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ENACTING MUSICAL MAQUETTES: A COGNITION-INSPIRED COMPOSITIONAL APPROACH

Abstract: This paper is a practice-led case study on Fred Lerdahl's "Cognitive Constraints on Compositional Systems". The model attempts to define an artificial compositional grammar in terms of a "universal listening syntax" based on Lerdahl's co-authored *A Generative Theory of Tonal Music*. Through demonstrating the practical application of the constraints, the author reflects on the model's usefulness in light of the contemporary compositional context. Notably, the theory presents abstracted pitch and rhythmic material as an aesthetically neutral syntax, therefore it can only provide stylistically ambiguous infrastructures akin to a musical maquette that needs to be further enacted at the composer's discretion.

Keywords: cognitive constraints, experimental composition, music cognition, phenomenology, enactivism, algorithmic music

In 1961, American composer James Tenney wrote his Master's thesis which was later published under the title *Meta + Hodos*.[1] In the book, Tenney explains that he found traditional music theory to be too outdated to function for contemporary music. For example, labels such as "atonal" and "irregular meter" are too vague to provide any nuanced insight for the music it is de-

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[1] James Tenney, *Meta + Hodos: A Phenomenology of Twentieth-Century Musical Materials and an Approach to the Study of Form*, Urbana, University of Illinois Press, 1968, 3.

scribing. This is often still the case where the term "atonality" encompasses all levels of consonance and dissonance in non-functional harmony.[2] Likewise, "ametricity" is used to describe not the absence of meter, but irregular meter where there is usually still traces of salient pulse within complex rhythmic structures.[3] As an attempt to theorize a new framework to describe such music, Tenney turned to the field of music perception in search for a new perspective to understand and describe music. Compositionally, Tenney has always strived to reflect his theoretical thinking in his music.[4] His theory and music had a reciprocal relationship where his music was driven by experimental ideas from his theory, and in turn, his music inspires him to theorize further. My musical interest is broadly inspired by this interdisciplinary crossover between composition and cognition, and this paper is an example of my practice-led approach where I experiment with composing based on a theory from music cognition.

To be sure, the notion of using music cognition for composition is by no means a novel idea.[5] In particular, Fred Lerdahl, a composer-turned cognition theorist, has attempted to theorize a model that promotes such applica-

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[2] Carol Krumhansl's research on the tonality of contemporary music makes a parallel observation where there is statistical data to show that there exist multiple levels of tonal-centredness even within dodecaphonic music. See Carol Krumhansl et. al., "The perception of tone hierarchies and mirror forms in twelve-tone serial music", *Music Perception*, 5, 1987, 153–184.

[3] Research on Auditory Gist Perception suggests that listeners have the ability to extract pulse information and synchronize body motion even from complex sound textures. See: Martin Clayton et al., *Experience and Meaning in Music* Performance, Oxford, Oxford University Press, 2013; Oliver Lartillot et al., "Multi-feature Modelling of Pulse Clarity: Design Validation, and Optimization", *Proceedings of the 11th International Conference on Digital Audio Effects (DAFx-08)*, Helsinki, University of Technology, 2008, 305–8; Sue Harding et al., "Auditory Gist Perception: An Alternative Selection of Auditory Streams?", in: Lucas Paletta and Erich Rome (Eds), *WAPCV*, Basingstoke, Springer, 2007, 1399–416.

[4] Larry Polansky, "Introduction", in: Larry Polansky et al. (Eds), *From Scratch: Writings in Music Theory*, Urbana, University of Illinois Press, 2019, xi.

[5] In his Master's thesis John Croft mentions Paul Hindemith, Leonard Bernstein, and George Rochberg as examples of composers who were concerned with linking their practice with cognition. However, along with Lerdahl's theory (which will be discussed in the following), Croft notes that these composers held an implication that atonality and ametricality were somehow innately unfit for the human mind – a view which Croft ultimately refuted against. Cf. John Croft, "Musical Memory, Complexity, and Lerdahl's Cognitive Constraints", unpublished Master's thesis, University of Sheffield, Department of Music, 1999.

tion of cognition into composition in his 1988 article titled "Cognitive Constraints on Compositional Systems" (CCCS).[6] The basis for this model came from his earlier co-authored book with Ray Jackendoff, titled *A Generative Theory of Tonal Music* (GTTM). The GTTM is seen to be influential to multiple (sub)disciplines of music cognition, such as in cognitive science, linguistics, semantics and syntax.[7] Despite the broad usages of the GTTM, as Lerdahl noted in his autobiography, he is yet to try composing using the constraints himself.[8] Hence, there is little evidence in practice to demonstrate the usefulness of the constraints. Therefore, this paper aims to demonstrate how the constraints can be used in practice, and in doing so, I hope to answer the following questions: 1) are the constraints useful for composition? 2) what kind(s) of music would the constraints facilitate? And 3) what can the constraints tell us about the relationship between composition and cognition in general? In the following sections, I will first give an overview of how the cognitive constraints work, then address several assumptions regarding the CCCS, followed by a discussion on the compositional process, and finish with a conclusion that revisits the three questions mentioned above.

Cognitive Constraints

For Lerdahl, the motivation for developing the theory came from his dissatisfaction for pieces such as Pierre Boulez's *Le Marteau sans Maître* he found that serial structures were impossible to hear.[9] He theorized that there is a "gap between method and result", which is caused by composers ignoring their listening grammars to rely solely on mathematical approaches. Lerdahl's aim with the CCCS is to promote a reconciliation between method and result by suggesting a framework for the artificial compositional grammar to stay in touch with the listening grammar, which is essentially already written out

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[6] Fred Lerdahl, "Cognitive Constraints on Compositional Systems", in: John A. Sloboda (Ed.), *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition*, Oxford, Oxford University Press, 1988, 231–259.

[7] Fred Lerdahl and Ray Jackendoff, *A Generative Theory of Tonal Music*, Cambridge, MIT Press, 1983; Fred Lerdahl, *Composition and Cognition: Reflections on Contemporary Music and the Musical Mind*, Oakland, University of California Press, 2019, 31; John McCarthy, *A Thematic Guide to Optimality Theory*, Cambridge, Cambridge University Press, 2001; Ray Jackendoff, *Semantics and Cognition*, Cambridge, MIT Press, 1983; Mark Baker, *The Atoms of Language*, New York, Basic Books, 2001.

[8] Fred Lerdahl, *Composition and Cognition*, op. cit., 85.

[9] Fred Lerdahl, "Cognitive Constraints on Compositional Systems", op. cit., 251.

as a detailed list of preference rules in the GTTM. For example, the first eight constraints are called "constraints on event sequences", and they are listed below:[10]

1. The musical surface must be capable of being parsed into a sequence of discrete events.
2. The musical surface must be available for hierarchical structuring by the listening grammar.
3. The establishment of local grouping boundaries requires the presence of salient distinctive. transitions at the musical surface.
4. Projection of groups, especially at larger levels, depends on symmetry and on the establishment of musical parallelisms.
5. The establishment of a metrical structure requires a degree of regularity in the placement of phenomenal accents.
6. A complex time-span segmentation depends on the projection of complex grouping and metrical structures.
7. The projection of a time-span tree depends on a complex time-span segmentation in conjunction with a set of stability conditions.
8. The projection of a prolongational tree depends on a corresponding time-span tree in conjunction with a set of stability conditions

Before proceeding to discuss how I eventually used the CCCS to generate new compositions, there are three issues from CCCS that are worth acknowledging. For one, the listening grammar (GTTM) claims to be a "universal musical grammar", but the constraints are clearly built to prefer western art music.[11] This implies a post-colonial thought where western art music has been placed in the centre and treated as if it represented music "universally". Furthermore, as pointed out by Cook and Croft, the concept of composing *based on* a listening grammar seems to suggest a structuralist attitude where a specific way of cognizing music is assumed to be indifferent among listeners.[12] Also, Lerdahl's terminology of "artificial" and "intuitive" compositional grammar is potentially misleading. In fact, the composers that Lerdahl ac-

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[10] Ibid., 239–49.

[11] Fred Lerdahl and Ray Jackendoff, op. cit., 290.

[12] Nicholas Cook, "Analysing Performance and Performing Analysis", in: Nicholas Cook and Mark Everest (Eds), *Rethinking Music*, Oxford, Oxford University Press, 1999, 247; John Croft, "Musical Memory, Complexity, and Lerdahl's Cognitive Constraints", op. cit., 19.

cused for using "artificial" grammars, such as Schoenberg, Boulez, and Xenakis, all relied on a great deal of intuition to design their systems as well as to act upon its results. Hence, it seems inappropriate to categorize those musics as "artificial" when they were clearly written based on intuition, albeit a more systematic implementation in and of itself.

The second issue is that Lerdahl seems to have missed the point for serialism. Lerdahl claims that goal for the constraints is to help "bridge the gap" between serial technique and heard structure, but serial structures are often not meant to be heard, especially in Boulez. In particular, in *Le Marteau*, Boulez allowed himself to deviate from the pre-determined material at certain moments of the piece (which is in itself determined by a serial process), so serial structures (i.e. tone rows) are not always present in the music.[13] Contrary to Lerdahl's impression of the piece, in writing *Le Marteau*, Boulez explicitly hoped to reconcile with expression in multiple serialism.[14] To put bluntly, the reason Lerdahl struggled to hear any serial structure in the piece, is because there is not one for him to hear in the first place. Even for serial music where tone rows were *actually* used, the rows are by no means used with an expectation to be clearly identifiable for listeners. In other words, Lerdahl seems to be trying to solve a problem that does not exist.

Thirdly, perhaps noticeable from the brief introduction to the constraints, it is apparent that no dodecaphonic music will be able to fulfil the constraints. The CCCS is grounded on the GTTM, which means the model's musical preference is implicitly conservative because the GTTM only works for a tonal corpus of music. Lerdahl's justification is that serial music is "incognizable" even for the "experienced" ear, which is why it will fail to achieve any heard structure in his model. It is beyond the scope of this paper to address further theoretical issues with Lerdahl's constraints. See John Croft's thesis for a more detailed critique of the theory, especially with regards to the misunderstanding that atonality is somehow "unnatural" to listen to. While I acknowledge the problematic discourses surrounding the theory, the focus for the rest of the paper will be on the practical application of the constraints to see how they would actually work.

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[13] See Lev Koblyakov, *Pierre Boulez: A World of Harmony* (New York, Harwood Academic Publishers, 1990) for a detailed analysis of *Le Marteau*.

[14] Pierre Boulez, *Orientations: Collected Writings*, Cambridge, Harvard University Press, 1990.

The Compositional Process

In order to investigate how the constraints function as an "artificial" compositional grammar, an autonomous algorithm on Max/MSP was designed to generate musical materials that satisfy all seventeen constraints. The compositional process is three-fold. In the initial stage, the score only consisted of a transcription of the computer-generated pitch and rhythm. An excerpt of this version of the piece is shown in Figure 1. At this point, the material can technically fulfil all the constraints regarding pitch and rhythm but contains no further instructions for other parameters such as tempo, dynamic, technique, articulation, and phrasing. The first observation to be made is that the constraints cannot be used as a comprehensive music generation system because they do not consider any non-pitch and rhythm parameters which are necessary aspects in writing a piece. The CCCS considers the concept of a compositional grammar in the abstraction of pitch and rhythm syntax, which is insufficient as a generative process because it problematically neglects the consideration for other non-pitch-rhythm parameters of a musical work.

Figure 1: Excerpt from version 1 of the piece

Version 1

Since there are no instructions on the non-pitch-rhythm parameters, I decided on the missing parametrical information according to my understanding of Lerdahl's theory. For example, the tempo is moderately slow to emphasize on clarity for constraints in event sequences. Dynamic markings and sustain pedal changes every four bars to separate between phrases structures, and the piano was chosen because it can be played with the least intervention in the remaining missing parameters such as articulation and phrasing. However, even with the addition of other parameters, the material was still not quite far from being a complete piece of music. The updated notation for the same excerpt shown in Figure 2.

Figure 2: Excerpt from version 2 of the piece

In Figure 2, the piece is technically a playable piece of music. There is no longer any missing parametric information where pitch, rhythm, dynamics, pedal markings, and tempo are all written on the score. If the goal of this paper is to see what a "perfect" piece that follows all the constraints would look like, this could be considered an acceptable answer. Even though the score is perfectly playable as it is, I was ultimately dissatisfied with the result at this stage. My problem with the piece, to borrow from phenomenology, is that in the experienced world, we encounter objects as we pursue our goals and enact our identities.[15] Sometimes when an object becomes broken, or perhaps missing, we confront the object as a stranger that is very much separate from us. In other words, our attention is attracted to problems. We hardly notice the unproblematic activities that remain in the background of our lives. Even though version 2 of the piece presents itself to be "unproblematic" in terms of Lerdahl's constraints, my problem is that there is too little to attend to within the piece, which is to say the material felt too "basic" and "un-stylized" for my taste. To be sure, I am aware that the results are never truly "un-stylized" as I have indirectly influenced the stylistic outcome by designing the algorithm myself.[16] Rather, what I mean by "un-stylized" is that the piece as shown in Figure 2 only presents the most basic structures of the piece. It is almost analogous to drawing a stick-figure or building a maquette

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[15] Martin Heidegger, *Being and Time*, trans. by John Macquarrie and Edward Robinson, New York, NY, Harper & Row, 1961. Originally published in German in 1927, 154.

[16] Sofian Audry terms this long-range influence between artist and the algorithm "indirect feedback" where the artist experiments with different evaluation functions to produce outcomes, as opposed to directly intervening with the system (direct feedback). See: Sofian Audry, *Art in the Age of Machine Learning*, Cambridge, MIT Press, 2021, 79–82 for more explanation on the process of creating art using machine-learning.

musically. The maquette contains every basic element necessary to create a piece, but it still lacked a stylistic connection to the broader compositional tradition to make any sense as a new piece of work.[17]

My dissatisfaction with version 2 of the piece has led me to revise the piece further to impose more intervention to the algorithmic outcome. To do this, I removed all barlines and stems from the score to create a quasi-indeterminate score that only has pitch notated. The rhythm, phrasing, and dynamics are up for the performer to interpret intuitively, and that made the solo piano piece titled *Stillness* (Figure 3).[18]

Figure 3: Excerpt from *Stillness* (Version 3 of the piece)

Discussion

This three-fold process of working with the constraints has been an unusual experience for algorithmic composition. Traditionally, when composers are dissatisfied with their algorithmic outcome, they would either rerun the algorithm, redesign the algorithm, or deviate from intuitively from the algorithmic material. Here, since the constraints consider compositional syntax in

[17] This is, perforce, a problem only to the extent of my preference and understanding in how I want to write music. There is nothing wrong with playing the material as it is in figure 2, but personally it sounded more like "material" than "work", which is why I proceeded to intervene with the algorithmic outcome.

[18] A recording of the piece can be found here: https://soundcloud.com/kenrick-ho/four-pieces-with-cognitive-constraints-i-stillness

terms of abstracted pitch and rhythm, they are incomprehensive and therefore insufficient to for music generation. To answer the first question raised in the introduction, "are the constraints useful for composition?" Borrowing from David Temperley's terminology, the constraints are useful at the level of infrastructure because they are supposed to be "ubiquitous" and "a means to an end."[19] He writes, "water mains and power lines do not normally bring us joy in themselves, but they facilitate other things – homes, schools, showers – whose contribution to life is more direct."[20] Similarly, the basic structures provided by the constraints can be thought to be ubiquitous, as Temperley writes, "every moment of every piece has a metrical and a harmonic structure."[21] Therefore, the constraints are most usefully considered not as some sort of prescriber for compositional grammar, but as infrastructures that are deliberately vague to function in the background as a means to an end.

At first sight, it may not seem particularly useful to view the constraints as an infrastructure for composition. However, borrowing from Marius Kozak's theory of enactivism, once the composer has become conscious of these infrastructures, the constraints can become situated in the foreground to become the subject of care. In *Enacted Musical Time*, Kozak views time as an infrastructure because all music involves being in time.[22] Time in its neutral state is also unnoticeable, but the composer can foreground it as an infrastructure by being aware of time and its effect. In parallel, take, for example, the first constraint: "the musical surface must be capable of being parsed into a sequence of discrete events."[23] Constraint 1 does not inform the composer what or how to write, but it exists passively in the background as an infrastructure. The constraint can only be foregrounded if the composer becomes aware of it and therefore becomes a subject of care. But even when it is foregrounded, constraint 1 is still not prescribing music because the composer can only "use" it by being "aware" of the criteria of the constraint and its effects. The same goes for constraints on underlying materials such as "stability conditions must operate on a fixed collection of elements" (constraint 9).[24]

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[19] David Temperley, *The Cognition of Basic Musical Structures*, Cambridge, MIT Press, 2004, 3.

[20] Ibid., 4.

[21] Ibid., 4.

[22] Mariusz Kozak, *Enacting Musical Time: The Bodily Experience of New Music*, Oxford, Oxford University Press, 2020, 11.

[23] Fred Lerdahl, "Cognitive Constraints on Compositional Systems", op. cit., 239.

[24] Ibid., 244.

Any given piece of music would have some sort of "fixed collection of elements", but once the composer has become conscious of their choice of "fixed collection of elements", this constraint becomes foregrounded, and it is now possible for this neutral state infrastructure to be situated as the point of concern for listeners and the composer to care for.

Moreover, to answer the second question, "what kind of music would the constraints facilitate?" Due to the stylistic vagueness in the constraints as an infrastructure, as it turns out, it is not a valid question to ask and there is no answer to this. Since the constraints do not function as a prescriber for music, it is up to the composer to decide how the initial "un-stylized" material should be "dressed up" and framed into music that they want to write. It is worth noting that this stylistic ambiguity mirrors Lerdahl's original intention for the GTTM to be a "universal listening grammar" but in a completely different way. Lerdahl's GTTM consists of an exhaustive list of preference rules that deals explicitly with Western Classical music. His idea of universality is rooted within the assumption that there is something inherently natural about cognizing the characteristics of classical music. Here, the stylistic ambiguity is a result of the incomprehensiveness of the constraints, which necessarily calls for the composer to intervene to turn material into work. In writing *Stillness*, I found that the "perfect" material that fulfils every constraint is akin to a musical stick-figure, or a basic maquette. My task as a composer was then to find a solution of framing the pre-determined material as a piece of work in a way that makes sense within the broader compositional context. If the musical maquette can be described as basic, "un-stylized", and "unproblematic", then my creative responsibility is solely to enact some sort of musical interest without altering the pre-determined pitch. For *Stillness*, it was a subjective decision to mould the material into a Feldmanesque slow piano piece. But if other composers were to work with the maquette-enacting approach based on the constraints, I can imagine many other ways of adapting these materials into a variety of genre and styles. In that sense, the maquette is stylistically ambiguous and can facilitate practically any styles and genres of music.

To answer the final question, what can the constraints tell us about the relationship between composition and cognition in general? The experience of working with the constraints has led me to reconsider the potential conflicts in the notion of "consulting psychology" in composition. It is important to note that music cognition is aesthetically neutral, and at the end of the day, it is entirely up to the composer to decide how the theory can be embodied

in a way that relates to its broader compositional context. Initially, I was consciously dependent on the algorithm to make decisions so I could test what the constraints might lead me to write. But consequently, I was faced with results that I described as "un-stylized" and maquette-like because the theory was aesthetically neutral, so it required my stylistic preference as intervention to formulate the material into a piece. It is precisely this tension between adhering to the stylistically neutral material and "stylizing" it into a more completed work that is most intriguing in the process of using the constraints. There are uniquely only the most basic infrastructural structures that are specified in creating the maquette, and there is plenty more scope to explore how new musical ideas can be enacted out of these maquette-like materials in the future.

Works Cited

Audry, Sofian: *Art in the Age of Machine Learning*. Cambridge: MIT Press, 2021.

Baker, Mark: *The Atoms of Language*. New York: Basic Books, 2001.

Boulez, Pierre: *Orientations: Collected Writings*. Cambridge: Harvard University Press, 1990.

Clayton, Martin, et al.: *Experience and Meaning in Music Performance*. Oxford: Oxford University Press, 2013.

Cook, Nicholas: "Analysing Performance and Performing Analysis", in: Nicholas Cook and Mark Everist (Eds), *Rethinking Music*. Oxford: Oxford University Press, 1999, 239–261.

Croft, John: "Musical Memory, Complexity, and Lerdahl's Cognitive Constraints", unpublished Master's thesis, University of Sheffield, Department of Music, 1999.

Harding, Sue, et al.: "Auditory Gist Perception: An Alternative Selection of Auditory Streams?", in: Lucas Paletta and Erich Rome (Eds), *WAPCV*. Basingstoke: Springer, 2007, 399–416.

Heidegger, Martin: *Being and Time*. Transl. by John Macquarrie and Edward Robinson. New York: Harper & Row, 1961.

Jackendoff, Ray: *Semantics and Cognition*. Cambridge: MIT Press, 1983.

Koblyakov, Lev: *Pierre Boulez: A World of Harmony*. New York: Harwood Academic Publishers 1990.

Kozak, Mariusz: *Enacting Musical Time: The Bodily Experience of New Music*. Oxford: Oxford University Press, 2020.

Krumhansl, Carol, et. al.: "The perception of tone hierarchies and mirror forms in twelve-tone serial music", *Music Perception*, 5, 1987, 153–184.

Lartillot, Oliver, et al.: "Multi-feature Modelling of Pulse Clarity: Design Validation, and Optimization", *Proceedings of the 11th International Conference on Digital Audio Effects (DAFx-08)*. Helsinki: University of Technology, 2008, 305–308.

Lerdahl, Fred: "Cognitive Constraints on Compositional Systems", in: John A. Sloboda (Ed.), *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition.* Oxford: Oxford University Press, 1988, 231–259.

Lerdahl, Fred:: *Composition and Cognition: Reflections on Contemporary Music and the Musical Mind.* Oakland: University of California Press, 2019.

Lerdahl, Fred; Ray Jackendoff: *A Generative Theory of Tonal Music.* Cambridge: MIT Press, 1983.

McCarthy, John: *A Thematic Guide to Optimality Theory.* Cambridge: Cambridge University Press, 2001.

Polansky, Larry: "Introduction", in: Larry Polansky et al. (Eds), *From Scratch: Writings in Music Theory.* Urbana: University of Illinois Press, 2019.

Temperley, David: *The Cognition of Basic Musical Structures.* Cambridge: MIT Press, 2004.

Tenney, James: *Meta + Hodos: A Phenomenology of Twentieth-Century Musical Materials and an Approach to the Study of Form.* Urbana: University of Illinois Press, 1968.

Summary

Fred Lerdahl's "Cognitive Constraints on Compositional Systems" is a rare example of a theoretical model that attempts to apply music cognition directly into composition. The article defines a compositional grammar of how composers compose in terms of a listening grammar of how listeners listen. Hypothetically, the constraints present a framework for composers to build artificial systems that is informed by the listening grammar. Since Lerdahl never composed with the constraints himself, the focus of this paper will be on the practical reflections from attempting to use the to compose. In doing so, I hope to 1) demonstrate the usefulness of the constraints, 2) find out what kinds of music can be facilitated, and 3) to reflect on the notion to use psychology theories for composition in general. A generative algorithm that follows all constraints has been built using Max/MSP. The first problem I encountered is that the algorithm is far from being able to compose autonomously. The constraints are inherently incomprehensive where they consider compositional syntax in an abstracted sense of pitch and rhythm, thus are insufficient for autonomous music generation. The second problem is that even after manually implementing the missing parameters, the generated material still felt too "basic" and "un-stylized" to be called a complete piece. This issue is discussed in terms of phenomenology where we as humans are naturally attracted to problems in the experiential world. By fulfilling every constraint, the material is analogous to an unproblematic maquette where basic structures are present, but the material requires further stylization to become a piece of work. On one hand, the constraints in themselves are too ambiguous to function as a prescriber for algorithmic music. But on the other, this ambiguity presents the potential for composers to enact on the maquette to create music in all sorts of styles and genres. This paper began with a focused aim to reveal the practical limitations of

using Lerdahl's constraints, but as a by-product of this study, I am inspired by the compositional process where I omit decisions in the note-to-note level and focus on enacting some sort of musical interest out of maquette-like materials in a way that deliberately tries to relate to the broader compositional tradition.