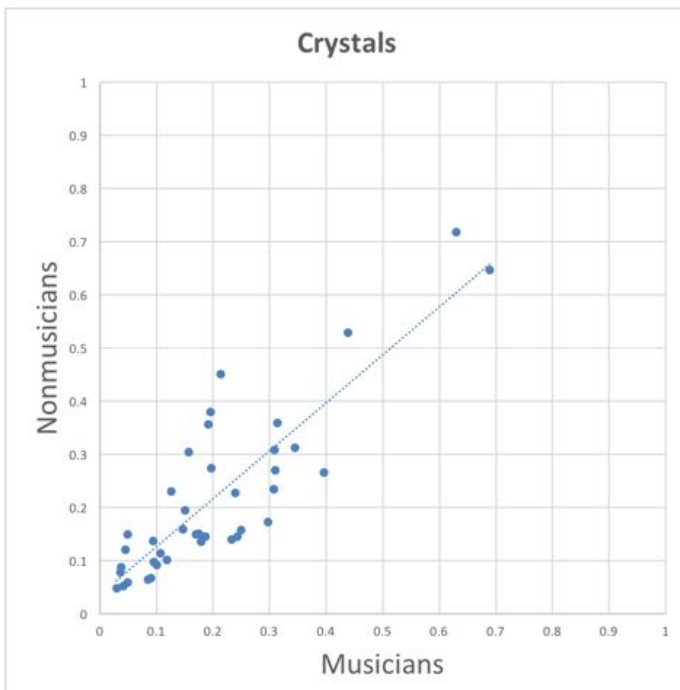

Galaxies (All)
Vox
Trois Poèmes d'Henri Michaux
Mycenae Alpha
Mimetismo
Pacific
Asterism (1)
Jeux Vénitiens
Lutoslawski Symphony No. 2
Tracés d'Ombres
Pithoprakta
Clair de Terre
Musique Funèbre
Polymorphia (1)
Volumina
Ligeti Double Concerto (2)
Ligeti Double Concerto (4)
Polymorphia (2)
Ligeti Double Concerto (1)
Requiem
Atmosphères (2)
Ligeti Double Concerto (3)
Lutoslawski Double Concerto
Metastaseis
Partiels
Threnody
Asterism (2)
Riverrun
Jaanilalud
Gorecki Symphony No. 3
Wings of Nike
Hyperion
Mi-Parti
Atmosphères (1)
Stimmung
Points de Fuites
Six Miniatures
Crystal Music
Du Cristal
Sud
Mortuos Plango


Galaxies
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

E.9 CRYSTALS

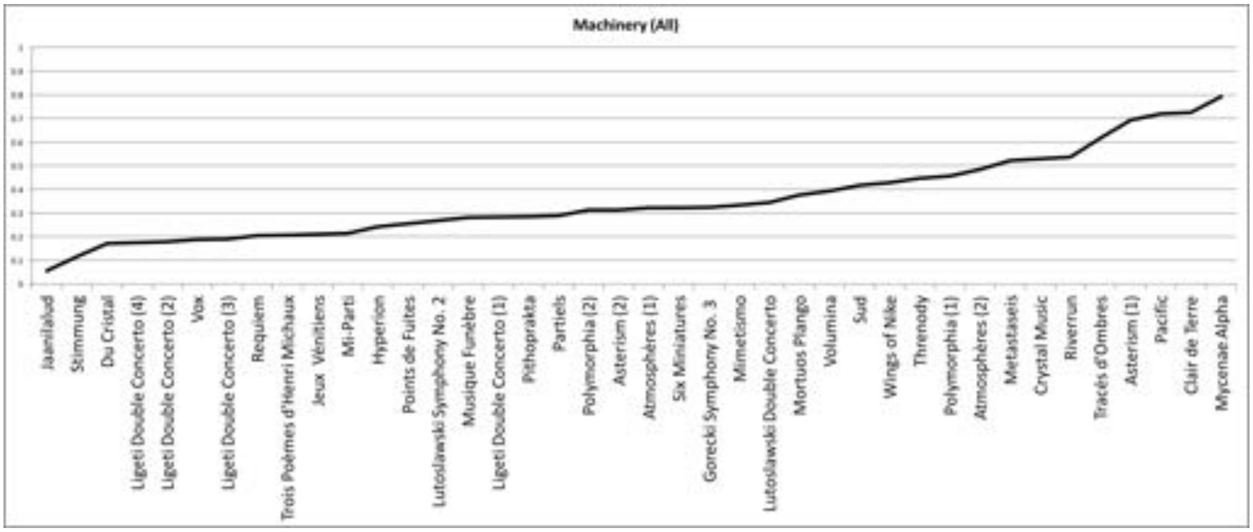


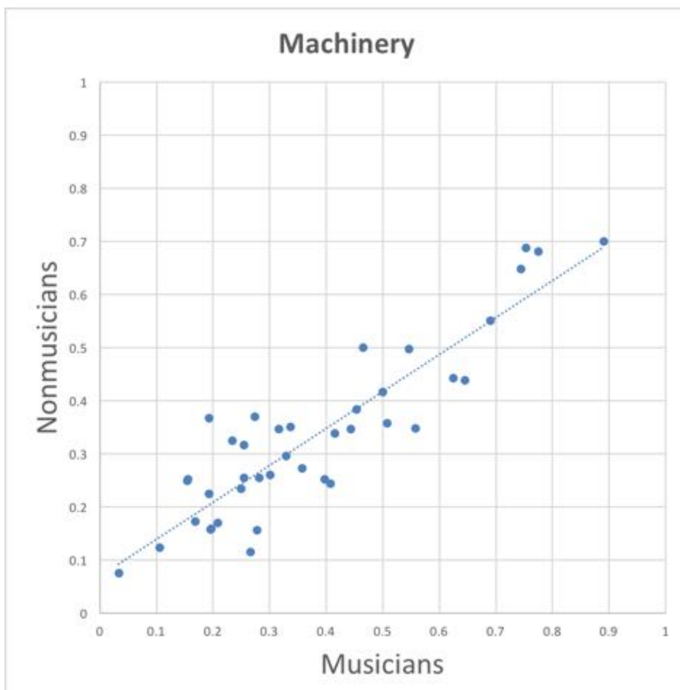
Crystals (All)
Vox
Asterism (1)
Gorecki Symphony No. 3
Polymorphia (1)
Atmosphères (2)
Musique Funèbre
Ligeti Double Concerto (1)
Mycenae Alpha
Lutoslawski Symphony No. 2
Requiem
Pacific
Metastaseis
Ligeti Double Concerto (3)
Polymorphia (2)
Jeux Vénitiens
Wings of Nike
Tracés d'Ombres
Sud
Volumina
Threnody
Lutoslawski Double Concerto
Mi-Parti
Partiels
Ligeti Double Concerto (2)
Six Miniatures
Mimetismo
Riverrun
Stimmung
Jaanilalud
Atmosphères (1)
Clair de Terre
Trois Poèmes d'Henri Michaux
Ligeti Double Concerto (4)
Mortuos Plango
Du Cristal
Hyperion
Pithoprakta
Crystal Music
Asterism (2)
Points de Fuites

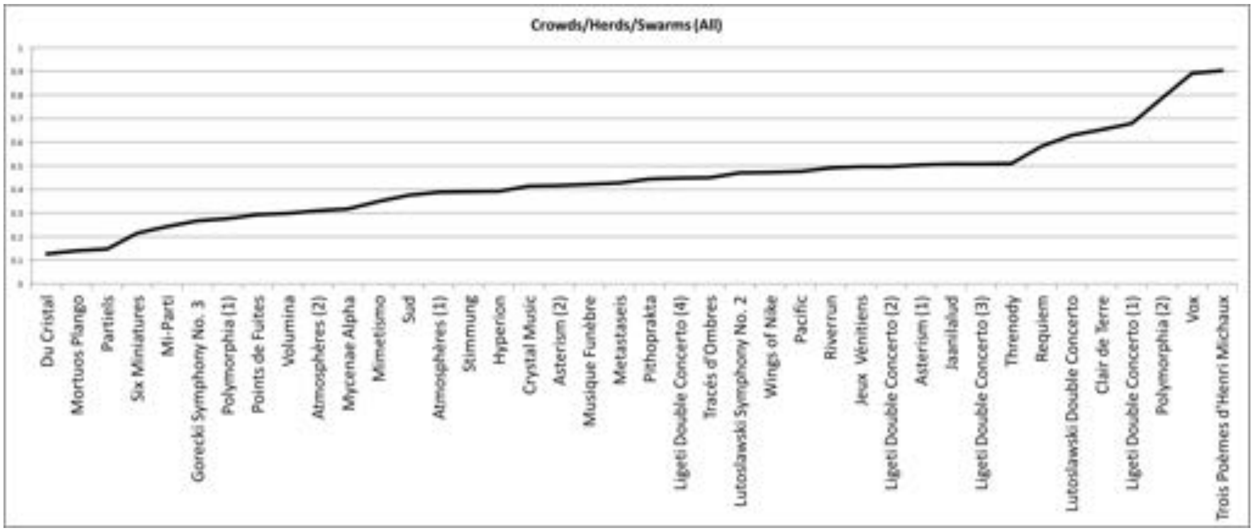


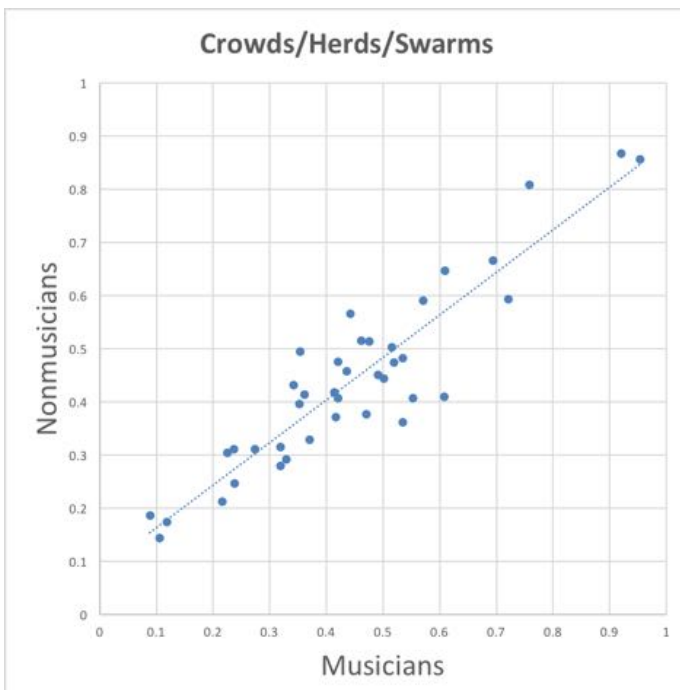
Crystals
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

E.10 MACHINERY






Crowds/Herds/Swarms (All)
Du Cristal
Mortuos Plango
Partiels
Six Miniatures
Mi-Parti
Gorecki Symphony No. 3
Polymorphia (1)
Points de Fuites
Volumina
Atmosphères (2)
Mycenae Alpha
Mimetismo
Sud
Atmosphères (1)
Stimmung
Hyperion
Crystal Music
Asterism (2)
Musique Funèbre
Metastaseis
Pithoprakta
Ligeti Double Concerto (4)
Tracés d'Ombres
Lutoslawski Symphony No. 2
Wings of Nike
Pacific
Riverrun
Jeux Vénitiens
Ligeti Double Concerto (2)
Asterism (1)
Jaanilalud
Ligeti Double Concerto (3)
Threnody
Requiem
Lutoslawski Double Concerto
Clair de Terre
Ligeti Double Concerto (1)
Polymorphia (2)
Vox
Trois Poèmes d'Henri Michaux


Crowds/Herds/Swarms
Nonmusicians
Musicians
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Appendix F: Experiment 4 Principal Component Analyses

(The percentages of variance in the data explained by each PC are indicated, as are the contributions (–1 to 1) of the primary scales forming the PCs.)

F.1 All Participants

PC1: 20.6% "*Liquid-Crystals*"	PC2: 17.2% "*Busy-Crowds*"	PC3: 17.2% "*Formless-Machinery*"	PC4: 15.2% "*Voluminous-Solid*"	PC5: 14.6% "*Wind-Gas*"
Liquid .907 Water .900 Crystals .878 Kaleidoscopic .713	Crowds .926 Busy .754 Volatile .618	Atmospheric –.924 Formless .798 Machinery .719 Clouds –.607 Volatile .604	Voluminous .936 Impenetrable .790 Solid .667	Wind .902 Gas .819

KMO index = .665, p <.001.

F.2 Musicians

PC1: 21.4% "*Busy-Crowds*"	PC2: 18.4% "*Liquid-Crystals*"	PC3: 16.7% "*Voluminous-Solid*"	PC4: 13.2% "*Formless-Machinery*"	PC5: 12.2% "*Wind-Gas*"
Crowds .873 Busy .845 Volatile .779 Static –.617	Liquid .886 Water .858 Crystals .831 Kaleidoscope .685	Voluminous .924 Impenetrable .863 Solid .651	Formless .764 Atmospheric –.731 Machinery .682	Wind .857 Gas .685

KMO index = .690, p <.001.

F.3 Nonmusicians

PC1: 20.8% "*Busy-Crowds*"	PC2: 18.7% "*Liquid-Crystals*"	PC3: 14.2% "*Voluminous-Solid*"	PC4: 13.7% "*Formless-Machinery*"	PC5: 13.7% "Wind-Gas"
Crowds .862 Busy .823 Volatile .703 Webs .661 Kaleidoscopic .616	Liquid .889 Water .886 Crystals .884 Kaleidoscopic .631	Voluminous .915 Impenetrable .702 Solid .644 Machinery .634	Atmospheric –.954 Formless .677 Machinery .655	Wind .894 Gas .773 Cloud .708

KMO index = .592, p <.001.

Appendix G: Experiment 4, Block 2 Participant-Added Categories

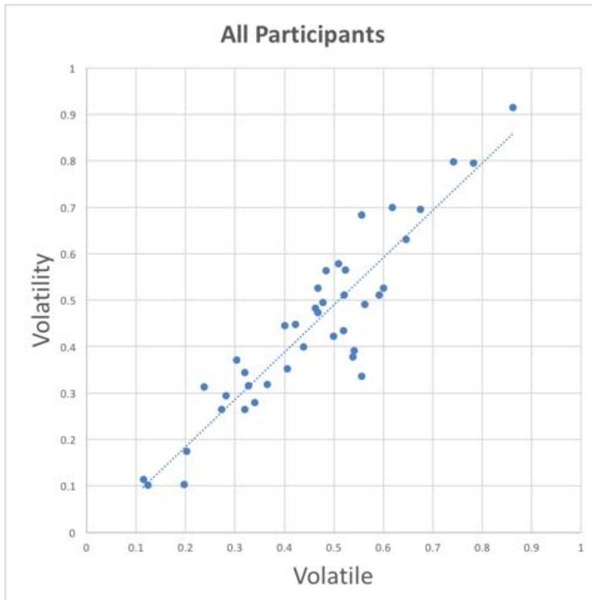
Excerpt	*Added Categories*
Atmosphères (1)	something learking in background (0.168)
Threnody	Doom (0.681)
Volumina	Scary (0.118)
Musique Funèbre	Scary (0.836)
Mi-Parti	Darkness (0.833)
Partiels	[unspecified] (0.706)
Six Miniatures	its gonna get ya (0.964)
Du Cristal	something is there, but not happening (0.727)
Stimmung	taking you to promise land (0.983)
Polymorphia (1)	Streets (0.889)
Atmosphères (2)	
Gorecki Symphony No. 3	dark sinister (0.746)
Requiem	dark souls (0.823) ; Voices (0.707)
Mycenae Alpha	Welding (0.827) ; Machine-like (0.93)
Asterism (1)	just white noise (0.919)
Sud	Flight (0.877)
Vox	busy bees (0.984)
Pacific	radio station not tuning in (0.988)
Tracés d'Ombres	Deathly (0.847)
Clair de Terre	so much going on, thick (0.903)
Pithoprakta	crazy person gonna hurt you , playing his guitar (0.993)
Ligeti Double Concerto (1)	bsuy bees (0.582)
Lutoslawski Symphony No. 2	something crazy (0.905)
Riverrun	alien like (0.608)
Wings of Nike	aliens coming to take over (0.945)
Crystal Music	Confusing (0.99)
Mimetismo	Static (0.793)
Lutoslawski Double Concerto	Confused (0.787)
Ligeti Double Concerto (2)	Dark (0.589)
Polymorphia (2)	busy street (0.841)
Ligeti Double Concerto (3)	anxiety creating (0.94)
Jeux Vénitiens	children playing (0.763)
Asterism (2)	scary sounding (0.908)
Ligeti Double Concerto (4)	also scary (0.706)
Metastaseis	impending doom (0.717)
Mortuos Plango	blwoing glass (0.709)
Jaanilalud	Prayer (0.782) ; Voices (1)
Trois Poèmes d'Henri Michaux	kind of like people yelling (0.843)
Hyperion	run/scary (0.818)
Points de Fuites	Playful (0.747)

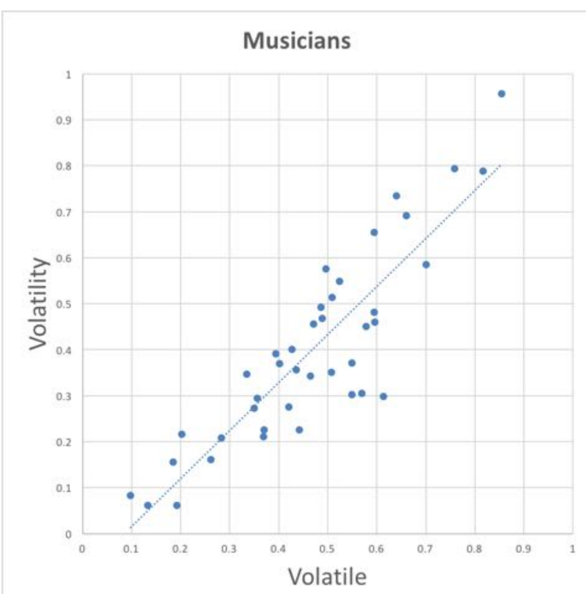
Appendix H: Experiment 4, Block 3 Participant-Added Categories

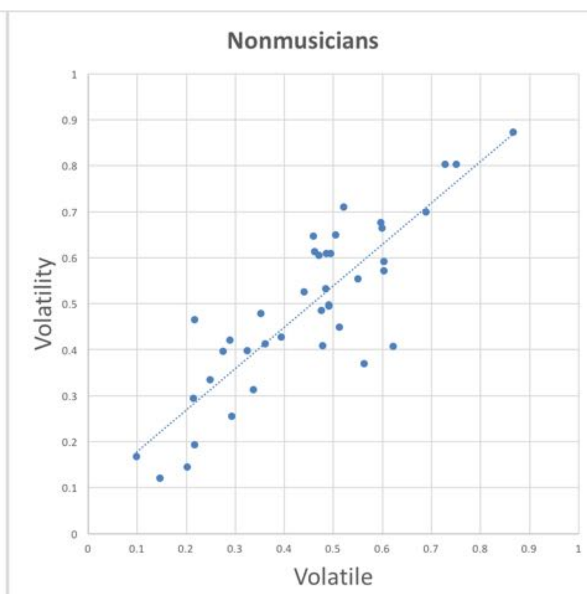
Excerpt	*Added Categories*
Atmosphères (1)	Dark (0.815)
Threnody	Heavy (0.819)
Volumina	keyboard synth fx (0.955) ; church organ (0.978)
Musique Funèbre	orchestral unisoin (0.991) ; eery (0.883) ; cinderella's evil step-mother (0.785)
Mi-Parti	orchestea (0.96) ; creepy (0.954)
Partiels	scary. (0.826)
Six Miniatures	Scary (0.753)
Du Cristal	background noise (0.066)
Stimmung	Sunlight (0.802) ; Mist (0.501) ; Cheerful (0.616) ; religious chants (0.83)
Polymorphia (1)	Dark (0.226)
Atmosphères (2)	Aeroplane (0.519) ; busy street (0.885)
Gorecki Symphony No. 3	Orchestra (0.952) ; Dark (0.995)
Requiem	Choir (0.973); church (0.923) ; Dark (0.749) ; Monastery (0.845) ; religious chants (0.842)
Mycenae Alpha	chainsaw, welder (0.937) ; Steam (0.897) ; planes flying (0.943)
Asterism (1)	Noise (0.973)
Sud	race cars (0.946) ; drifting (0.704) ; spaceships or time travel (0.892)
Vox	busy bees (0.986) ; bees (0.96) ; insects (0.964)
Pacific	guns (0.76) ; broken radio (0.159) ; trains or helicopters (0.927) ; gun shots (1)
Tracés d'Ombres	animals in pain (0.989); ? (0.604) ; dark (0.777)
Clair de Terre	Motorbike (0.749) ; Doomsday (0.953)
Pithoprakta	strings pizzicato (0.977) ; creepy (0.748)
Ligeti Double Concerto (1)	Blood (0.827) ; busy bee (0.862)
Lutoslawski Symphony No. 2	brass (0.986) ; confused (0.741) ; an orchestra (0.746) ; Lots of people talking (0.894)
Riverrun	computers (0.944); computers, typing, machines (0.765) ; aliens (0.879) ; lasers (0.949)
Wings of Nike	Aliens (0.723)
Crystal Music	Computers (0.901) ; broke radio (0.83)
Mimetismo	guitar and flies? (0.988) ; creepy (0.732)
Lutoslawski Double Concerto	Eery (0.306) ; confusion (0.86)
Ligeti Double Concerto (2)	flute (0.97) ; scary (0.059)
Polymorphia (2)	Creepy (0.587)
Ligeti Double Concerto (3)	Creepy (0.865) ; insects (0.806)
Jeux Vénitiens	orchestra (0.99) ; playful (0.638) ; insects or vultures (0.811)
Asterism (2)	orchestra (1) ; wind chimey (0.224)
Ligeti Double Concerto (4)	Birds (1) ; Death (0.929)
Metastaseis	Eeery (0.815) ; A plane flying above (0.899)
Mortuos Plango	Alien (0.43)
Jaanilalud	Churhcy (0.779)
Trois Poèmes d'Henri Michaux	dogs, foxes, wolves (0.753) ; excitement (0.727)
Hyperion	orchestra (0.984) ; scary (0.315) ; alice in wonderland's confusion (0.915) ; stairs (0.937) ; falling down the rabbit hole... (0.895)
Points de Fuites	diing ling (0.838)

Appendix I: Experiments 4-5, Block 2 (Adjectival → Nominal) Ratings

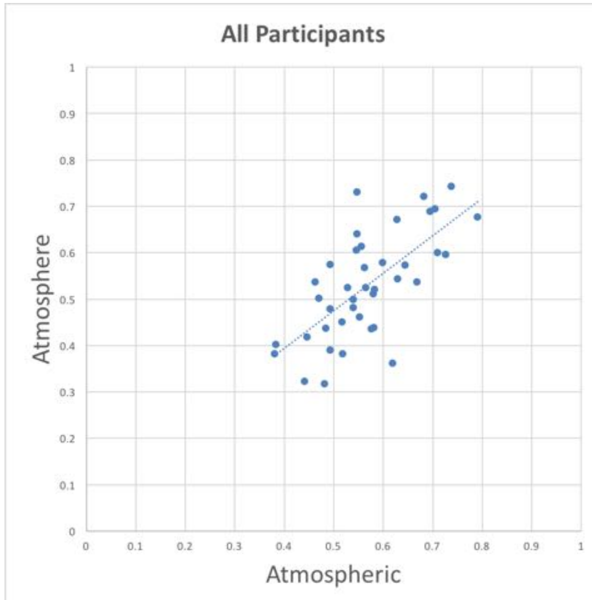
I.1 VOLATILE-VOLATILITY

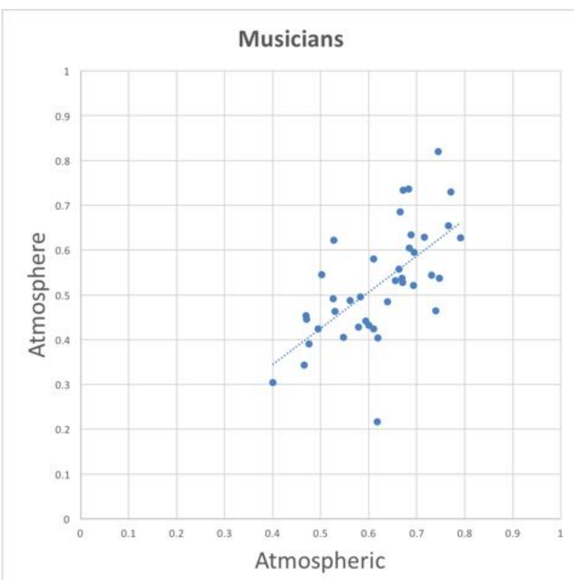


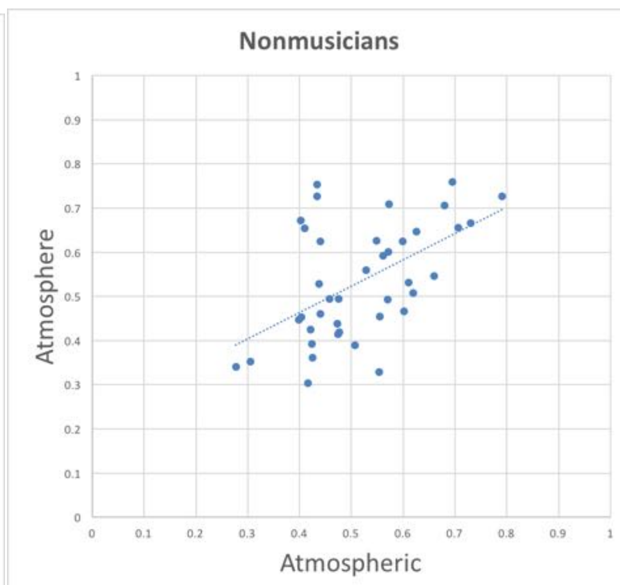




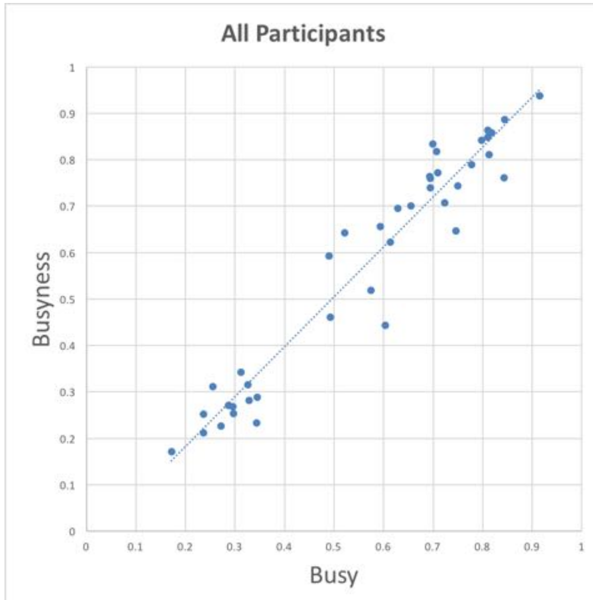
I.2 Atmospheric-Atmosphere

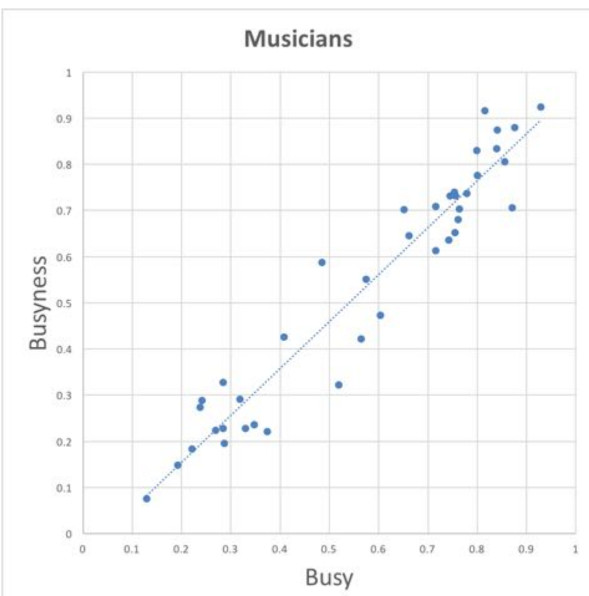


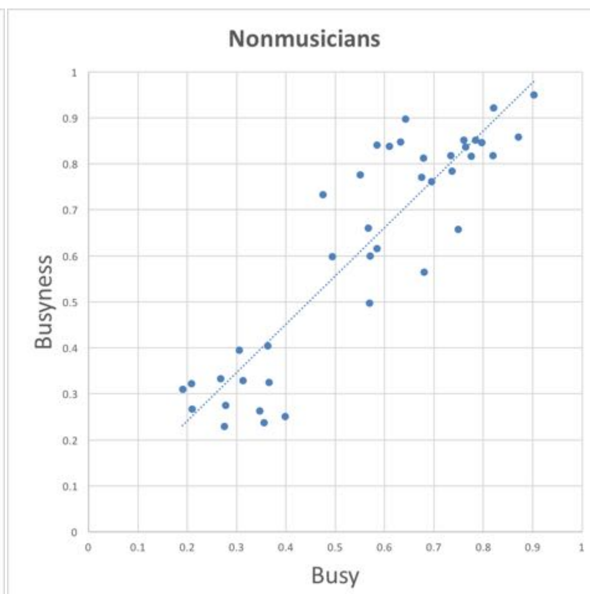




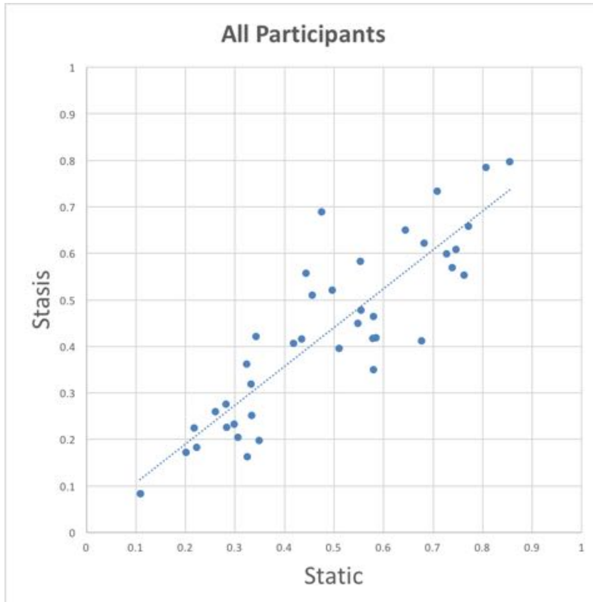
I.3 BUSY-BUSYNESS

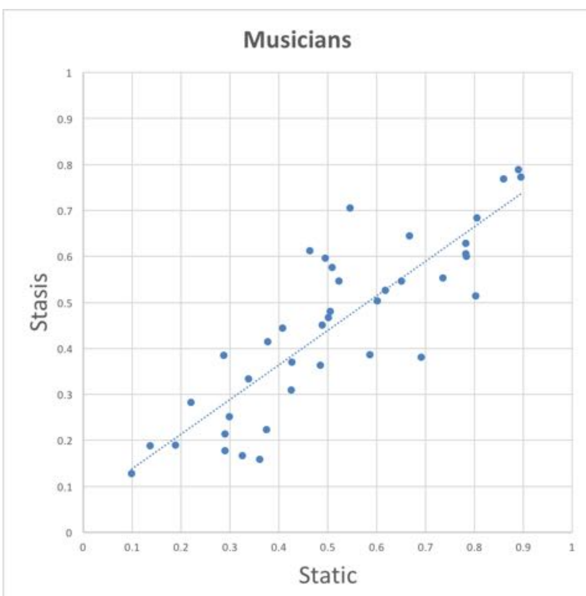


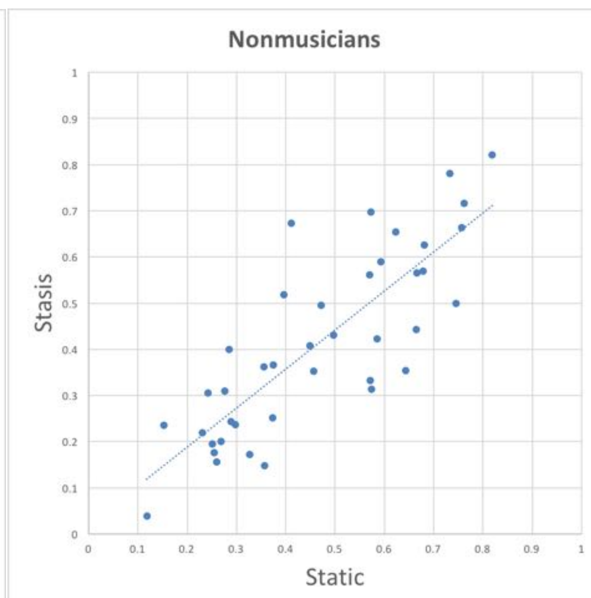


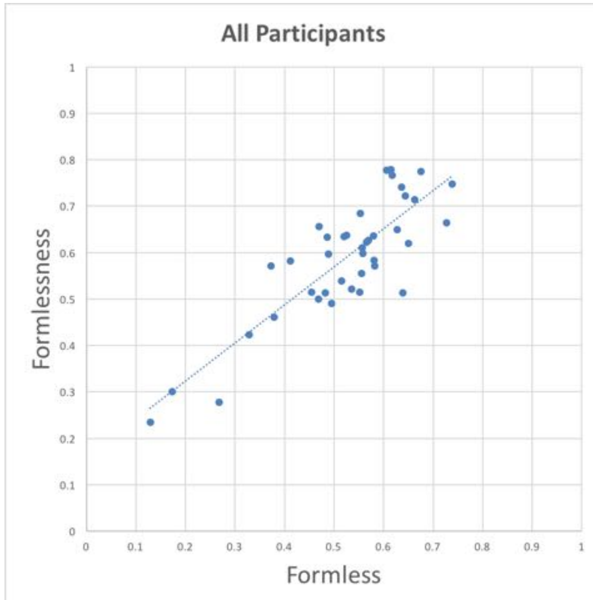


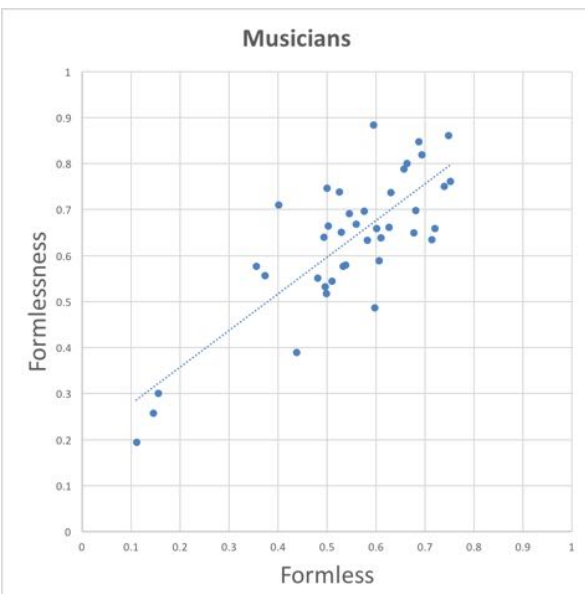
I.4 **STATIC-STASIS**

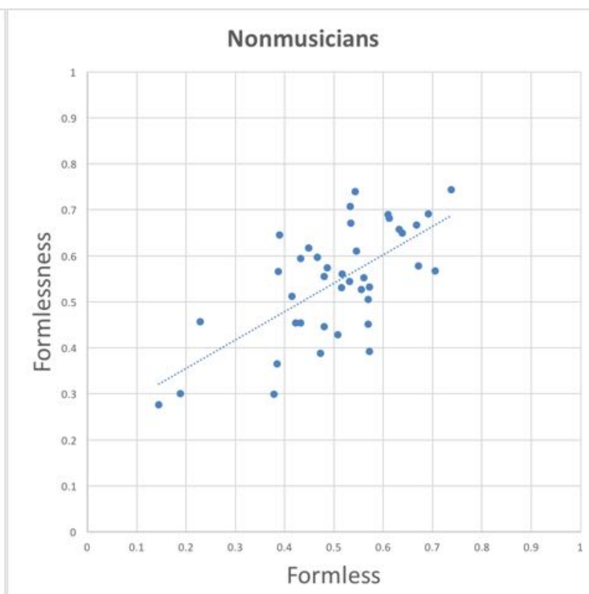




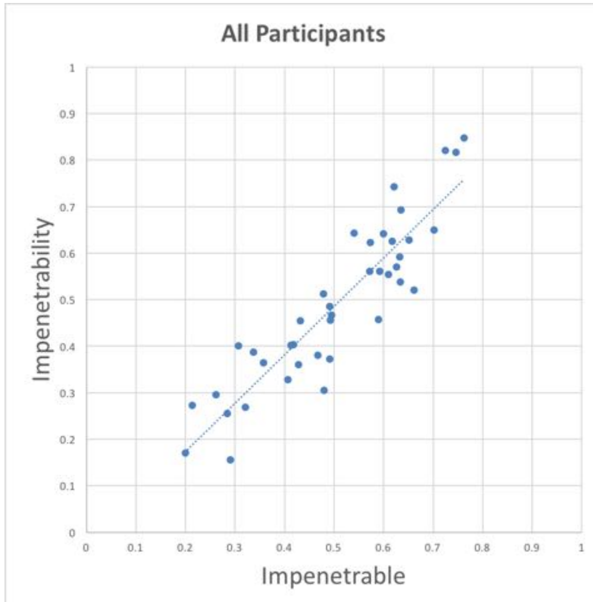


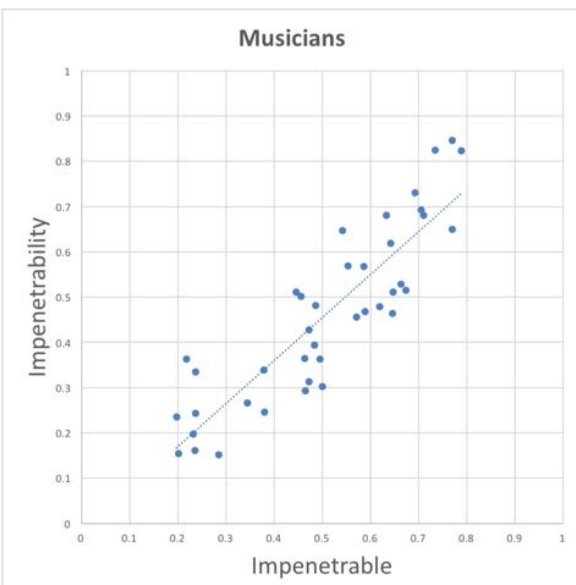

All Participants
Formlessness
Formless
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

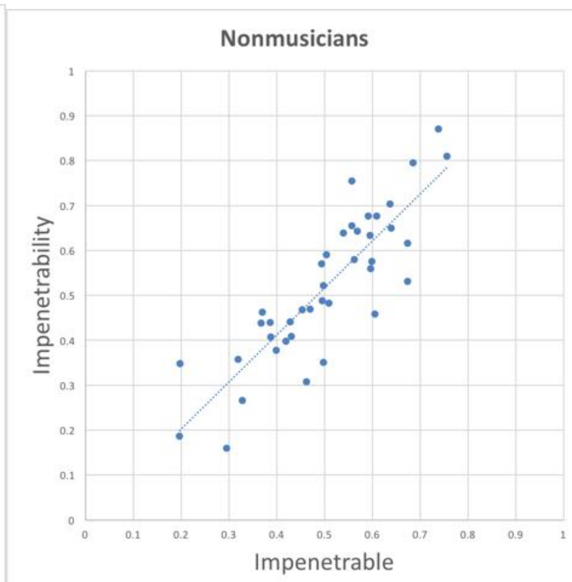

Musicians
Formlessness
Formless
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

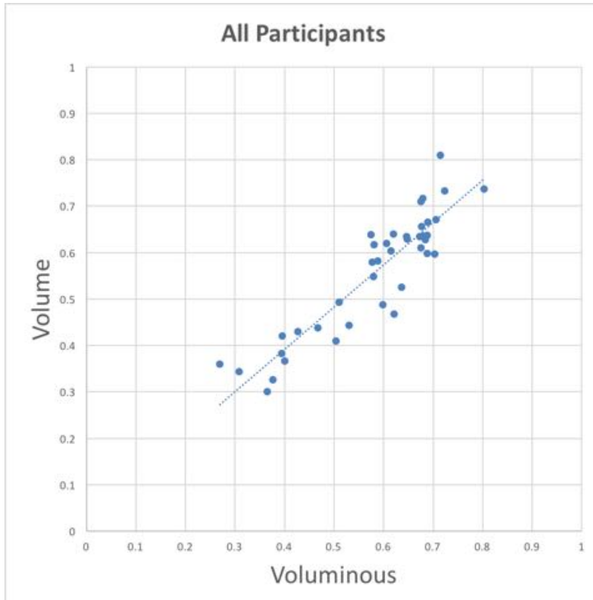

Nonmusicians
Formlessness
Formless
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

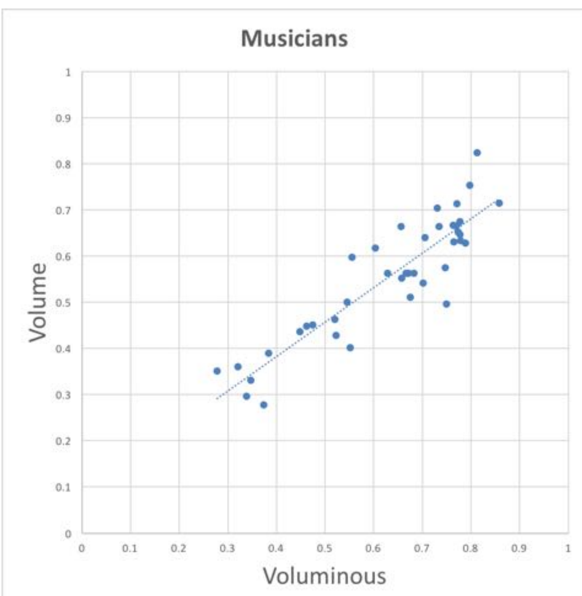
I.6 IMPENETRABLE-IMPENETRABILITY

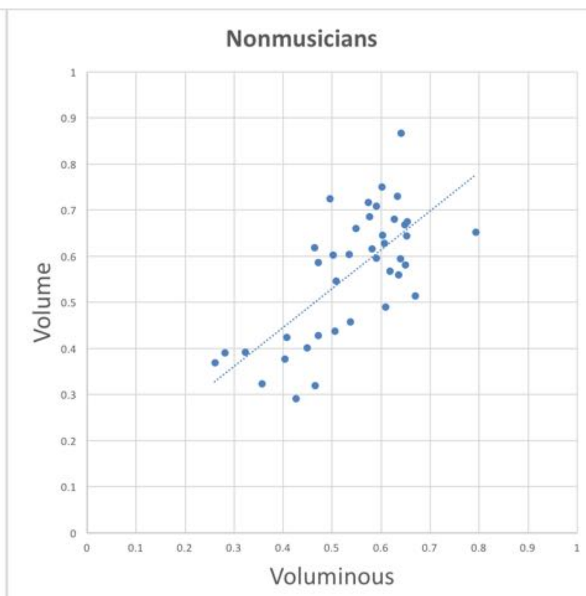


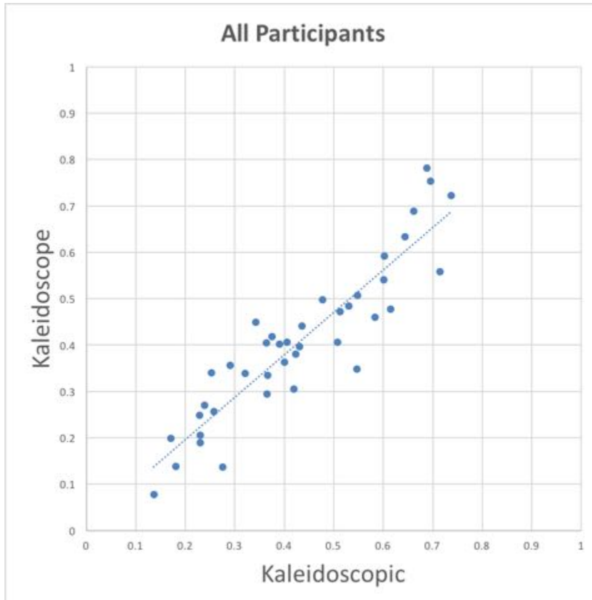


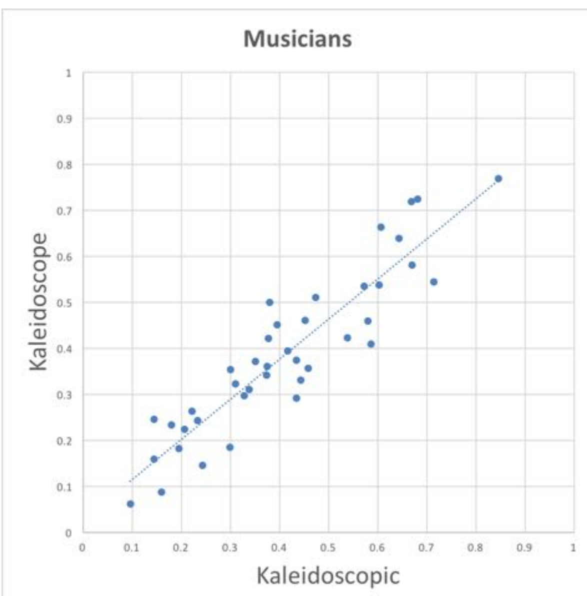


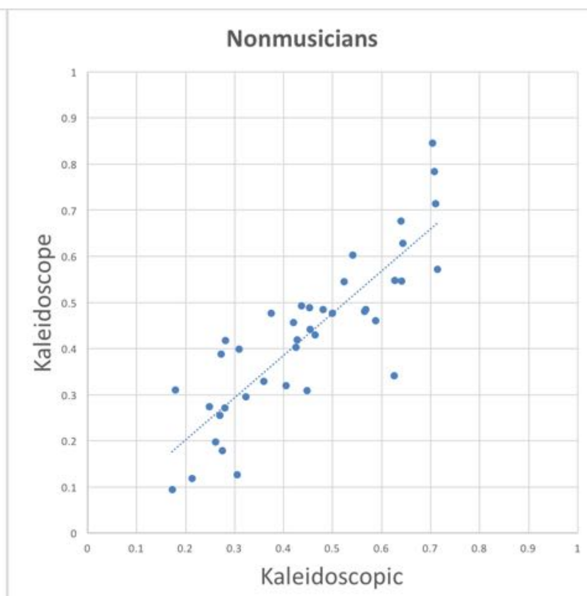

All Participants
Volume
Voluminous
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Musicians
Volume
Voluminous
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Nonmusicians
Volume
Voluminous
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

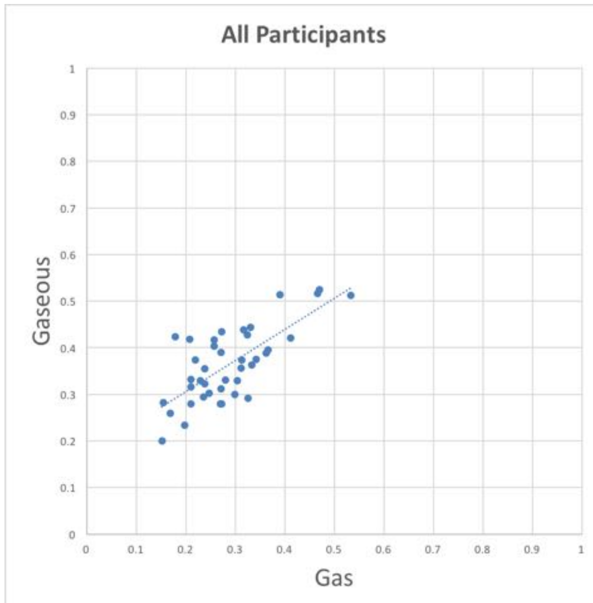

All Participants
Kaleidoscope
Kaleidoscopic
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

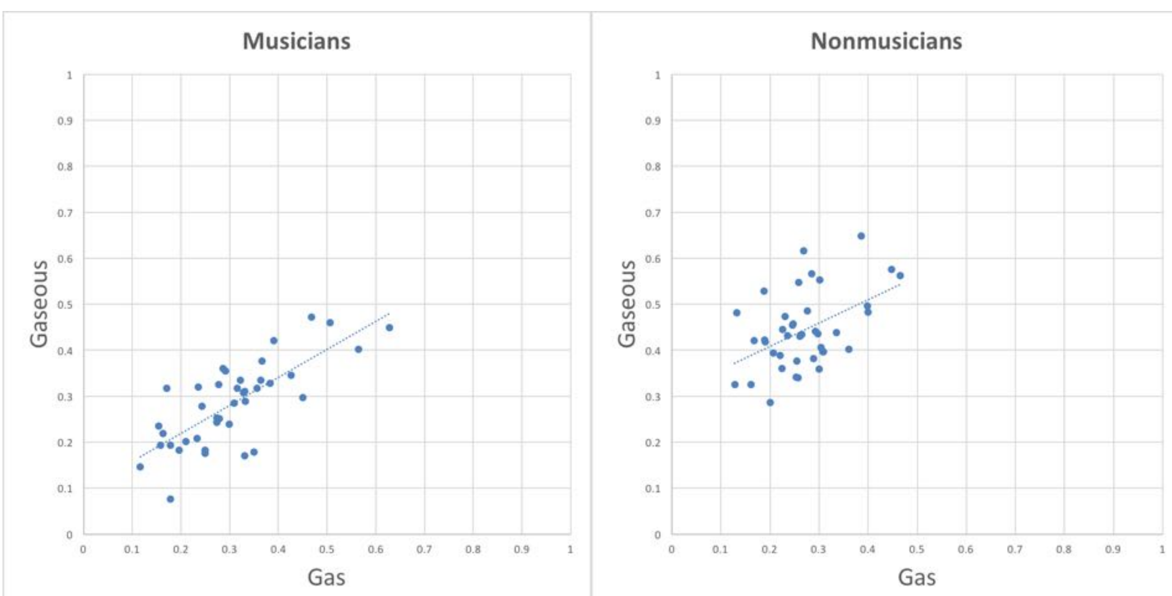

Musicians
Kaleidoscope
Kaleidoscopic
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Nonmusicians
Kaleidoscope
Kaleidoscopic
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

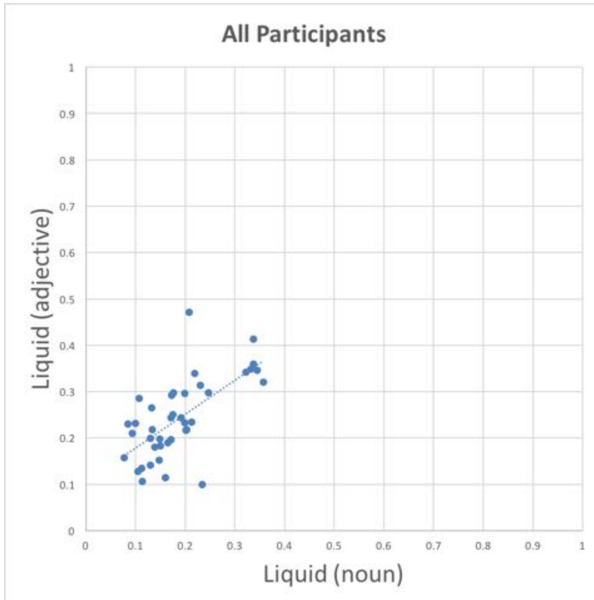
Appendix J: Experiments 4-5, Block 3 (Nominal → Adjectival) Ratings

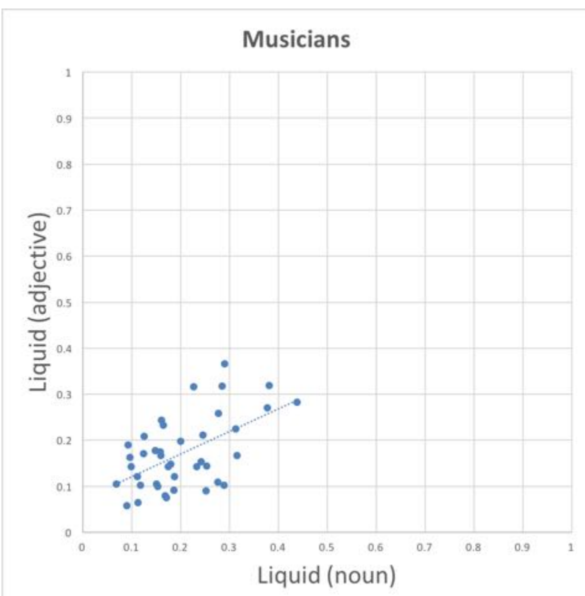
J.1 GAS – GASEOUS

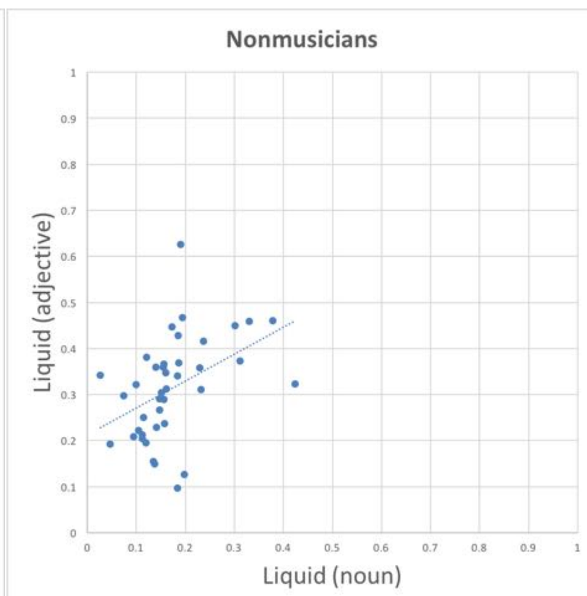




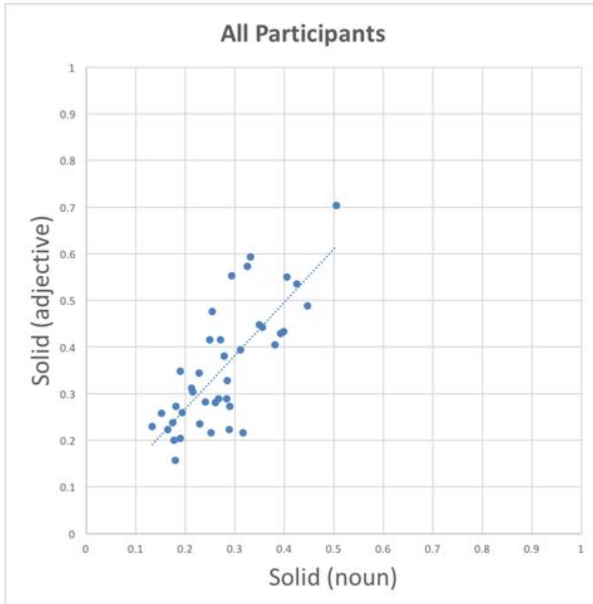
J.2 LIQUID (NOUN) – LIQUID (ADJECTIVE)

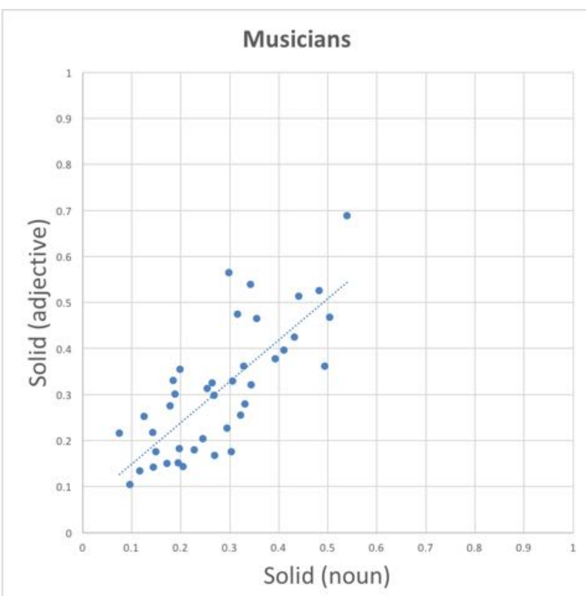


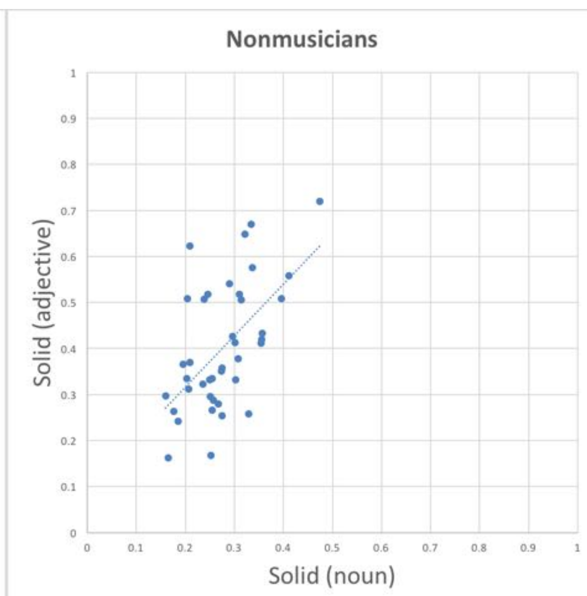




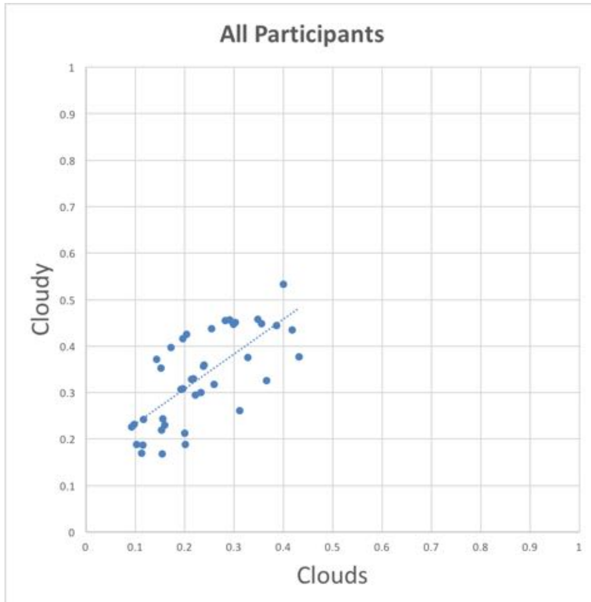
J.3 SOLID (NOUN) – SOLID (ADJECTIVE)

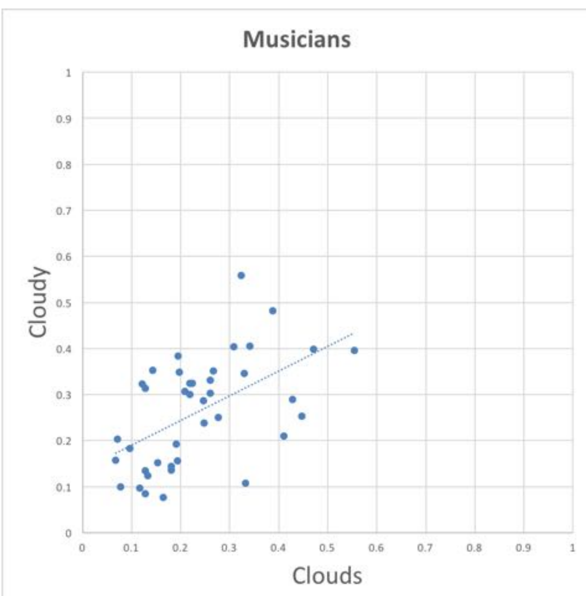


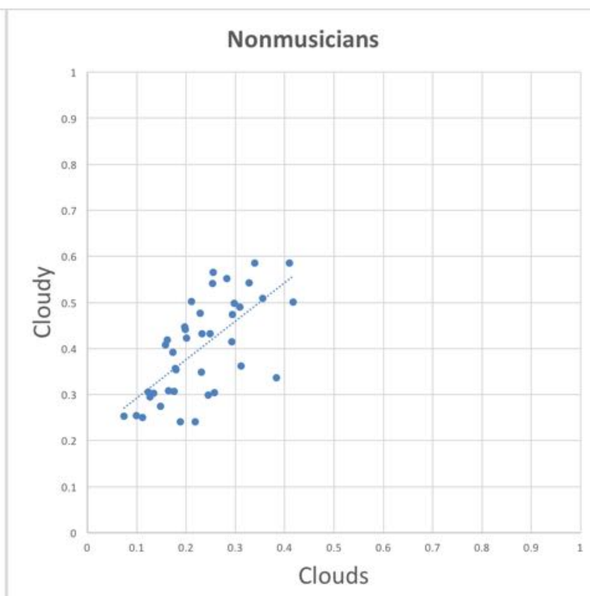




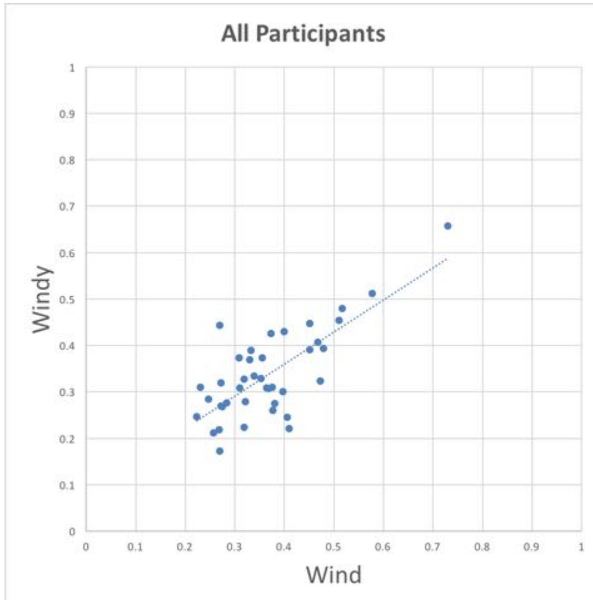
J.4 **CLOUDS – CLOUDY**

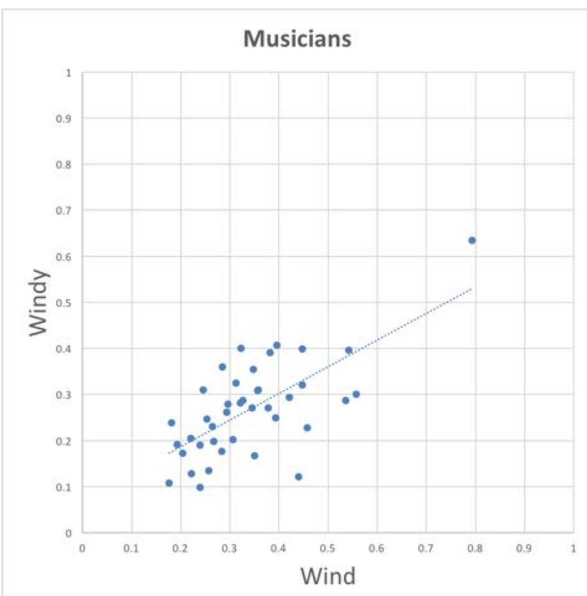


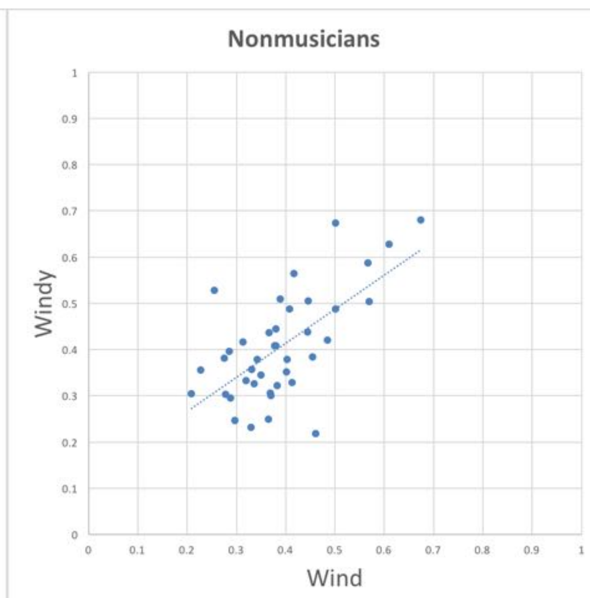




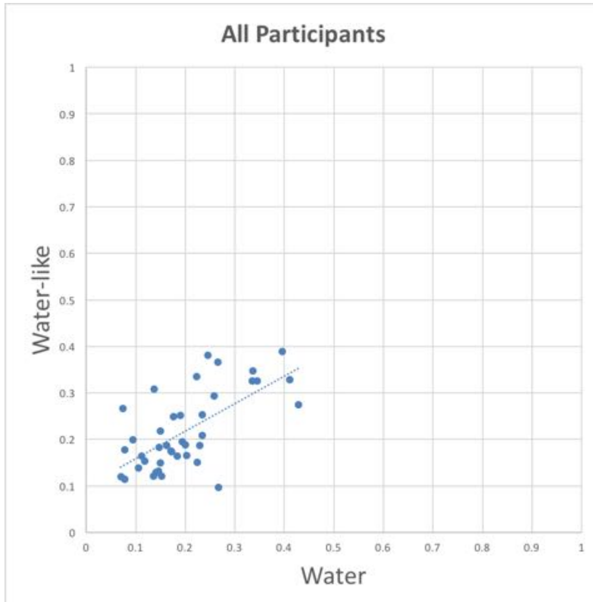
J.5 WIND – WINDY

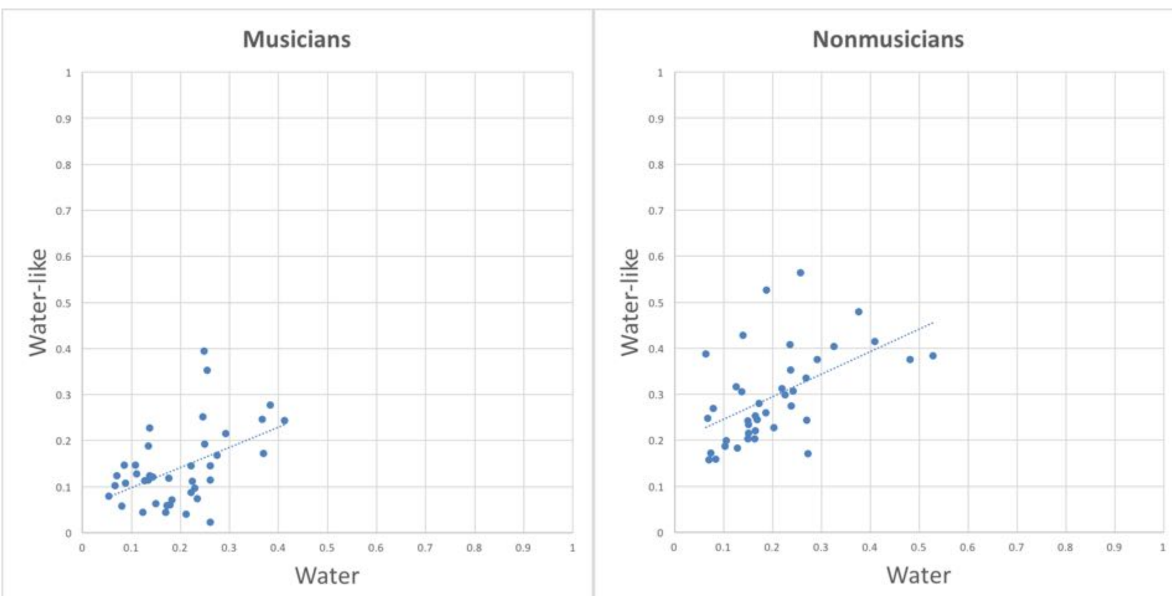




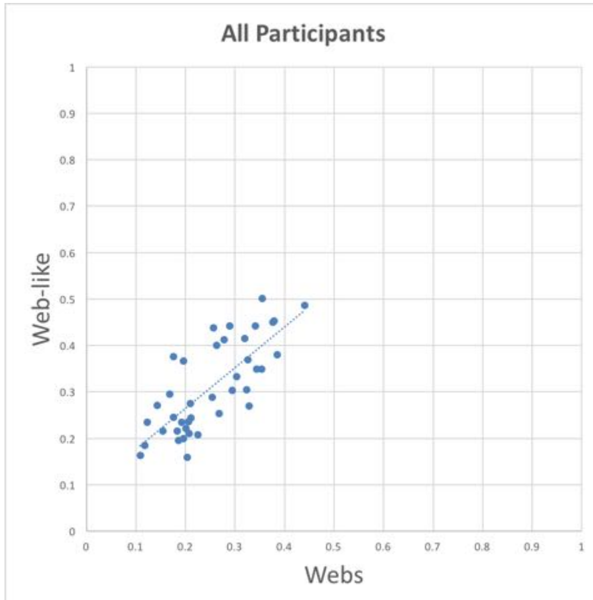


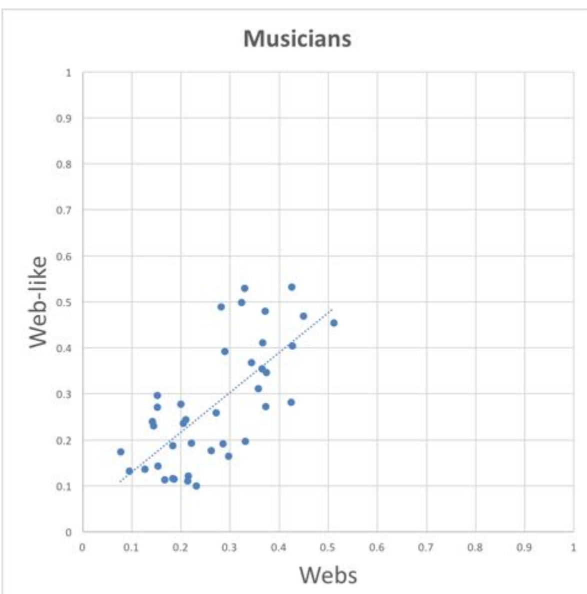
J.6 **WATER – WATER-LIKE**

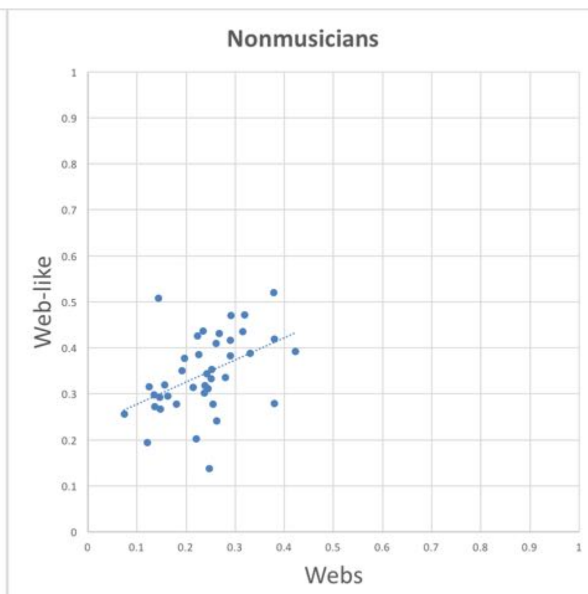




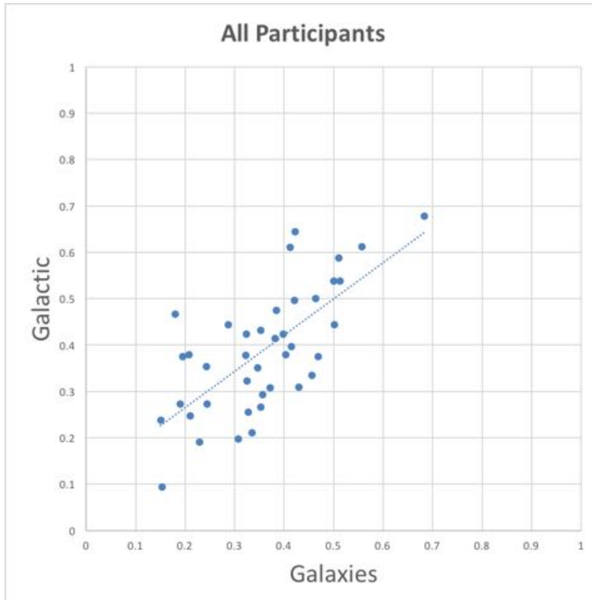
J.7 WEBS – WEB-LIKE

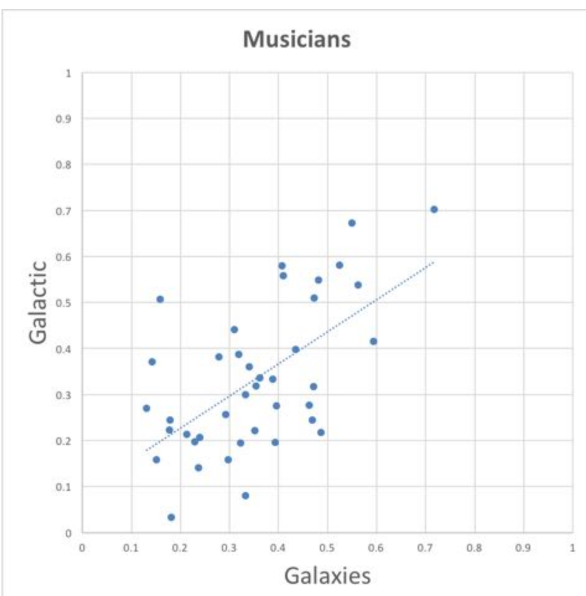


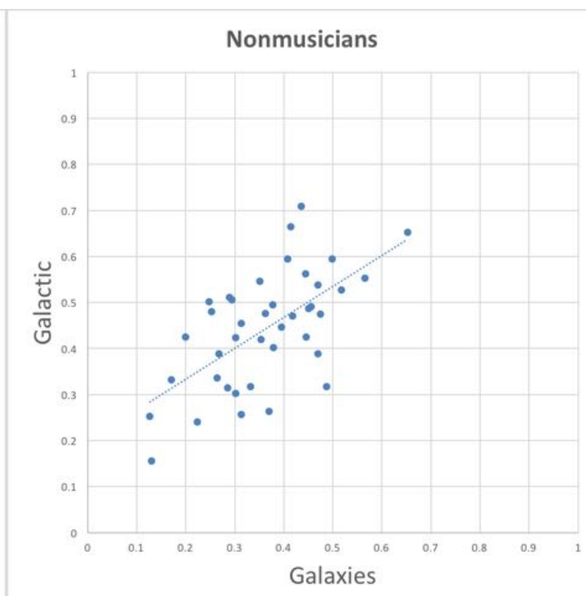




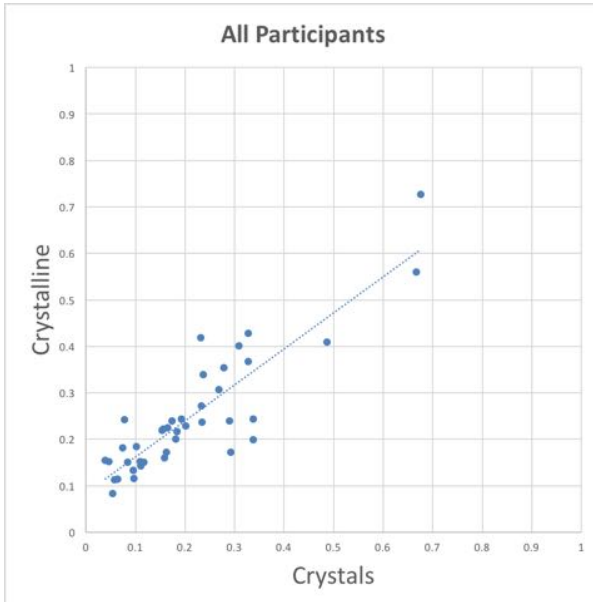
J.8 GALAXIES – GALACTIC

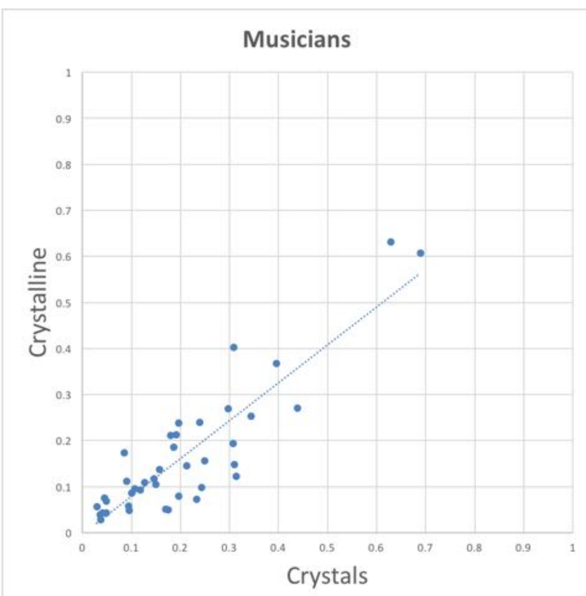


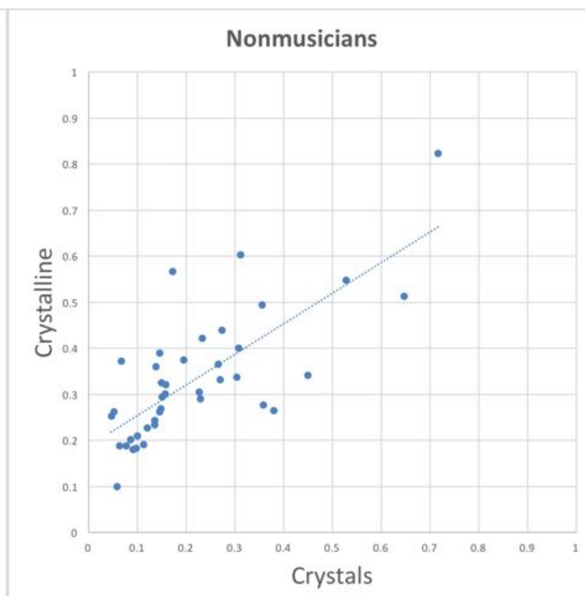


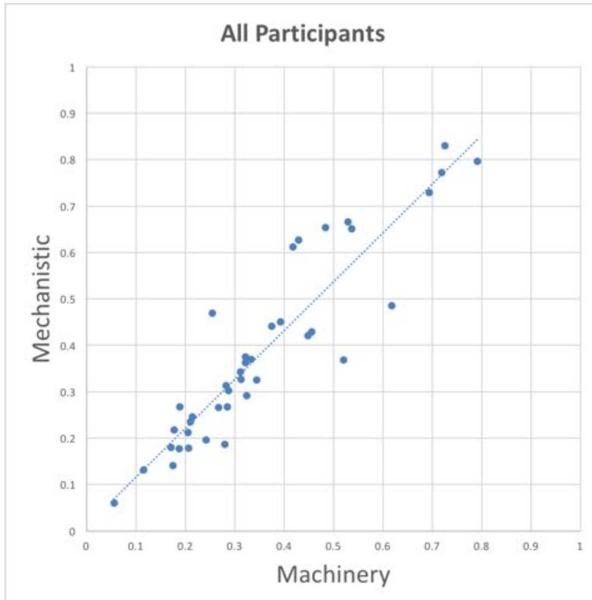


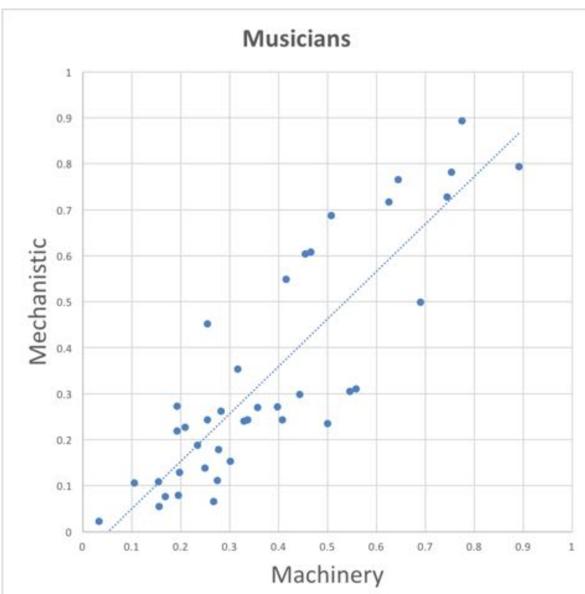
J.9 CRYSTALS – CRYSTALLINE

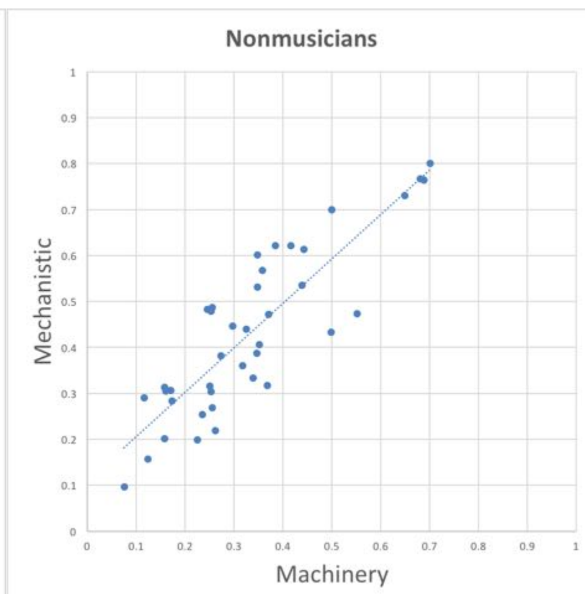




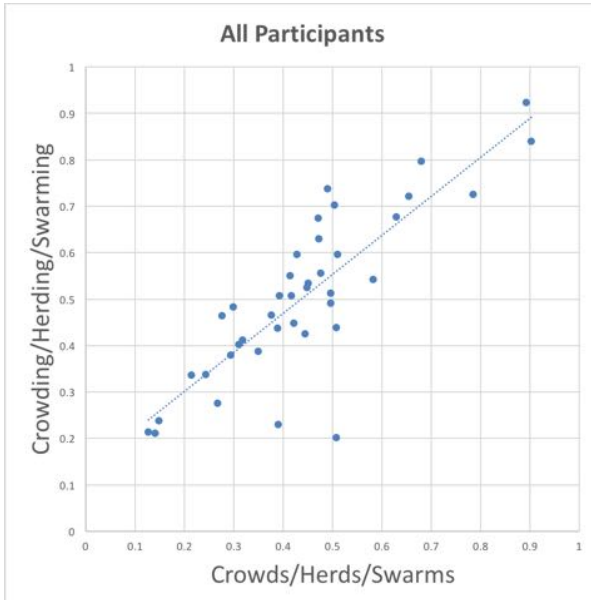


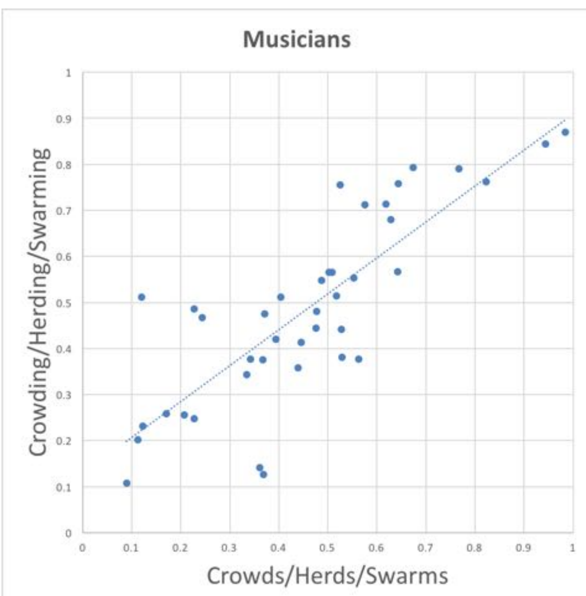

All Participants
Mechanistic
Machinery

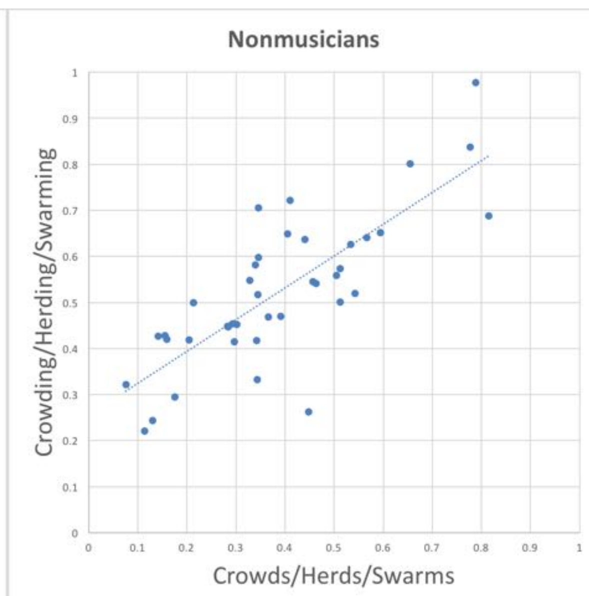

Musicians
Mechanistic
Machinery


Nonmusicians
Mechanistic
Machinery

J.11 CROWDS/ HERDS/SWARMS –CROWDING/ HERDING/SWARMING







Appendix K: Experiment 5 Principal Component Analyses

(The percentages of variance in the data explained by each PC are indicated, as are the contributions (–1 to 1) of the primary scales forming the PCs.)

K.1 ALL PARTICIPANTS

PC1: 28.2% "*Cloudy-Stasis*"	PC2: 25.8% "*Water-like – Liquid*"	PC3: 11.6% "*Windy-Formlessness*"	PC4: 11.5% "*Galactic-Mechanistic*"
Cloudy .868 Volatility: –.867 Stasis .837 Gaseous .820	Water-like .883 Volume –.822 Liquid .816 Solid –.779 Impenetrability –.715 Crystalline .695	Windy .735 Crowding .653 Formlessness .661	Galactic .821 Mechanistic .786

KMO index = .634, $p < .001$.

K.2 MUSICIANS

PC1: 23.5% "*Cloudy-Stasis*"	PC2: 23.0% "*Water-like – Liquid*"	PC3: 14.7% "*Formlessness-Crowding*"	PC4: 9.9% "*Galactic-Mechanistic*"	PC5: 8.0% "*Windy*"
Stasis .946 Busyness –.756 Kaleidoscope –.687 Atmosphere .682 Volatility –.657 Cloudy .663	Water-like .862 Liquid .816 Solid –.785 Volume –.766 Impenetrability –.735	Formlessness .821 Crowding .778	Galactic .901 Mechanistic .730	Windy .915

KMO index = .680, $p < .001$.

K.3 NONMUSICIANS

PC1: 25.0% "*Cloudy-Stasis*"	PC2: 16.8% "*Water-like – Liquid*"	PC3: 16.4% "*Formlessness-Mechanistic*"	PC4: 9.8% "*Galactic*"	PC5: 9.1% "*Web-like*"
Volatility –.873 Stasis .821 Busyness –.817 Cloudy .792 Gaseous .763 Atmosphere .719 Kaleidoscope –.630	Water-like .904 Liquid .883	Formlessness .851 Impenetrability .783 Mechanistic .781	Galactic .819 Crowding –.636	Web-like .860

KMO index = .571, $p < .001$.

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