Optimality Theory in Jazz and Classical Music

A Senior Thesis by Nicole E. Calma

1.0 Introduction

It is not uncommon for parallels to be drawn between music and language. Recent research seems to support these intuitions, showing that the boundary between language and music may be much narrower than is currently recognized. Recent studies show that children with certain kinds of language impairment also show signs of deficiency with musical syntax (Jentschke, et al. 2005 and Jentschke, et al. 2008). Additionally, music and language may be processed in the same regions of the brain (Maess, et al. 2001). As we slowly recognize the connections between these two areas, we may ask if it is possible to explain them in similar terms as well.

In this investigation, we explore the rules of jazz and classical music according to Optimality Theory. Optimality Theory (hereafter, OT) is a theory first proposed in linguistics which uses a system of inputs and outputs to describe the properties of languages. In OT, violable constraints are formulated and ranked to create a representation of a language’s grammar. These constraints act on the input in order to produce an output which is acceptable in

* Many thanks to my adviser, Professor Dan Finer, for his help on this journey— which was often one of exploring new territory. Your guidance, input, and experience have been invaluable! Recognition and gratitude are also due to Stony Brook University’s Linguistics Department and department of Undergraduate Research and Creative Activities (URECA), who each made this work possible in their own way. To Professor Winkler, Stony Brook University Music Department, for his excellent input regarding my musical analyses, the outstanding recommendation of my transcriptionists, and, more indirectly, the information I gained from his History of Jazz class. To Phil Salathé and Krystal Grant for their transcriptions; Dan Cohen for his chord analysis; Rich Fantasia for his musical insights; and Tim Chiraz, James Joseph Messina, Scott Rossano, Jay Epelman, Hector Rodriguez Jr., Michael Cummings, Chaomin Tang, Rich Fantasia, Dave Galler, Prithviraj Rajebhosale, Farha Islam, Prasoon Goel, and Natasha Harris for their “native speaker intuitions” as participants in composition and listening tasks.
the given language. According to OT, differences in constraint ranking account for cross-linguistic differences in grammatical structure. Here, we reframe musical rules and tendencies as sets of ranked constraints with the hypothesis that different rankings create different genres.

In Section 2, we introduce the theories of Style Analysis which shape our approach. Section 2.1 explores the approach described in La Rue 1992, while Section 2.2 reviews Meyer 1989. Section 3 discusses the idea of implicit knowledge, which is introduced briefly by Section 2.2. This section also includes a discussion of OT. Section 4 describes the composition experiment which was performed, while Section 5 describes the listening experiment. Subsections within these sections relate the methods, data, and analysis of each task, respectively. Section 5.1.3 includes additional theory about category membership which bridges our discussion about the listening tasks. Section 6 draws on the analysis found in Sections 4 and 5 to propose constraints, constraint rankings, and sample tableaux for jazz and classical music. Subsection 6.1 explores harmony, while 6.2 explores melody, and 6.3, rhythm. Finally, Section 7 concludes our discussion.

2.0 Background: Style Analysis

For this project, we explored two methods of Style Analysis, the first by La Rue (1992) and the second by Meyer (1989). Each of these informed our approach towards this project in a different way.

2.1 La Rue

La Rue (1992) proposes a method for style analysis in terms of SHMRG: Sound, Harmony, Melody, Rhythm, and Growth (10). This approach provides us with a basis for viewing our data in parts, in addition to seeing the whole. La Rue states that:
the five basic elements do not stand on a completely equal footing. Taken singly in isolation, Sound, Harmony, Melody, and Rhythm in most cases cannot individually maintain successful musical structures… As a result, they typically function as contributing elements. Growth… is the combining, controlling element. (1992: 11)

In this paper, we primarily examine Harmony, Melody, and Rhythm, although a brief discussion of Sound is included in our analysis and conclusions (Sections 6 and 7). We will ignore the notion of Growth as described by La Rue, although Section 6 will include a re-assembling of these “contributing elements” (La Rue 1992: 11).

2.2 Meyer

Meyer (1989) looks at musical style with the premise that style may be described on many “hierarchical levels” (Meyer 1989: 13). Specifically, he delineates that style may include culture, movement, time period or the characteristics invoked by a single artist or “single work of art” (Meyer 1989: 13). Meyer takes both a theoretical and historical approach, discussing how different levels of style may interact, as when one discusses “French versus Italian opera in the first half of the eighteenth century” or when a composer’s approach changes over time, causing their work to be “divided into periods such as early, middle, and late” (Meyer 1989: 24).

Furthermore, Meyer proposes that “human behavior,” including musical style, “is subject to… constraints” (Meyer 1989: 8). While it is unclear if this use of the word constraints lines up with the OT use of the word, the two certainly seem to have much in common on a superficial level. Meyer claims,

the constraints of a style are learned by composers and performers, critics and listeners. Usually such learning is largely the result of experience in performing and listening rather than of explicit formal instruction in music theory, history, or composition. In other words, knowledge of style is usually ‘tacit.’ (1989: 10)

These are precisely the terms linguists use to discuss language and the acquisition of language. We will return to this idea in Section 3.
Additionally, Meyer details how constraints apply to each of the hierarchical levels of style. As we have limited our work to an investigation of genre (although we take a somewhat broad reading of what this means), this detail is not applicable to our current discussion; however, it may inform future research in this area.

Later, Meyer discusses musical “syntactic rules” and distinguishes between “possible” and “probable” (1989: 19). States Meyer:

Syntactic rules establish sets of possible functional relationships within parameters. In addition, because of the rules, some simultaneities and some successions tend to be more probable than others. In tonal harmony, for instance, it is more likely that a chord built on the second degree of the scale (II) will be followed by one built on the fifth (V) than by one built on the third (III) or the tonic (I). But neither of the latter progressions is impossible. Though such probabilities are consequences of syntax… they are not in themselves rules. (1989: 19).

We part ways with Meyer’s view here as we regard probability to be a marker of preference. We assume some underlying basis for preference and form constraints based on preferred structures in our data. It is important to note that in Meyer’s hierarchical approach to style, he considers probability to be a part of a level he terms “strategy” (1989: 19). For our purposes, we will not differentiate between the hierarchical levels claimed by Meyer.

### 3.0 Implicit Knowledge (in Music and Language) and Optimality Theory

In the previous section, we spoke of musical constraints being learned through practical use rather than teaching (Meyer 1989: 10). Guasti (2004) explains the same phenomenon occurring in language acquisition:

Unlike learning a second language in adulthood, acquiring a first or native language does not require systematic instruction. Parents usually do not teach children the rules of language or tell them what kinds of sentences they can and cannot say. Language develops spontaneously by exposure to linguistic input, that is, on the basis of what children hear. (3)¹

---

¹ For the purposes of this paper, we will ignore any potential difference between learning a “second” musical grammar vs. a “native” musical grammar. We will assume that all music is learned implicitly, at least on the perceptual level (while formal teaching is sometimes given for music composition, this is not always the case, as
Levitin echoes these thoughts (regarding music) when he states, “The appreciation we have for music is intimately related to our ability to learn the underlying structure of the music we like—the equivalent to grammar in spoken or signed languages—and to be able to make predictions about what will come next” (2007: 111). This is precisely the approach we take in this paper, assuming that both musicians and casual listeners have internalized the structure of the music, specifically, the structure of different genres. Given this intersection of Meyer’s and Levitin’s ideas with linguistic theory, we seek to access this implicit knowledge in both of the experiments we performed (which we explain in Sections 4 and 5).

For the participant, a response often constitutes a gut feeling or a decision based on what “sounds right.” For the linguist, such a response is a window into the implicit knowledge native (or, perhaps, fluent) speakers have, but cannot directly express. This is precisely the kind of knowledge we seek in exploring what makes up a genre and how this may be defined. In the experiments performed, we do not test participants’ expectations directly, but instead seek responses based on the expectations each has internalized and connected with a particular genre.

The plausibility of the hypothesis that musical and linguistic grammars are acquired the same way, and that both constitute what is considered implicit knowledge, reinforces our goal. It is with this in mind that we attempt to uncover what it is about the musical structure that distinguishes one genre from another in the mind, that is, what the mental representation of the musical structure is and how this can be represented using OT. Specifically, OT holds that constraints are universal. There are two important features of the theory that explain why languages nevertheless have different phonologies. First, languages differ in the importance they attach to the various constraints. That is, the phonology of a
language is given by the ranking of the set of universal constraints, known as that language’s constraint hierarchy. Second, constraints may be contradictory, and thus be violated: if two constraints are contradictory, the one that is ranked higher will have priority. (Gussenhoven and Jacobs 2005: 41)

OT is framed as the interaction between faithfulness and markedness. Faithfulness calls for “the exact preservation of the input in the output” (Prince and Smolensky 2002: 10). Markedness specifies “conditions on the well-formedness of the output” (Prince and Smolensky 2002: 10). For each instance of constraint ranking, which can be visualized by a tableau, a number of potential outputs will be given for a particular input. Each constraint is examined (from left to right and in order of hierarchy) and candidate outputs are eliminated as they violate constraints “until there is only one form left” (Gussenhoven and Jacobs 2005: 41). This final, remaining candidate becomes the “optimal form,” which is the output (Gussenhoven and Jacobs 2005: 41). One should note that an OT output may still violate constraints, but it is optimal in that it violates less important constraints than its competitors.

We also see the application of OT to textsetting in Hayes 2005. Hayes opens his argument with the following statements:

The textsetting problem, proposed by Halle and Lerdahl (1993), concerns how lines of linguistic text are arranged in time against a predetermined rhythmic pattern. It arises in the context of sung and chanted verse. We suppose when a person knows at least one verse of a particular song or chant, she has internalized its rhythmic pattern (2005: 2).

In these statements, we see the internalization of a pattern as the acquiring of implicit knowledge. In the case of textsetting, this is both a linguistic and musical acquisition, supporting our claim thus far that not only can implicit knowledge be linguistic or musical, but that there may be intersection between these processes or they may be the same process. Additionally,

---

2 A tableau (plural: tableaux) is a table used in OT to evaluate “the collection of possible output forms” for a particular input (Gussenhoven & Jacobs 2005:42). Tableaux will be addressed in Section 6 and will be explained thoroughly in discussion there.
Hayes goes on to frame the textsetting problem using OT’s method of “conflicting, ranked constraints” (Hayes 2005: 4). This creates a precedent for the use of OT in a musical context.

We have now provided a theoretical framework for our approach to music, as well as an exploration of the concept of implicit knowledge and how this relates to both music and language in our investigation. In the following two sections, we will describe the experiments conducted for this project. These experiments were formulated to mimic linguistic tasks.

A composition task, analogous to the collection of loanword data, is described in Section 4. Loanword data looks at what happens when speakers are “faced with the task of pronouncing an expression in a foreign language while using only the phonology of their native language” (Gussenhoven and Jacobs 2005: 35). In this situation, the input would be the foreign word or phrase, with the output exhibiting the result of the faithfulness and markedness constraints which have acted on the input.

A listening task, similar to grammaticality judgments, is described in Section 5. In grammaticality judgments, native speakers of a language rule novel stimuli as grammatical or ungrammatical based on their experience with their native language.

While both tasks seek access to the implicit knowledge the participants possess, the composition task pursues this from the standpoint of production while the listening task looks specifically at how music is perceived as one genre or another.

4.0 Composition Task

The composition task sought responses from participants who are immersed in either the jazz or classical tradition and consider themselves fluent in their given genre.
4.1 Procedure

This task asked classical and jazz musicians/composers\(^3\) to reinterpret a short musical selection of the opposing style into their own style. That is, classical musicians were given a jazz excerpt (the input) and were asked to produce a classical reinterpretation (the output). Similarly, jazz musicians were given a classical excerpt (the input) and were asked to produce a jazz reinterpretation (the output).

A total of nine participants completed this task. This was divided as follows: six participated in the original run of this task, consisting of three classical musicians/composers (the classical group) and three jazz musicians/composers (the jazz group). After this was complete, the experiment was run a second time, this time with three participants (jazz musicians/composers only). This was done in response to questions which were raised by the original jazz group data, with the purpose of confirming or refuting the results. This will be discussed further later in this section, as well as in Section 4.2.2.

Experiments were performed at Stony Brook University during three-hour sessions, although some musicians took less time. Musicians were provided with an audio recording of the excerpt which was played on an iPod via a portable speaker system (with the exception of one case, where the excerpt was played on a Dell netbook as a result of technical difficulties). Additionally, musicians were given sheet music of the excerpt. This was a transcription of the audio segment, completed prior to the experiment. Participants were also provided with blank sheet music, pencils and erasers, and a keyboard or piano. They were told they could bring other

\(^3\) For simplicity’s sake, we will use the terms “musician/composer,” “musician,” and “composer” interchangeably. While all participants reinterpreted a composition, we are referring to composition as the creation of both written and practiced (for example, improvised) music. This distinction may even be a semantic one based on what genre the musician is associated with. As stated in the earlier note, explicit instruction in composition may or may not be given based on the norms of the genre. Additionally, as we are claiming that music is learned implicitly, it may be possible for a musician (of any genre) to eventually internalize enough of the structure of his/her genre to compose within the genre. Finally, as the task required a reinterpretation (composition), we refer to these participants as composers, whether or not they would refer to themselves as such.
instruments, or a laptop (with music notation software) if they felt this would help complete the task. One participant worked on guitar, while another used an electric bass. The other seven used the piano/keyboard, a laptop, or both. It should be noted that even of those who used a keyboard, not all submissions were composed for piano.

Finally, participants were given the option of submitting their work by notating it on staff paper, using music notation software, or by playing their work and having it recorded on a portable audio recorder. Two participants chose to record their work; these pieces were then transcribed.

Excerpts were approximately 10-12 measures in length and approximately one minute long. The classical input was an excerpt of “Stormy Weather” by Art Tatum. The input for the first jazz group was an excerpt of Bach’s Prelude in Eb Minor. The input for the second jazz group was Bach’s Little Prelude in F major. This piece was chosen specifically because it matched both the time signature and key signature of the classical group’s input. Additionally, it was chosen for having stronger melodic characteristics than the excerpt chosen from Prelude in Eb Minor as this was a concern in light of the first jazz group’s results. This will be discussed in Section 4.2.2.

4.2 Results and Musical Analysis

In the following sections, we state the results found by the composition tasks. We will frame these from a musical standpoint, setting the stage for the application of OT in Section 6. For the sake of clarity, as well as style analysis based on La Rue 1992, we will discuss harmony, melody, and rhythm separately.
4.2.1 Harmony

Harmony refers to the chords and chord progressions, as well as “all other relationships of successive vertical combinations, including counterpoint, less organized forms of polyphony, and dissonant procedures that do not make use of familiar chord structures or relationships” (La Rue 1992: 39). Chords will be shown here, at times, using musical notation, but we will typically refer to them using a standard Roman Numeral Analysis. For ease of comparison, this analysis was then transferred into a spreadsheet, from which some of our figures are taken.

When multiple interpretations of a chord or chord voicing are possible, we will list all of these possibilities as [chord 1] or [chord 2]. When several chords occur in a measure, we will list additional possibilities in line with the chord they alternate with, when possible.

In the composition task, we found that most participants altered the chord progression of the input selection they were given. The resulting chord progressions were often similar enough to the original so that patterns could be extracted, although the new progressions clearly worked to transform the piece into a new genre as well as avoid or repair any structures that were inappropriate to this new genre (to be discussed further in Section 6).

Specifically, we noted that Classical musicians often omitted chords or even several adjacent chords in the progression. We will refer to this hereafter as deletion. On the other

---

4 Roman Numeral Analysis is a common form of musical analysis. “Roman Numerals are employed to indicate the chord within the tonality of the composition” (Cole & Schwartz 2011). Most chords used are built on thirds (triads) and are identified as being built on the various scale degrees (1-7, representing the notes which, within an octave, are named using letters A-G, with the 8th note repeating the first in the pattern). Explain Kostka and Payne, “to distinguish the triads built on the various scale degrees from the scale degrees themselves, we use roman numerals instead of arabic numerals” (2004: 60). “The Roman Numerals are placed under the staff inline with the chord” they represent (Cole & Schwartz 2011). Furthermore, Roman Numeral Analysis describes not only the scale degree the chord is built on, but the quality of the chord. “Upper-case numerals represent major triads. Lower-case numerals represent minor triads. Upper-case numerals with a small plus sign represent augmented triads. Lower-case numerals with a small circle represent diminished triads” (Adams 2011). While the correct notation will be shown in our examples, we will not concern ourselves with chord quality. Additionally, superscript and subscript numbers next to roman numerals mark chord inversions, this too will not be a main topic of our focus. What should be attended to is the roman numeral itself, as well as added notes (marked by a superscript 7 representing the addition of the 7th or the word add followed by the scale degree added).
hand, Jazz musicians in the first Jazz group had a tendency to add new chords into the progression, between pre-existing chords found in the original. We will refer to this now as *epenthesis*. These terms will be discussed in greater detail in Section 6. Right now, we will say that these phenomena occurred when the participant of a certain genre found something about the original selection to be unacceptable or not preferred by his/her genre. The assumption here is that if a structure contained in the original was acceptable and/or preferable, it would not be changed in the output. Furthermore, if a structure was changed, there was a motivation for this change. It is these motivations that we will be framing as constraints, based on the consistency with which they appear in the output selections of each genre.

Beyond these two main trends, other alterations often appeared. For instance, the first chord of the Classical input was $i$. This was changed by the three jazz participants to $i^7$, $I^7$, and $I^7$ (See Figure 1). We will ignore the alternation between major and minor.

*Figure 1*

<table>
<thead>
<tr>
<th>Excerpt</th>
<th>m1</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;C&quot;</td>
<td>i</td>
</tr>
<tr>
<td>J1</td>
<td>$i^7$</td>
</tr>
<tr>
<td>J2</td>
<td>$I^7$</td>
</tr>
<tr>
<td>J3</td>
<td>$I^7$</td>
</tr>
</tbody>
</table>

Likewise, in the Jazz input, the first measure contains a $III \text{ add } b9$ chord. This is picked up by two of the Classical musicians (or all three, depending on how the chords are interpreted). Both (or all) of the Classical participants drop the flatted 9th to create a simpler $iii$ chord (See Figure 2). Note that we have highlighted the pertinent chords in yellow. Again, for our purposes, we will ignore the change in quality here (from major to minor).
Stating that Classical music simplifies things while Jazz music amplifies them would be a gross over-simplification and often a misrepresentation of the two styles, both of which are complex in their own right. However, certain chords or elements of chords are more typically found in Jazz, and for this reason the presence or addition of 7th s or 9th s in Jazz chords, while these are absent or dropped in Classical chords, is not surprising.

Lastly, some chords appeared to play multiple roles or defy overall categorization. For instance, the I chord (the tonic) seemed to operate according to a different set of rules from the other chords and was able to repeat multiple times (appearing adjacent to itself three or more times) or appear without apparent prompting. This was not the case for other chords. We observe, for instance, a dispreference for VVV in Jazz (three V chords appearing adjacent to one another). This is observed only once in all of the Jazz selections (input and outputs). When multiple V chords appear in the Classical input, one Jazz participant solves this by inserting a bIII, two variations of a IV chord and swaps the last input V with the following i chord (metathesis), as seen below in Figure 3. Note that we have highlighted the V chords in yellow, the epenthesized III and IVs in blue, and the metathesis in green.
The second Jazz group did not seem to support the results seen in the first Jazz group as much as expected. Specifically, there was much more deletion seen and simple changing of chords. One participant omitted all V chords in the input, using the V only in the final cadence. This deletion, however, seemed to be a trend with all three participants for this input selection. Many of the participants chose a few chords to focus on, ignoring the other input chords. As with the earlier composition tasks, most participants’ reinterpretations greatly exceeded the length of the input. For the second Jazz group, the input was a fifteen-measure selection. Interestingly enough, the first two participants created identical chord progressions (looking at the roman numeral analysis, but not specifically at the chord voicing/quality) from measures 17 through 45\(^5\). The exception here is that every time Participant 1 used a vii\(^o\) chord, Participant 2 used a V. We cannot attempt to explain the cause of this result, although this seems to reflect some sort of clear intuition regarding the acceptable reinterpretation of the given Classical input.

4.2.2 Melody

If Harmony refers to the vertical aspects of a musical selection, Melody refers to the horizontal aspect. La Rue calls this the “profile formed by any collection of pitches” (1992: 69).

For the purpose of this paper, we will consider melody to be two adjacent pitches of an equal

---

\(^5\) Participant 2’s selection ended at this measure, measure 45. Participant 1’s selection continued, ending at the 64\(^{th}\) measure.
interval, regardless of the duration of those pitches (Rhythm). So with an input of Figure 4, we would still consider Figure 5 to be faithful to the melody. In Figure 5, we have shown only the melody.

**Figure 4**

![Figure 4](image)

**Figure 5**

![Figure 5](image)

Additionally, if a particular output is in a different key or is built on a different chord than the input, it would still be considered faithful to Melody if the adjacent pitches are of an equal interval (even if these are not the exact pitches heard in the given input). So with an input of Figure 6, we would still consider Figure 7 to be a faithful representation of this melody.

**Figure 6**

![Figure 6](image)
In the original run of the composition experiment, we found that when reinterpreting the input selection, Classical musicians adhered more strictly to the original melody than Jazz musicians did. In fact, we observed very little similarity between the input melody the Jazz musicians received and the output selections they created. (In Section 6, this will be interpreted as a lack of Faith (Melody), meaning that the input and output is the same for the domain of Melody.)

This finding prompted the second composition run to be performed. This task used a new Classical selection as the input and was completed by three new Jazz musicians, based on the possibility that the original Classical input may not have had a strong enough melody for the Jazz participants to latch on to. The results of the second Jazz group composition task disprove our initial theory that Faith (Melody) is of lower priority in Jazz. In fact, the results of the new Jazz group for Melody were not appreciably different from the results of the Classical task.
4.2.3 Rhythm

Rhythm “is a general term used to refer to the time aspect of music” (Kostka & Payne 2004: 25). Terms associated with rhythm are beat\(^6\), tempo\(^7\), and meter\(^8\). Musical notation assigns certain durations to certain symbols, based on the time signature\(^9\). Figure 8 shows a sample of musical notation and the value of each symbol.

*Figure 8*

<table>
<thead>
<tr>
<th>Value</th>
<th>Note</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breve</td>
<td>(\mathbb{M} = \text{\textbullet} + \text{\textbullet})</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
</tr>
<tr>
<td>Whole</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
</tr>
<tr>
<td>Half</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
</tr>
<tr>
<td>Quarter</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
</tr>
<tr>
<td>Eighth</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
</tr>
<tr>
<td>Sixteenth</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
<td>(\text{\textbullet} = \text{\textbullet} + \text{\textbullet})</td>
</tr>
</tbody>
</table>

(Kostka & Payne 2004:25)

In the composition experiment, we will consider a rhythm faithful if the durations of notes and rests are kept in proper proportion to the input selection. That is, if a particular input note has been doubled in duration, we will not view this as a violation of Faith (Rhythm) so long as other adjacent notes have also been doubled in duration. An example of this is shown in Figure 9 (input) and Figure 10 (output). These figures are identical to Figure 4 and Figure 5, but

---

\(^6\) Beat refers to the “basic pulse of a musical passage” (Kostka & Payne 2004: 26).

\(^7\) Tempo is “the rate at which the beats occur” (Kostka & Payne 2004: 26).

\(^8\) Meter expresses the “pattern” the beats “tend to be grouped into” (Kostka & Payne 2004: 26).

\(^9\) A time signature “is a symbol that tells the performer how many beats will occur in each measure, what note value will represent the beat, and whether the beat is simple or compound” (Kostka & Payne 2004: 29). Most of the music we deal with here contain simple time signatures, with three or four beats to a measure, although there are some exceptions.
we will look at them now through the lens of rhythm. Note that we now show more of this output segment. There are still more instruments in this arrangement, but all others are at rest in these measures. We have provided both voices which are heard at this time. Note that for both of these voices, durations are doubled\textsuperscript{10}.

Figure 9

![Figure 9](image)

Figure 10

![Figure 10](image)

\textsuperscript{10} As the time signatures differ for these two pieces, we might consider this a lack of faithfulness as the feel of the stress of the beat will be different. However, we will choose to focus on the note values themselves.
Rhythm will be discussed further in Section 5 with discussion of the listening tasks, and again in Section 6.3. Based on the composition task, no further conclusions based on rhythm were drawn as participants seemed to violate or uphold *Faith (Rhythm)* with equal acceptability.

**5.0 Listening Task**

Two listening tasks took place. Although they are similar in some regards, they differ enough that we will treat them separately for the sake of clarity.

**5.1 Listening Part I**

The first listening task was performed following the first run of the composition task. This task is described in the following sections.

**5.1.1 Procedure**

In this task, segments of the reinterpretations from the first run of the composition task were chosen and ordered so that similar sections could be compared. Segments were created on music notation software and played for participants using the same software. Each segment was approximately 1-2 measures long and was played at the tempo notated by the composer-participant who created it.

Seven people participated in the task. Due to the simple set up of the task, which required only a laptop, the task was run in many locations, all of which were quiet to moderately quiet to enable the participants to hear the selections clearly.

Participants completed a short questionnaire asking them to describe how often they listened to jazz and classical music, as well as what other styles of music they had experience with. Participants then listened to the segments, which were played on a laptop using the laptop’s internal speakers.
Segments were played in groups of twos or threes and participants rated each grouping according to how well segments fit the style being asked about (See Figure 11). Participants had access to the audio only and were not able to see the notation. For instance, a participant listening to a group containing segments X1a and X1b might be asked to respond by marking which segment was more “jazz.” Participants were asked to mark their answers on a response sheet which they were provided with. The response sheet offered a multiple-choice style selection as seen in Figure 12. In this way, only one response would be chosen for each grouping, although groupings of three segments also included response choices of combinations of two segments being equally classical or jazz, while excluding the third segment of the group. There were twenty-eight groupings of segments that each participant listened and responded to.

Figure 11

Figure 12

For X-Z, Please select the choice that sounds more “jazz.”

Section X.

1. a  b  both equally  neither

2. a  b  both equally  neither

At the completion of the task, all participants’ responses were tallied. Notations were made as to which responses seemed to show strong preferences (5 or more out of 7 selecting the
same response). Additionally, attention was given to which questions did not invoke strong preferences, specifically, when responses were scattered over many choices or there was a strong split between two choices.

### 5.1.2 Results and Musical Analysis

Of the twenty-eight questions, nine invoked strong preferences. Twelve were shown to not invoke any strong preferences. Table 1 explains the criteria for these observations. We will then discuss a few examples.

**Table 1**

<table>
<thead>
<tr>
<th>Strong Preference Exists</th>
<th>5, 6, or 7 participants selected a particular example over another</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Strong Preference Exists</td>
<td>Participants’ selections scattered over many choices (ie, 1-2-1-3) or Strongly split between two choices (ie, 3-4 or 3-3-1)</td>
</tr>
<tr>
<td>Other</td>
<td>Some preference shown, but not particularly strong or scattered (ie, 4-2-1 or 4-1-1-1)</td>
</tr>
</tbody>
</table>

In terms of Harmony, Melody, and Rhythm, these brief examples (~2 measures each) were too short for a listener to hear much of a chord progression; in fact, most of the samples only contained between one and three chords. Additionally, as Melody is the horizontal aspect of music and we constrained the length of the piece, only a few melody notes could be heard. While these short melodic elements and chord progressions certainly contributed to listeners’ perception of the music, what could be heard best was the quality of the chords used and rhythm. As we discuss the following examples, we will use lower case letters in parentheses (x) to refer to segments as marked in the figures. Capital letters not in parentheses will refer to note names.
Examples of Strong Preference

Figure 13 is an example of one comparison listeners were asked to make. In this section of the task, listeners were asked to select the segment which sounded “more classical” to them. Both selections (a) and (b) should be considered classical, as each was taken from a classical reinterpretation of the Jazz input. Specifically, we are looking at the first half-measure (approximately) of each piece, in response to the first two or three chords of the Jazz input.

In this comparison, six of seven participants chose (b) as sounding more classical. (One participant said “both” sounded more classical. In other words, they sounded equally classical.) Based on our chord analysis, we see that the chord progression and chord qualities are approximately the same. This leaves the domains of Melody and Rhythm as the basis for the difference perceived. The last two melody notes are equivalent (an octave apart). Melodically, the difference between (a) and (b) is the G# in (a), and the F in (b), which is

---

11 We will consider melody to be the top line in example (a). In addition to the tendency for melody to be read as the top line, this is also identical to the melody of the Jazz input.

12 An octave is the span of any note, as identified by its letter name, up to the next occurrence of the next note which has that same letter name. Remember, as discussed in a previous footnote, that notes of the scale are named using letters A-G as a repeating pattern. So two notes an octave apart will be the same scale degree, but will sound as higher or lower than its counterpart.
probably replacing the G#\(^{13}\). Segment (b) also contains an additional note in the beginning, C, which results in a melodic leap from C to F. We may note here that the melody of the Jazz input is identical to segment (a). While this may explain the tendency for (b) to sound more Classical, we must not ignore the very different rhythm of (b), which may also account (at least in part) for this Classical sound. Specifically, while (a) uses quarter and half notes to produce chords, (b) presents a straight sixteenth note rhythm. We may also note that, as an intersection of melody and rhythm, the accompaniment of (b) is arpeggiated, that is, the chord is played in such a way as to create a melodic pattern (as opposed to the block chord method where all the notes of the chord are played at once).

*Example of No Strong Preference (Split)*

In Figure 14, we see another comparison listeners were asked to make. For this example, listeners were again asked to choose the more classical sounding sample and each segment was taken from a Classical reinterpretation of the Jazz input. For this example, three participants said both sounded more classical (equally classical), three participants selected (d) as the more classical segment, and one participant chose (c) as the more classical.

*Figure 14*

---

\(^{13}\) The Jazz input and all three Classical reinterpretations were written in F major, so one should note that any difference in specific notes used is not a function of key.
We might note that the melodic and rhythmic ideas in these segments are largely similar. (Recall our earlier discussion on rhythmic values: (c) uses eighth notes where (d) uses sixteenth notes in the first measure of the melody. Likewise, (c) uses a quarter note in the first measure of the bass where (d) uses an eighth note. In this way, (c) doubles the rhythmic values used in (d).)

It is the chords here that differ, although with only one or two chords in each segment, it is questionable whether or not this is enough for a listener to grasp in order to distinguish genre. As there was such a strong split between responses, we see that it was difficult for listeners to differentiate between the two pieces. Not only was there a clear split between the responses, but approximately half of the participants heard the segments as equally Classical. To account for the other half, which heard (d) as more classical, we might hypothesize a connection with our assessment of (b) in Figure 13, as both of these segments used sixteenth notes (despite our discussion of (c) and (d) as having approximately equivalent rhythmic features).

Example of No Strong Preference (Scatter)

Figure 15 shows two segments listeners were asked to compare. For this question, listeners were asked to identify the piece that was “more jazz.” Both segments were taken from Jazz reinterpretations of the first Classical input.

Figure 15
This is another example of a comparison for which there was no strong preference. However, unlike our last example (where the results were primarily split between two choices), our results showed far less preference for any one or two responses (recall that each participant could respond in one of four ways). For this comparison, three participants claimed (e) was “more jazz,” two selected (f), and two said neither were.

We might note that, again, the chords used in these segments are similar, and there is nothing particularly distinguishing about either melody. Furthermore, there appears to be no distinct difference in rhythm. Note that (e) shows an eighth note melody with a whole note accompaniment, while the second measure of (f) shows sixteenth notes in the melody with half notes in the accompaniment. As discussed in Section 4.2.3, we treat these as approximately equivalent.

5.1.3 Rosch, Levitin, and Category Membership

In retrospect, this experiment touches on the work of Eleanor Rosch. Rosch’s work, based on the philosophies of Wittgenstein, discusses category membership (Levitin 2007: 141). Rosch came to five main conclusions:

(a) categories are formed around prototypes;
(b) these prototypes can have a biological or physiological foundation;
(c) category membership can be thought of as a question of degree, with some tokens being “better” exemplars than others;
(d) new items are judged in relation to the prototypes, forming gradients of category membership;
(e) there don’t need to be any attributes which all category members have in common, and boundaries don’t have to be definite. (Levitin 2007: 145)

Levitin goes on to discuss the results of some “informal experiments” he has done (2007: 145).

This research has found that:

People appear to agree as to what are prototypical songs for musical categories, such as ‘country music,’ ‘skate punk,’ and ‘baroque music.’ They are also inclined to consider certain songs or groups as less good examples than the prototype: the Carpenters aren’t
really rock music; Frank Sinatra is not really jazz, or at least not as much as John Coltrane is. (Levitin 2007: 145)

This, in fact, is a basic assumption of our work. While in the composition task, we view the inputs and outputs as either Classical or Jazz, this first listening task recognizes the gradient effect Levitin and Rosch talk about. This task often asked participants to compare two segments which should be viewed as the same genre, but to choose what would, essentially, be more prototypical of that genre. In doing this, we seek to identify the technical aspects of a selection and identify what genre these structures are prototypical of. By doing this, we begin to see how different musical structures are perceived by listeners and how these structures (and manipulations of these structures) fit into the categories we consider to be genre. If OT may be used to describe music, a manipulation of one domain may actually change what is perceived in the output. For instance, a change in a ranking of constraints may actually create a new grammar, so an altered output based on such a new constraint ranking may be perceived as an entirely different genre.

In the previous section, we discussed how we identified structures which appeared to be associated with either the Classical genre or the Jazz genre. In the following section, we will discuss the second listening task which was performed. In this task, we made specific alterations to audio segments based on the structure-identity relationships we identified in the first listening task.

5.2. Listening Part II

While the original listening task looked for more general tendencies, the second listening task looked specifically for ranking between constraints for Harmony and constraints for Rhythm, to see if any such preference exists and, if so, how it might be qualified. As this task was performed after the second run of the composition task (making it the last task to be
performed in our data collection), the question we seek answers to here is based on the results and interpretations of both composition trials as well as the original listening task.

5.2.1 Procedure

An excerpt of the selection the Classical group received and an excerpt of the selection the second Jazz group received were chosen. Using these excerpts, four segments were created. The first of these was identical to the Classical excerpt. The second used the harmony of the Classical excerpt, but paired with the rhythm of the Jazz excerpt. The third was identical to the Jazz excerpt. The fourth reversed the second sample, using the Jazz harmony paired with the Classical rhythm. See Table 2.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>Harmony Used</th>
<th>Rhythm Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>Classical</td>
<td>Classical</td>
</tr>
<tr>
<td>Sample 2</td>
<td>Classical</td>
<td>Jazz</td>
</tr>
<tr>
<td>Sample 3</td>
<td>Jazz</td>
<td>Jazz</td>
</tr>
<tr>
<td>Sample 4</td>
<td>Jazz</td>
<td>Classical</td>
</tr>
</tbody>
</table>

These were copied into or created using music notation software and playback from the music notation software was recorded and exported as MP3 files. This was done in order to avoid personal or stylistic changes to the music that might be added in real performance, as well as to control the tempo. Furthermore, as the task required a mismatch of harmonies and rhythms, the unnatural matching might be hard to play, complicating what the listener would hear on playback.
Data was collected during a poster presentation session at Stony Brook University. Participants completed the task using a laptop and headphones. While the setting was not very quiet, the headphones used were partially noise-cancelling and a test was done on set-up to be sure that the selections were audible and could be easily heard. For this reason, noise should not be viewed as affecting the completion of the experiment.

The four MP3 files were embedded into a PowerPoint Show, which a participant could self-pace their way through. Specifically, a participant would click to open the PowerPoint Show and follow the directions stated on each slide which instructed them to listen to each selection and answer if each selection was “Classical,” “Jazz,” or “Neither” on the provided response forms. Figure 16 shows a sample screenshot from this task. Response forms were numbered to correspond with the four samples, with space for the participant to write in his or her choice for each selection. Participants could listen to each selection as many times as needed to complete the task. Twelve people participated in this task. The task was open to anyone who listened to music and wanted to participate.

*Figure 16*

**Sample 1**

For the following segment, please answer if the selection is JAZZ, CLASSICAL, or NEITHER.

Write your choice on the response form provided next to \#1. Then click to advance to the next slide.
5.2.2. Results and Analysis

The results of this task are summarized in Table 3.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Classical Harmony</td>
<td>Classical Harmony</td>
<td>Jazz Harmony</td>
<td>Jazz Harmony</td>
</tr>
<tr>
<td>Classical</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Jazz</td>
<td>2</td>
<td>6</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Neither</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total # of Participants</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

As seen in Table 3, of our samples with matching rhythms and harmonies, Sample 1 was primarily perceived as Classical. Sample 3 was overwhelmingly heard as Jazz. Of our mismatched samples, Sample 4 (Jazz Harmony with Classical Rhythm) was largely perceived as Jazz. Sample 2 (Classical Harmony with Jazz Rhythm), on the other hand, was the only Sample without a clear consensus. Listeners had a distinct split for this sample, with almost half choosing each Jazz or Classical.

These mismatched samples tell us some interesting things about how genre may be perceived. Much more data would be needed in order to generalize this result beyond our specific examples (especially, data collected reflecting participants’ perceptions of several token harmonies and rhythms of each genre). However, from our data, we can see clearly that the Jazz harmony we chose to test is clearly perceived as Jazz. Furthermore, this seems to be what listeners attended to, even when this was paired with the Classical rhythm we chose. In the next section, we will discuss this as a potential ranking of Harmony as more important than Rhythm.
within the genre of Jazz. This is not to say that Jazz does not have a tendency or preference to use certain rhythms more than others. An alternative interpretation is that the Classical rhythm chosen is simply also acceptable in Jazz.

In Sample 2, we might interpret participants’ lack of agreement on genre as a sign that perhaps there is no ranking between Harmony and Rhythm for Classical music. Alternatively, there may be a constraint which states that it is the combination of Harmony and Rhythm that is ranked high. Although a larger sample size may give clearer results, we may also view the results for Sample 2 as supporting our hypothesis from the first listening task regarding Classical Rhythm. We see in our results that, while there was an almost equal split between participants who said this selection was Classical as participants who said this selection was Jazz, slightly more claimed this piece was Jazz. As all other factors were controlled for, we may explain this by hypothesizing, as we did after the first listening task, that certain rhythms (such as strings of straight sixteenth notes) are preferable in Classical music. The absence of this rhythm, as replaced by a rhythm with a slight swing\(^\text{14}\) to it, caused a slight majority of participants to perceive this selection as Jazz. Once again, further research would be needed in order to more confidently make these claims. As with the results for Sample 4, it is possible that both rhythms and harmonies used in Sample 2 are simply equally acceptable in both genres. Furthermore, with both Samples 2 and 4, we also encounter that the terms “Jazz” and “Classical” may mean different things to different people (we might refer back to Meyer’s theory and how genre intersects with location, era, and other variables).

\(^{14}\text{Swing} \text{ may be defined as the “sense of momentum created by push and pull over the constant underlying beat” (Winkler 2011). This often is heard as an effect of subdivisions of the beat, or “rhythmic pulses smaller than the beat” (Winkler 2011:1). Swing occurs as an uneven division of these subdivisions (Winkler 2011:2).}\)
6.0 Constraints and Constraint Rankings

In this section, we will discuss some of the examples we have looked at previously, while overlaying an OT perspective. Constraint rankings will be proposed and tableaux used to further explain this analysis.

6.1 Harmony

Here we will discuss constraints regarding Harmony. Table 4 defines the constraints we will utilize in this discussion, as well as some common OT symbols.

Table 4

<table>
<thead>
<tr>
<th>Constraint/Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Violation of Constraint</td>
</tr>
<tr>
<td>!</td>
<td>Fatal Violation</td>
</tr>
</tbody>
</table>
| \(
\)               | Correct/Selected Output                      |
| IDENT-IO (Harmony)| Input and output are equal for Harmony (faithfulness) |
| DEP-IO (Harmony)  | No epenthesis for Harmony; do not insert chords |
| MAX-IO (Harmony)  | Do not delete chords                         |
| DEP-IO (Chord)    | Do not epenthesize chords; do not insert notes into chords |
| *VVV              | No V-V-V progression                         |
| Insert 7th        | Insert 7th of chord                          |

6.1.1 Example 1

In this example, we will revisit Figure 1, labeled here as Figure 17. Remember that our observation in this example was the addition of the 7th of the chord in the Jazz reinterpretations.
As shown in Table 4, the constraint proposed for this very strong tendency (shown by all three participants) is *Insert 7th*. This is countered by the opposing constraint of *DEP-IO (Chord)*. In order for the result we encountered in our experiment to occur, *Insert 7th* must be ranked higher for Jazz musicians than *DEP-IO (Chord)*. This is shown in the following Tableau.

**Tableau 1**

<table>
<thead>
<tr>
<th>Input</th>
<th>Insert 7th</th>
<th>DEP-IO (chord)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>i</td>
<td>*!</td>
</tr>
<tr>
<td>(b)</td>
<td>i7</td>
<td>*</td>
</tr>
<tr>
<td>(c)</td>
<td>i + add4</td>
<td>*!</td>
</tr>
</tbody>
</table>

In Tableau 1, we see the input is the Classical *i*. Three potential output candidates are proposed as shown in (a), (b), and (c). Candidate (a) represents an exact replica of the input. Candidate (b) is the actual output we observed. Candidate (c) is another possible alternative. Given this constraint ranking, we see that Candidates (a) and (c) both receive a violation for *Insert 7th*. This violation is fatal and only (b) moves on as a potential output. While (b) violates *DEP-
IO(Chord), this constraint is ranked lower than Insert 7th. Since this is a lower-ranked constraint and Candidate (b) is the only remaining candidate. This is selected as the optimal output.

6.1.2 Example 2

Tableau 2 references Figure 3, which is relabeled below as Figure 18. We will ignore the metathesis here, focusing only on the epenthesis. This is used as a repair strategy to address the violation of *VVV and attempt to create an acceptable output.

Figure 18

<table>
<thead>
<tr>
<th>&quot;C&quot;</th>
<th>V6 V5</th>
<th>V5sus4 i (vi6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J2</td>
<td>IV bV V bIII bV IV IV6</td>
<td>....(roots only, passing dissonance, etc)</td>
</tr>
</tbody>
</table>

Tableau 2

<table>
<thead>
<tr>
<th>V6 V5 V6sus4 i</th>
<th>*VVV</th>
<th>IDENT-IO (Harmony)</th>
<th>DEP-IO (Harmony)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) V6 V6 V6sus4 i</td>
<td>*!</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>b) bV V bIII bV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) I I IV I V I</td>
<td></td>
<td></td>
<td>****!</td>
</tr>
</tbody>
</table>

In Tableau 2, Candidate (a) again represents an identical form to the input. Candidate (b) is the observed form according to our data. Candidate (c) is a blues progression—an alternative chord progression that could have been chosen. Candidate (a) receives a violation for *VVV.

Violations for IDENT-IO (Harmony) are given according to how many chords are different from

---

15 A repair strategy is the way in which a speaker goes about addressing unacceptable or impossible forms according to his/her grammar.
the input. Candidate (b) incurs a violation here due to the addition of the $bIII$. Candidate (c) incurs four violations because only the last two chords of this progression match the input chords. As $*VVV$ and $IDENT-IO$ ($Harmony$) are not critically ranked (that is, one does not take priority over the other), and Candidate (c)’s four violations outweigh Candidate (b)’s single violation, both (a) and (c) are eliminated.\footnote{At present, we have no data giving us reason to believe that one of these constraints is ranked higher than the other. Furthermore, critically ranking either constraint over the other will still provide an output of Candidate (b).} This leaves Candidate (b) as the winning candidate and our output.

6.1.3 Example 3

The following tableau shows a very schematic constraint ranking for the Classical group’s response to the input Jazz Harmony.\footnote{The data contained in this tableau was mentioned previously in our discussion of Harmony in the composition task, however, this data does not reference a specific example given. This tableau should be viewed as a sample of a potential constraint ranking for this observed phenomena rather than a proposed ranking.} Based on our data, there is no overt reason why deletion took place, although we assume this to be a repair strategy used to repair some dispreferred form. In Tableau 3, we refer to the motivation for deletion as Constraint $X$.

Candidate (a), an identical form to the input, is eliminated by Constraint $X$. Candidates (b) and (c) are both outputs observed in our data. While we are focusing on the output (b) as the winning candidate in this example, we cannot explain the alternation between (b) and (c). For our purposes, we have used Constraint $Y$ as a placeholder here, eliminating (c) as a potential output; however, these outputs may occur in free variation or operate on some other rule set. Further research may help to shed light on this issue.
In this section, we will discuss melody using the constraints in Table 5. Common OT symbols have been included in this table again for convenience. Two tableaux follow; the first giving an account of a faithful melody and the second of an unfaithful melody (this example is taken from the first Jazz group’s data). As our data did not lend itself towards a hypothesis for why FAITH (Melody) was ranked low for the first Jazz group (besides commentary by some of our participants and a fellow musician), we will not specify an opposing constraint for FAITH (Melody), but will simply notate this as Markedness.

**Table 5**

<table>
<thead>
<tr>
<th>Constraint/Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Violation of Constraint</td>
</tr>
<tr>
<td>!</td>
<td>Fatal Violation</td>
</tr>
<tr>
<td>→</td>
<td>Correct/Selected Output</td>
</tr>
<tr>
<td>IDENT-IO (Melody)</td>
<td>Input and output are equal for Melody; FAITH (Melody)</td>
</tr>
<tr>
<td>Markedness</td>
<td>Opposition to IDENT-IO (Melody)/FAITH (Melody)</td>
</tr>
</tbody>
</table>
6.2.1 Example 1

This example gives a representation of the musical notation shown in Figures 4 and 5. We will notate these examples here using the note’s letter names.\(^{18}\) Note that we have ignored the grace note. See Tableau 4, below.

<table>
<thead>
<tr>
<th>Tableau 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Db C Bb F F Gb F Eb Db C Bb Ab Gb Ab F</td>
</tr>
<tr>
<td>a) Db C Bb F F Gb F Eb Db C Bb Ab Gb Ab F</td>
</tr>
<tr>
<td>b) F Eb Db Eb C Bb A Bb F</td>
</tr>
<tr>
<td>c) F Gb F C Ab F</td>
</tr>
</tbody>
</table>

In this tableau, we see the winning candidate, (a), is the most faithful candidate to the input. Candidates (b) and (c) represent possible alternatives to this and incur fatal violations by IDENT-IO (Melody).

6.2.2 Example 2

Tableau 5 looks at the same input/output scheme as Tableau 4. Here, however, we see that in the musical grammar, Markedness and IDENT-IO (Melody) have switched places, creating a different output due to the new constraint ranking. Note that we now need a third constraint in order to eliminate Candidate (c). As no such constraint can be proposed based on our current data, we have marked this as Constraint Z.

\(^{18}\) Input and output are written in the same key.
6.3 Rhythm

The most notable occurrences we observed for the domain of Rhythm was swing in Jazz and our hypothesis regarding strings of straight sixteenth notes for Classical music. Table 6 proposes constraints for Rhythm, followed by Tableaux 6 and 7.

Table 6

<table>
<thead>
<tr>
<th>Constraint/Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Violation of Constraint</td>
</tr>
<tr>
<td>!</td>
<td>Fatal Violation</td>
</tr>
<tr>
<td>→</td>
<td>Correct/Selected Output</td>
</tr>
<tr>
<td>IDENT-IO (Rhythm)</td>
<td>Input and output are equal for Rhythm (faithfulness)</td>
</tr>
<tr>
<td>Swing</td>
<td>Use uneven subdivisions of beat</td>
</tr>
<tr>
<td>16thNotes</td>
<td>Use 16th Notes</td>
</tr>
</tbody>
</table>
In this example, we see a rhythmic idea taken from the second Classical input. Candidate (a) is completely faithful to the input, while Candidates (b) and (c) give other potential rhythmic ideas. Candidate (c) is an actual representation of the rhythm of one of the Jazz reinterpretations for this input. As we see, Swing is ranked high, immediately eliminating (a) and (b).

In Tableau 7, we see the opposite ranking of Swing and 16th Notes. The input for this Tableau is a rhythmic idea from the Jazz input. Candidate (a) is a rhythmic idea from one of the Classical reinterpretations of this segment, (b) is an alternative rhythm, and (c) is a completely faithful rhythm. Here, we see that 16th Notes is ranked high, eliminating (b) and (c).


6.4 Sound

Referring back to La Rue 1992, Sound encompasses timbre, dynamics, and texture/fabric (23). Although dynamics and texture certainly may play a role in genre, the feature most notable to our discussion is timbre. Timbre includes the factor of instrumentation.

Recall that, for the composition task, all three input selections were solo piano. However, many of the output selections altered the instrumentation of the input. See Table 7 for a summary of how participants changed instrumentation (and, therefore, Sound).

Table 7

| Classical input 1: Solo piano | Jazz reinterpretations: solo piano  
solo guitar  
band consisting of clarinet, saxophones, trumpet, trombone, percussion and piano |
| Classical input 2: Solo piano | Jazz reinterpretations: piano and electric bass  
score for saxophone, trumpet, trombone, guitar, drums, and double bass  
score for saxophones, trumpets, trombones, guitar, piano, bass, and drums |
| Jazz input: Solo piano | Classical reinterpretations: solo piano  
string quartet (cello, viola, and two violins)  
woodwinds and horns (flute, oboe, clarinet, bassoon, horn, trumpet, trombone, and tuba) |

Clearly, it is possible for both genres to be played by a solo piano. However, instrumentation and Sound may still impact the perception of genre. Specifically, we might note the use of a string quartet by one of the Classical musicians and the use of electric instruments (here, bass) by one of the Jazz musicians. We might ask if switching these sounds has a bearing on category perception.

---

19 A piano sound was also used for both listening tasks.
While it is outside of the scope of this project, we might note that there are many Classical groups which play Rock or Heavy Metal music. Further research might address if, when hearing such groups, listeners perceive the selections played as Rock or Classical (or if these pieces are perceived as somehow belonging to both categories). We might also ask if, when adapting such pieces, only the instrumentation is changed or if there are other changes to harmony, melody, or rhythm as well.

Looking into other aspects of Sound, we might pose questions about timbre and dynamics. For instance, does the timbre of electric instruments affect the genre associated with them? While dynamic changes are frequently made throughout a performance, some genres (such as Rock music) are often known for being loud. Is loudness a marker of category membership for the genre of Rock? Is a Rock song played quietly somehow less Rock?

Constraints may be proposed for these qualities as well, although we hypothesize that these may be utilized in combination with other constraints. Specifically, we might propose a *Electric constraint for Classical music or a *Orchestra constraint for Rock\textsuperscript{20}.

Finally, different instruments may also have physical constraints when adapting a new genre of music. Repair strategies may be needed in order to satisfy the genre’s constraints. An example of this would be blue notes\textsuperscript{21} in Jazz. When played on the piano, blue notes seem to fall “in between” the keys and impossible to reach. To repair this problem, Jazz pianists may strike two adjacent keys together in order to give an effect as close as possible to the desired note (Winkler 2011).

\textsuperscript{20} *Electric = No electronic instruments; *Orchestra = Not to be played by an orchestra

\textsuperscript{21} A blue note is “a slight drop of pitch on the third, seventh, and sometimes the fifth tone of the scale, common in blues and jazz. Also bent pitch” (Cole & Schwartz 2011).
6.5 Constraint Combinations

Clearly, while the above sections contain simplified tableaux designed to illustrate examples, they cannot possibly capture the whole picture of what a musical constraint ranking might look like. Additionally, as we saw in the second listening task and in the last section on Sound, the true picture must be more complex. It is likely that constraints must be ranked in groupings in order to create a structure that will be perceived as a particular genre. In light of Rosch’s work on category membership, we realize that, while categories do have attributes associated with them, it is not necessary for all attributes to be present. At the same time, some group of attributes must apply to the item in question for it to be considered a category member. In this way, we might explore the possibility of a ranking for Jazz such as the following:

Swing, Insert 7th, *VVV >> DEP-IO (Chord), IDENT-IO (Harmony), IDENT-IO (Rhythm)

Likewise, a possible ranking for Classical may look something like the following:

16th Notes, *Electric >> Swing, MAX-IO (Harmony), IDENT-IO (Rhythm)

In this way, we see that, as La Rue points out when he states that Sound, Harmony, Melody, and Rhythm “in most cases cannot individually maintain successful musical structures” (1992: 11), it is the combination of rankings for these domains that result in the grammar for a genre.

7.0 Conclusion

Our discussion began with theoretical principles of philosophy, psychology, linguistics, and music. Next, we described and discussed the two experiments we performed. Finally, we have suggested constraints and rankings based on the data we gathered, constructing an OT analysis of the musical theories presented.

This work would be incomplete without mention of Lerdahl and Jackendoff (1983). Clearly, in this paper, we have made some of the same claims regarding the connection between
music, language, and psychology/cognitive science. However, one might note that our approach is quite different, as we take the perspective of OT (used mostly in phonology), while Lerdahl and Jackendoff’s work focuses more on syntax, grouping, and hierarchy regarding form such as “motives, phrases, and sections” (1983: 8).

Additionally, Lerdahl and Jackendoff include only brief discussion of genre, taking most of their examples from Western Classical music. However, their thoughts on musical universals and Jazz easily fit within our OT framework:

One might be tempted to claim that in such an idiom [as Jazz] an accent or a stress is indeed a mark of a weak beat, violating the putative universal. However… the normal preference rules do not fail to apply; in fact they are exploited as a means of creating the desired metrical tension, which results from a conflict among rules. (Lerdahl & Jackendoff 1983: 279)

Another difference between the approach of Lerdahl and Jackendoff and our approach is stated in Schreuder 2006:

…Lerdahl and Jackendoff give only one ranking of well-formedness rules, while in OT a ranking of the universal constraints… has to be made for every language. Although Lerdahl and Jackendoff only offer one ranking for tonal music, one can imagine that, for example, prolongation of a melodic line is relatively more important in Eastern music than in Western music, while possibly in Western music relatively more weight is attributed to harmonic consonance of a piece. (12)

Schreuder goes on to state that “perhaps differences in musical styles can be accounted for in the same way as for differences between languages” (2006: 12). Schreuder (2006) uses an OT approach to discuss prosody in music and language with attention given to position, consonance, cadences, intonation, recursion, rhythm and syllables. While, like Lerdahl and Jackendoff’s work, these topics are beyond the scope of our discussion, Schreuder makes use of both OT and experimental procedures, thus taking a similar approach as this work, although with a different

---

22 There is some discussion of phonological/prosodic concepts, but this is still far from our treatment of music and language here.
focus. Further research might examine any intersection of Lerdahl and Jackendoff 1983 and Schreuder 2006 with the work we have presented here.

Further research would also be necessary, as stated earlier, to explore in more detail the reliability of the results we observed, as well as to continue to fine-tune the potential constraints and constraint rankings we have proposed here. If an OT analysis is found to be an appropriate means of describing genre, this can then be used to describe other genres. Specifically, OT may be helpful in describing Pop/Rock music. Speaking of this style, Chuan and Chew claim a “lack of well-documented analyses in the literature, and of formal compositional rules” which makes “the Pop/Rock style hard to define” (Chuan & Chew 2008: 67). Additionally, “the Pop/Rock style has not been explicitly articulated in musical terms” (Chuan & Chew 2008: 67).

Not only would this type of analysis benefit musicologists in their desire to describe genre, but it would also have implications in music composition and education with the possibility of music notation software grammar check. Chew (2003) discusses a prototype of Palestrina Pal, “an automatic grammar checker for compositions in the style of Palestrina. This form of counterpoint forms the pedagogical foundation for composition classes today and consists of numerous well-defined rules” (341). The ability to specifically define the rules of other genres would open the possibility that such programs could be designed for composition within these genres as well.

Finally, an OT analysis of music might shift how we think about the mind and the cognitive sciences. This may have implications for perceptual psychology, such as the work of Rosch and Levitin, or for neuropsychology and neurolinguistics, as in the work of Jentschke, who we mentioned at the very beginning of this paper. Hopefully, recent interest in these areas will lead to greater understanding of these processes.
References


