LANGUAGE AND MUSIC IN OPTIMALITY THEORY

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1 Introduction

Jackendoff and Lerdahl (1980) point out the resemblance between the ways both linguists and musicologists structure their research objects. This insight gave rise to the proposal of a formal generative theory of tonal music (Lerdahl and Jackendoff 1983), in which they describe musical intuition. Above all, insights from non-linear phonology (*cf.* Liberman 1975; Liberman and Prince 1977; Selkirk 1984; Hayes 1984 a.o.) led to scores provided with tree structures, indicating heads and dependent constituents in the investigated domains. In this way, composer Lerdahl and linguist Jackendoff bring to life a synthesis of linguistic methodology and the insights of music theory. Gilbers (1987) shows that music theory in turn can be useful to describe linguistic rhythmic variability. Further examples of musical and linguistic cross-pollination are Guéron (1974), Liberman (1975), Attridge (1982), Oehrle (1989), Hayes and Kaun (1996), Hayes and MacEachern (1998), Gilbers and Schreuder (2000).

In this paper we offer new arguments for the proposition that every form of temporally ordered behaviour, like language and music, is structured the same way (*cf.* Liberman 1975; Gilbers 1992). In both disciplines the research object is structured hierarchically and in each domain the important and less important constituents are defined. In Lerdahl and Jackendoff's music theory, these so-called 'heads' and 'dependents' are defined by preference rules determining which outputs, i.e. the possible interpretations of a musical piece, are well-formed. Some outputs are more preferred than others. Preference rules, however, are not strict claims on outputs. It is even possible for a preferred interpretation of a musical piece to violate a certain preference rule. This is only possible, however, if violation of that preference rule leads to the satisfaction of a more important preference rule.

This system of violable output-oriented preference rules in music theory leads us to a second investigation of the similarities of language and music, for a practically identical evaluation system, which uses similar well-formedness conditions, can be found in Prince and Smolensky's Optimality Theory (1993) (further OT). This theory, first introduced in phonology, owes a great deal to the work of Lerdahl and Jackendoff. It seems to be winning attention among linguists and is expanding more and more from phonology to other linguistic disciplines. In OT too, well-formedness conditions on outputs, constraints, determine grammaticality. And in this theory as well, the constraints are not strict, but soft, or violable. In this paper we will show that in the present state of phonology the resemblances are even more striking than in the time of Lerdahl and Jackendoff (1983). On the basis of these resemblances we will show that insights of music theory can help out in phonological issues.

An important issue in prosodic variability research is, for example, the question whether the influence of a higher speaking rate leads to adjustment of the phonological structure or just to phonetic compression. For this issue the phonologist could profit from the musicologists' knowledge. In this paper, we give an example of re-/misinterpretation of rhythm in fast or sloppy playing. From such misinterpretations, we can learn about the working of musical cognition, just as phonological mistakes during first-language acquisition give us insight into the way phonology is structured. On the basis of the similarities between language and music and the insight that restructuring can occur in rate adjustments in music, we suppose that phonological adjustment/restructuring on account of differences in speaking style and speaking rate is possible.

This paper is constructed as follows: in section 2 we sketch the resemblances between music theory and OT. In section 3 an analysis follows of rhythmic variability in OT and section 4 gives our conclusion in relation to the study of temporally ordered behaviour.

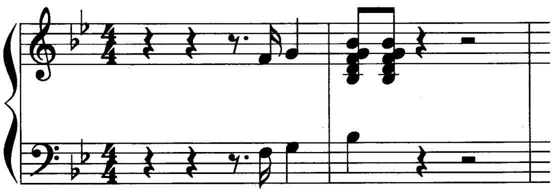
2 The resemblances between language and music

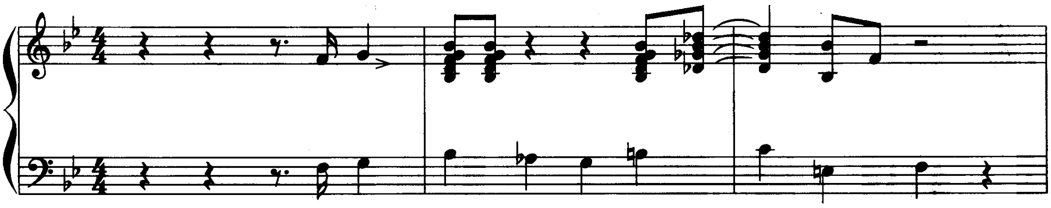
In their generative theory of tonal music Lerdahl and Jackendoff (1983) describe how a listener (mostly unconsciously) constructs connections in the perceived sounds. The listener is capable of recognizing the construction of a piece of music by considering some notes / chords as more prominent than others. This enables him for example to compare various improvisations on one theme and to relate them to the original theme. It enables him to get to the bottom of the construction of a complete piece, as well as the constructions of the different parts of that piece. Where does a new part start? What is its relation to a preceding part? Which are the most prominent notes in a melody? Our cognition thus works in a way comparable to how a reader divides a text (often unconsciously too) into different parts. A reader also distinguishes paragraphs, sentences and constituents. He structurally divides a text. What is the nucleus of a sentence? What is attributive and therefore less prominent? In section 2.1 we will show what the resemblances are between language and music with regard to the division of the research object into smaller domains. Section 2.2 is about the resemblances in well-formedness rules, which are output-oriented, and which determine the main constituent and the dependent constituents for each domain.

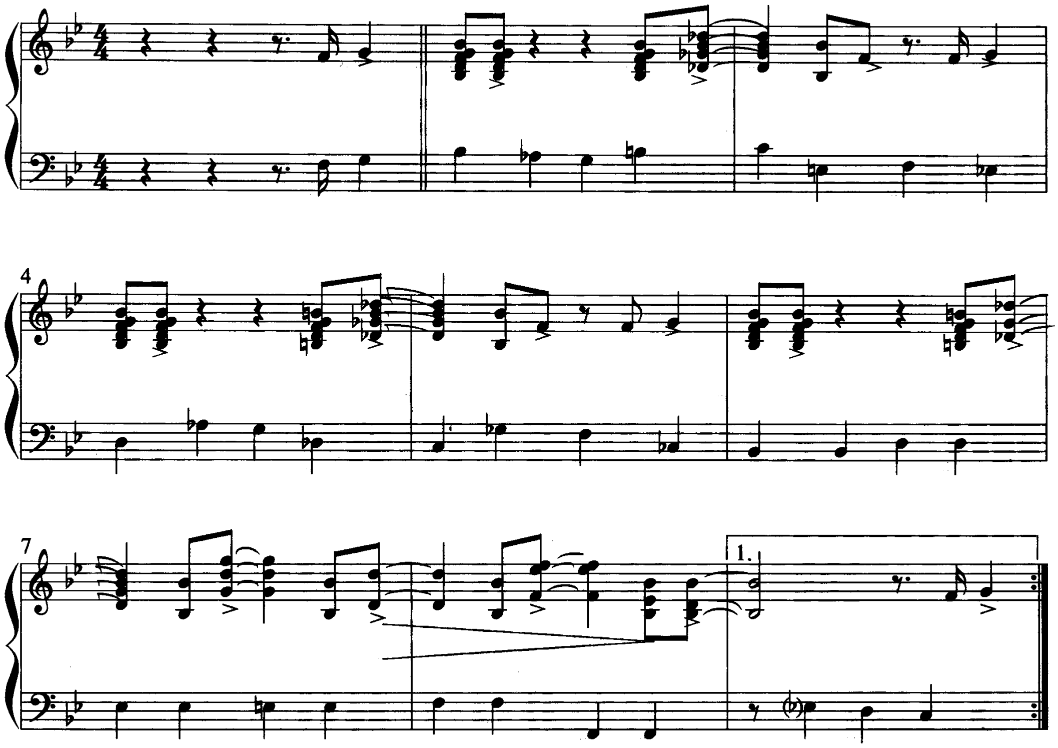
2.1 Structuring

In music theory the musical stream of sounds is hierarchically divided into domains. Each domain contains some smaller domains, which in turn contain smaller domains. The smallest domain in music is the motif (built up out of notes), a little, rhythmic, melodic or harmonic building block, which is a recurrent element in the whole piece of music. Several motifs together form themes. A theme generally covers several measures and is regularly varied upon during the whole piece. The listener is always able to recognize the theme, although it can be somewhat different each time. He does this by reducing every occurrence of the theme to its underlying structure. The motifs and themes together determine the character of the piece of music. Several themes together form a phrase, a kind of musical sentence. Several phrases can form a verse or chorus, etc. By imposing this hierarchical structure on the entire piece, the listener is able to understand it. (1) shows an example of the construction in the jazz original 'Tuxedo Junction'.

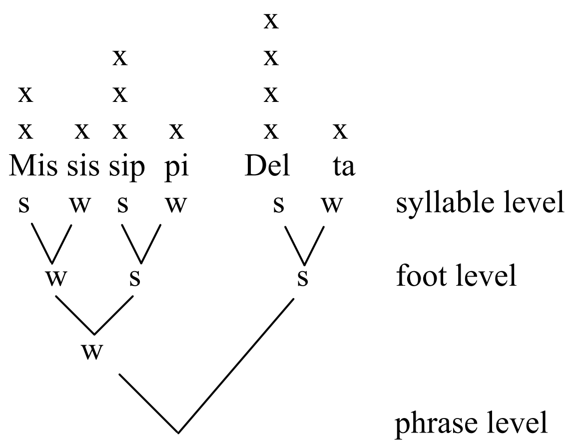
(1) Tuxedo Junction

Motif

Theme (phrase)



Section (verse)

Comparable domains can be found in language. The building block in language comparable to the motif in music is the morpheme (built up out of phonemes). Morphemes are joined together into larger meaning-bearing units: words, compounds, constituents (phrases), etc. And just as we have a rhythmic division (*metrical structure*) in addition to a melodic division (*grouping structure*) in music, we can divide rhythm in language into syllables as well, united into feet, which are comparable to the musical measure. In language – as in music – this division of the sound signal into domains allows us to grasp the structure and to understand how to interpret the whole text. (2) shows an example of a structured phrase in language. The height of the grids reflects the degree of stress and the tree diagram represents the relative strength between the syllables and feet. In language as well as in music the head of each domain (the s-constituents in the tree) is chosen by means of well-formedness conditions.

(2) Prosodic construction of a phrase (Liberman & Prince, 1977 a.o.)
(s indicates strong constituent; w weak constituent)



2.2 Conflicting preference rules

2.2.1 Evaluation of possible output candidates

A coherent whole of the well-formedness conditions (or constraints) indicates what is grammatical in a language and which mode of perception is optimal in music. In language for example one has to know which of two syllables in a foot is stressed and in music which chord of a certain sequence is the most prominent in the progression of the whole piece.

Possible candidates for every output form are evaluated by the constraints. These constraints can be contrasting and lay down opposite requirements on the output structure or interpretation to be preferred. Conflicts are thus solved by assuming differences in weight between the different constraints. In this way a weight hierarchy of constraints is arranged. One could compare this to traffic rules. Traffic coming from the right has priority, unless the traffic coming from the left is driving on a major road. This last rule, however, is overruled by the rule stating that one has to wait for a red traffic light. In traffic we are dealing with a collection of hierarchically ordered rules. Note that these rules are soft. They can only be violated in order to satisfy a higher preferred rule (minimal violability).

An innovation in linguistics is the fact that in OT linguistic constraints are soft too. An output candidate can be grammatical, even if it violates constraints. As long as no better candidate comes up, the least bad candidate is the optimal one. Suppose we have a word with two syllables CVCVVC (*papaap*) for which it must be determined on which syllable stress falls, and there are two relevant constraints: a positional constraint i (stress never falls on the last syllable) and one in which syllable weight plays a role, constraint j (stress falls on the heaviest syllable). The best output according to constraint i is then: *pápaap*, but *papáap* is the best according to constraint j. There is no output which satisfies both constraints. In a grammar conflicts like these are solved by a language-specific ranking of the constraints according to their importance. These universal constraints are not ranked in themselves, but in the grammar of a particular language they are strictly ordered. A language learner has to accomplish that in language X constraint i has priority over constraint j, while in language Y it can be the other way around.

The well-formedness rules in music theory are also potentially conflicting and soft. One of the conditions implies that a chord in a metrically strong position (for example the first position in a measure) is more important than a chord that is not in such a position. A chord in a strong position is preferred by the listener to act as most prominent chord (the head) of the measure or the phrase, above all other chords in the same sequence. Another preference rule states that, given the tonality of the piece, all chords are harmonically unequal in their strength. In a piece in the key of C, the G-chord is harmonically more consonant than a B-chord. Thus there will be a conflict between preference rules if a B-chord is in the first position of a measure and a G-chord is in the last. Lerdahl and Jackendoff solve this kind of conflicts by hierarchically ranking the preference rules. In our example the preference of a harmonically more consonant chord outweighs the preference of a metrically stronger chord. Consequently, the listener will choose the G-chord as head and not the B-chord, given the key C.

An apparent difference between music and language is that Lerdahl and Jackendoff give only one ranking of well-formedness rules, while in OT a ranking of the, in themselves unranked, 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. Perhaps differences in musical styles can be accounted for in the same way as for differences between languages.

In the next subsections we will discuss two examples of a conflict between positional and segmental markedness. In 2.2.2 we present a linguistic example based on language acquisition data; in 2.2.3 a comparable example in music is given.

2.2.2 A linguistic example of conflicting constraints: language acquisition

The language acquisition data in (3) prove that several kinds of markedness play a role in the acquisition of clusters. In this example we can see a conflict between segmental markedness and positional markedness in the realizations by Steven of respectively *acht* ‘eight’ and *korst* ‘crust’.

(3) Cluster reduction Steven

age:	target word:	input:	realisation:
1;11	*acht*	/ xt/	[t]
2;2	*korst*	/k rst/	[k s]

The dominating constraint in both cases is *COMPLEX, a prohibition on consonant clusters in the output. Prince and Smolensky (1993) propose HMARG to indicate that in marginal syllable positions less sonorant segments are prefererred to more sonorant ones. The child has come in a phase of its development in which the correspondence constraint MAX I-O, a constraint which demands a 1:1 relation between segments in the input and segments in the output, and therefore forbids deletion, is dominated by *COMPLEX and HMARG. With the help of these constraints we get to the analysis in (4).

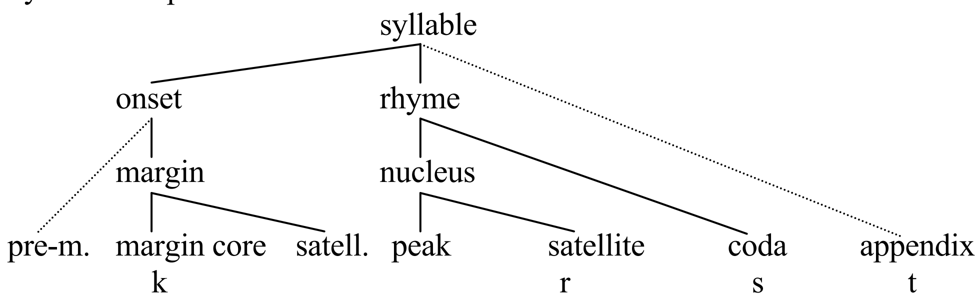
(4) Provisional OT analysis

constraints → / / candidates ↓	*COMPLEX	HMARG	MAX I-O
[ ]	*!		
[ ]		/ /!	*
☞ [ ]		/ /	*

The constraint ranking in (4), however, wrongly predicts that the realisation of *korst* would be [k t]. We assume that Steven's realisation [k s] should be explained by the supposition that the difference between the syllable positions of /t/ and /s/ has its influence. HMARG is violated to satisfy a higher-ranked constraint with respect to positional markedness.

A straightforward CVC-syllable model and constraints like *COMPLEX and *CODA is not satisfactory for describing phonotactic restrictions and positional markedness relationships between segments in a Dutch syllable. We therefore copy a more complex syllable template in (5) from Gilbers (1992). This model is based on a proposal in Cairns and Feinstein (1982), in which differences in positional markedness are stipulated, mixed with a proposal in Van Zonneveld (1988), in which an X-bar theory for syllable structure is developed[1].

(5) Syllable template



The model in (5) represents a hierarchical organization of the segmental distribution in a syllable. The vertical lines indicate the head of a branching constituent and the slanting lines the dependent parts. Thus, the MARGIN CORE is the head of the ONSET, which is dependent on the RHYME constituent. In OT this hierarchical structure is expressed in a series of ranked universal constraints. A SATELLITE always takes a more marked position than a CODA. The most marked positions are the PRE-MARGIN and the APPENDIX, the so-called extra-syllabic positions (X-SYLLABICITY). (6) represents the ranking of the relevant constraints. The order is universal, but other constraints can be placed in between the various positional constraints.

[1] Cairns and Feinstein indicate differences in markedness between consonant sequences like obstruent–liquid; obstruent–nasal. Unfortunately their model lacks sequences with fricatives such as in *schaap* [s a:p] 'sheep'.

(6) Positional markedness

*X-SYLLABICITY >> *SATELLITE >> *CODA

In the original model subcategorization rules were given for the contents of the various syllable positions. Thus in the nucleus position only vowels can occur and in the satellite positions only sonorant consonants are allowed. In OT, however, all constraints are violable and we therefore state that a SATELLITE prefers sonorant consonants above other consonants. In an optimal parsing of *acht*, /x/ takes the coda position and /t/ the appendix position.

Steven's realisations can be described by means of the the tables in (7). In (7a) we see that before his second birthday he is at a stage in which segmental markedness dominates positional markedness, but that after his birthday positional markedness has become more important than segmental markedness. Finally, the correspondence constraints will dominate all markedness constraints. Phonological development is then completed.

(7) Analysis *acht* and *korst*

a. table for *acht* (phase Steven (1;11))

constraints → / / candidates ↓	*COMPLEX	HMARG	*XSYLL	*SATELLITE	MAX I-O	*CODA
[ ]	*!	/ /	*			*
[ ]		/ /!			*	*
☞ [ ]		/ /	*		*	

b. table for *korst* (phase Steven (2;1))

Constraints → /k❷rst/ candidates ↓	*COMPLEX	*XSYLL	*SATELLITE	HMARG	MAX I-O	*CODA
[k❷rst]	*!			/rst/		*
[k❷r]			*!	/r/	**	
☞ [k❷s]				/s/	**	*
[k❷t]		*!		/t/	**	

In music too conflicts arise between positional and 'segmental' markedness. In the next subsection we give an OT analysis of a passage from Mozart.

2.2.3 A musical example of conflicting constraints: OT analysis of Mozart K. 331, I

In music different preference rules can be arranged, similar to language, which may make for conflicting choices concerning the head of a domain. These constraints are comparable. Segmental markedness has its musical equivalent in the hierarchical relationships between notes in a given tonality. Positional markedness is comparable to the strength differences between different positions in a measure.

With regard to segmental markedness musical segments – like segments in language – keep hierarchical relationships with each other. The hierarchy of musical segments, the pitches, is connected to the tonality of the piece. In tonal music, every piece is based on a given scale (the key or tonality of the piece), which means that all notes are arranged around the most important notes in that scale; the melody will preferably end in the tonic, the keynote of that scale.

The tones of the scale can be combined in several ways, following each other in a melody, or harmonizing in chords. One harmony or succession sounds better than the other. Tones sounding well together are called 'consonant', tones sounding poor are called 'dissonant'. Like sonority in language, consonance and dissonance are gradual concepts. The hierarchical division of pitches in a piece happens on the basis of the relative consonance (Lerdahl and Jackendoff 1977, 1983). A relative consonant tone in the key of the piece is higher in the hierarchy than a relatively dissonant tone.

In addition to segmental markedness, there is also positional markedness in music. The first position in a measure is stronger than the second, and in for example the 4/4-measure the third position is less strong than the first, but stronger than the second or the fourth.

Lerdahl and Jackendoff developed the so-called *timespan reduction*, a kind of tree and grid construction, based upon the metrical structure and the grouping structure of a part of a music piece, as to reflect the hierarchical relationships between all pitches in relation to the tonality of the piece. These relationships are determined by application of the preference rules, which determine the head in each domain. The head of a timespan Z is selected from the heads of the time spans directly dominated by this time span Z. The subordination relationship is transitive here; if X is an elaboration of Y and Y of Z, than X is also an elaboration of Z. Lerdahl and Jackendoff (1983) treat nine timespan reduction preference rules (TSRPR). (8) gives three examples of such rules.

(8) Time span reduction preference rules

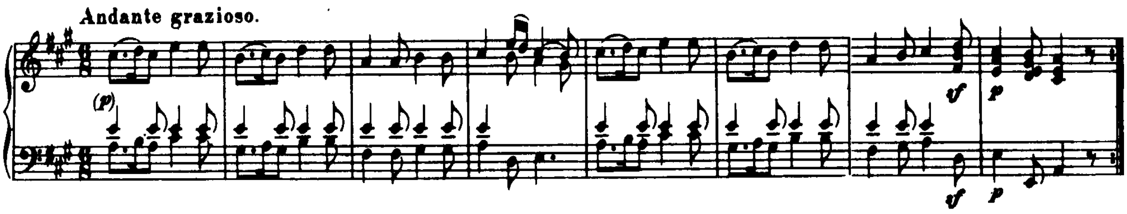
TSRPR 1: Choose as the head of a timespan the chord (or the note) which is in a relative strong metrical position (positional markedness).

TSRPR 2: Choose as the head of a timespan the chord (or the note) which is relatively harmonically consonant (segmental markedness).

TSRPR 7: Choose as the head of the timespan the chord (or the note) which emphasizes the end of a group as a cadence (comparable to the boundary marking effect of alignment constraints in language).

An example of a strong metrical position from TSRPR 1 is the first position in the measure. TSRPR 2 is connected to a hierarchy of chords based on harmonic stability. A triad tonic–tierce–fifth (c-e-g) is more stable than a seventh chord (c-e-g-b flat), while a seventh chord in its turn is more stable than for example a sus4 (c-f-g). The optimal chord according to TSRPR 7 is the final chord, a chord which generally is built on the tonic, preceded by a dominant chord. In C the dominant is G. Each smaller group concludes with a chord suitable for a cadence, but there are also 'lighter' cadences, indicating that a group is not definitely concluded, and that the melody will continue after the cadence, moving to a next group. Often the sequence subdominant–tonic is used (F-C). The first three positions in the harmonic hierarchy are occupied by the tonic, the dominant, and the subdominant, respectively.

As in OT the set of preference rules from music theory is hierarchical. TSRPR 2 is stronger than TSRPR 1; TSRPR 7 is stronger than TSRPR 1 and TSRPR 2 together. In (9) we give a part of a sonata from Mozart.

(9) Mozart: Sonata K. 331, I

(Lerdahl & Jackendoff, 1977)

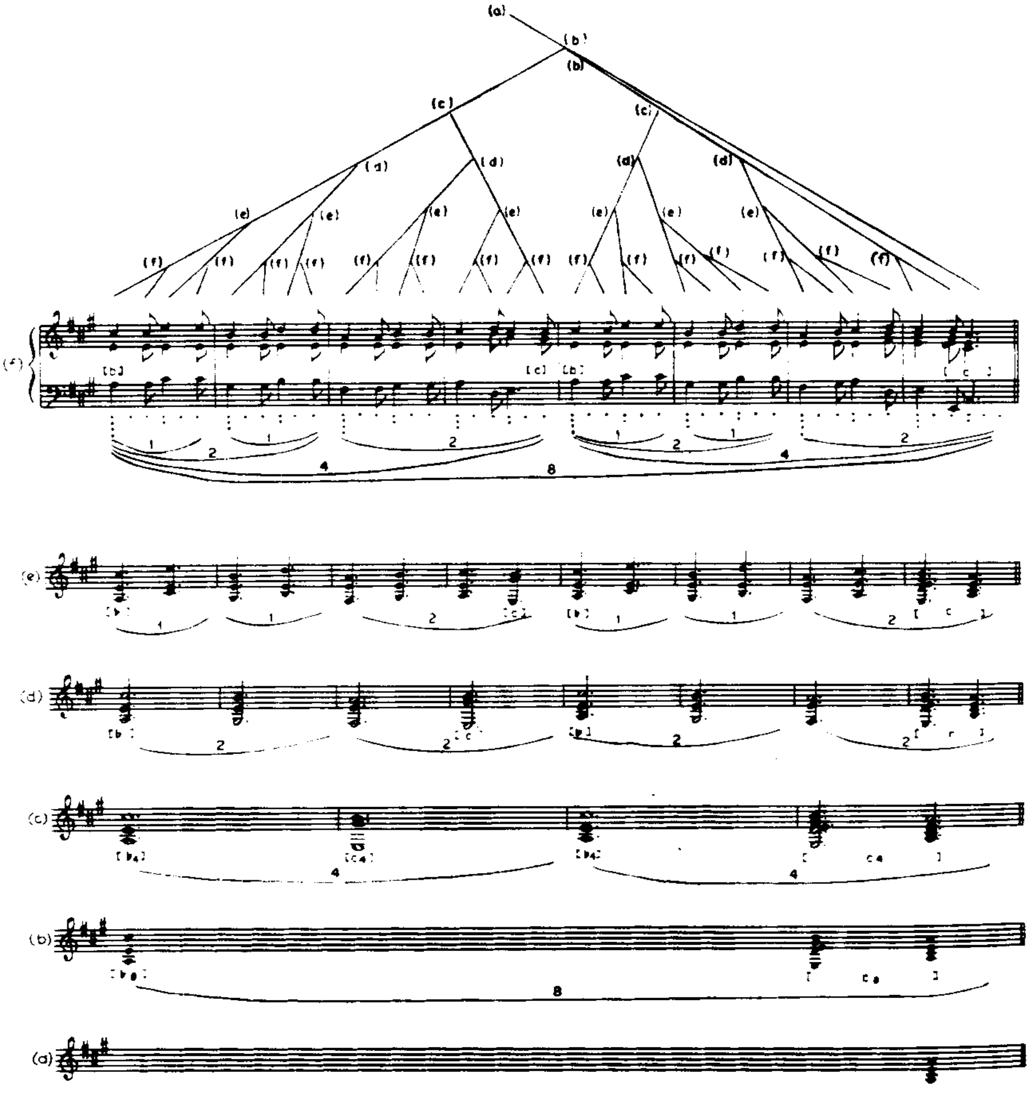
For this part we can determine the heads, by means of application of the TSRPR-hierarchy. The first four measures from the piece form the first group. In measure 4 the A^6-chord is the most stable chord, and thus the head. In measure 4 the E-chord is the head, because it marks the end of the whole group of four measures. Now the head has to be chosen for the group which is formed by measures 3 and 4 together. Metrically speaking, the A^6-chord is still the strongest. But TSRPR 7 dominates TSRPR 1. In (10) we give an example of an OT-like musical analysis. Although the A^6-chord is metrically speaking in a stronger position than the E, the dominant TSRPR 7 prefers the dominant chord E as the cadence in this phrase.

(10) OT analysis

constraints → A^6 – E Candidates ↓	TSRPR 7	TSRPR 2	TSRPR 1
☞ E			*
A^6	*!	*	

This choice has repercussions on the tree in (11), in which the E-chord dominates the A^6-chord. The E-chord in its turn is dominated by the harmonically more consonant initial A-chord of the piece. At the top of the hierarchy is the final chord of the whole group of eight measures, again an A-chord, because it is the head according to both TSRPR 1 and TSRPR 7.

(11) Timespan reduction



(Lerdahl & Jackendoff, 1983)

When one replaces all notes/chords which are chosen as heads of every timespan by gridmarks, one can see the resemblance with metrical phonological representations as proposed in Liberman (1975), Liberman & Prince (1977) and Hayes (1984) amongst others (12). The underlined gridmarks (x̲) indicate *silent beats* (*cf.* Selkirk 1984). Silent beats are filled either by a rest or by lengthening of a preceding note.

(12) Grid of the timespan reduction in (11) (two adjacent phrases)

```
                                             x
x                                         x  x
x                 x     x                 x  x
x     x     x     x     x     x     x     x  x
x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x
xxxxx̲xxxxxx̲xxx̲xxx̲xxx̲xxx̲xxxxxx̲xxxxxx̲xxx̲xxx̲xxx̲xxx̲x
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The analysis shows that the beginning and end of the phrase are emphasized. The TSRPR 7 dominates the constraints referring to segmental and positional markedness. In language too we often see that boundaries of a phrase are emphasized. In this way a stress shift as in *Mississìppi Délta*, realized in fast speech as *Mìssissippi Délta* (Hayes, 1984), can be described (*cf*. Visch, 1989). We will examine this in the next subsection.

2.2.4 The marking of boundaries

In both music and language, several processes can be considered to be boundary markers. Secondary stress shift and final lengthening are such processes. In OT so-called *generalized alignment* constraints are proposed for the analysis of boundary marking processes (McCarthy and Prince 1993). All alignment constraints refer to constituent boundaries, and they have the following form:

(13) *Alignment*
Align (Cat 1, Edge 1, Cat 2, Edge 2) =
∀ Cat 1 ∃ Cat 2 where Edge 1 of Cat 1 and Edge 2 of Cat 2 coincide

Alignment constraints prefer output candidates in which for example a constituent boundary coincides with a stressed syllable or in which a morphological boundary coincides with a phonological one.

A predecessor of alignment constraints for the controlling of rhythmical boundary marking in language is the Phrasal Rule of Hayes (1984). Hayes gives examples of preference rules for an ideal rhythmic structure in language: *eurhythmy* rules. He attributes rhythmic shift to adjustments to ideal patterns for rhythmic sequences. Because Hayes' *eurhythmy* rules are set up for outputs, his theory can be seen as a kind of predecessor of OT. An example of such a *eurhythmy* rule is the Quadrisyllabic Rule (QR), which demands that a secondary accent in a phrase is ideally at a distance of four syllables from the main accent. For longer phrases it is the case that at the so-called 'level of scansion', the level immediately under the level on which the gridmark of the main accent is situated, the major beats are at a distance of four syllables from each other. In the traditionally cyclically derived structure of *Mississippi Delta* this is not the case. The secondary accent on *sip* is just two syllables apart from the main accent on *Del* here. The QR thus prefers a secondary accent on the first syllable of the phrase and indeed the phrase often is pronounced as *Mìssissippi Délta*. In this case a conflict arises between the QR and an output-output correspondence rule (*cf*. Burzio, 1998) which prefers, on the basis of *Mississíppi*, the accent to fall on the penultimate syllable. In fast speech the QR is dominant.

(14) OT analysis

constraints → Mississippi Delta candidates ↓	QR	Correspondence
☞ Mìssissippi Délta		*
Mississìppi Délta	*!	

The QR divides language in a kind of 4/4 measure. In tonal music this is also a common kind of measure, in which – as was said in the foregoing section – the first count in the measure is important and the third count receives a lighter accent. This last effect is seen again in the *eurhythmy* rule Disyllabic Rule of Hayes: immediately under the level on which the major beats are at a distance of four syllables from each other, the major beats are ideally two syllables apart. A rhythmic pattern satisfying these *eurhythmy* rules shows a regular alternation of strong and weak elements at all levels.

Hayes (1984) also formulates an asymmetrical principle of *eurhythmy*. His Phrasal Rule (PR) implies that a grid is more eurhythmic if it contains two marks as far apart from each other as possible, at the second-highest level. The PR makes that the boundaries of the phrase are emphasized. Van Zonneveld (1983) called this phenomenon ‘Rhythmic Hammock’.

(15) Rhythmic Hammock in *twenty-seven Mississippi legislators*

<table>
<tr><th>constraints →
twenty-seven Mississippi legislators
candidates ↓</th><th>Hammock</th><th>QR</th><th>DR</th><th>Correspondence</th></tr>
<tr><td>x
x x x
x x x x x x
x x x x x xx x xx xx
twenty-sèven Mississìppi législators</td><td>*!</td><td>**</td><td></td><td></td></tr>
<tr><td>x
x x x
x x x x x x
x x x x x xx x xx xx
twènty-seven Mìssissippi législators</td><td>*!</td><td></td><td></td><td>*</td></tr>
<tr><td>x
x x
x x x
x x x x x x
x x x x x xx x xx xx
☞ twènty-seven Mìssissippi législators</td><td></td><td></td><td></td><td>*</td></tr>
</table>

In (15) the hammock pattern is visible in the grid of the third candidate. This pattern is comparable to the grid pattern in (12) for the music passage in (11). Because Hammock, like the TSRPR 7 in music, is a dominant constraint, the third candidate in (15) wins. So like similarities in segmental and positional markedness we also see a great similarity between language and music in the way boundaries are marked. Hammock patterns are found in phonology as well as in music.

Another form of boundary marking which we find both in language and music is *Final Lengthening* (FL) (Lindblom 1978, Ladd 1996). FL is the phenomenon of lengthening of a note or a speech sound at the end of a phrase. According to experimental research by Lindblom (1978) in spoken Swedish the duration of the vowel [ ] in [‘] is longer at the end of a phrase (16a) than when the word is in another position (16b).

(16) Final Lengthening in Swedish

a. *en finurlig Dag* ‘an ingenious Dag’
b. *Dag berättar* ‘Dag tells’

In (16a) the vowel is in final position and because of that it lasts ± 55 msec longer than in initial position, as in (16b). Example (17) shows an example of FL in music, where it is a very common phenomenon.

(17) Final Lengthening in music (after Liberman, 1975)

♏ ♏ ♏ ♏ ♏ ♏ ❑ ⓿ ♏ ♏ ♏ ♏ ♒ ⓿
Old Mc Do-nald had a farm, ee-i ee-i oh.

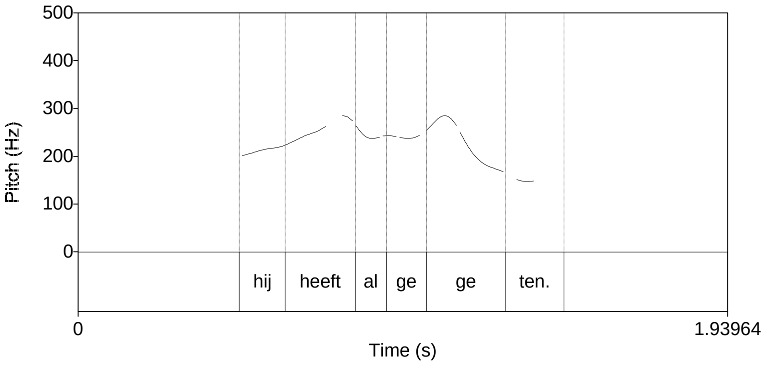
♏ ♏ ♏ ♏ ♏ ♏ ❑ ⓿ ♏ ♏ ♏ ♏ ♒ ⓿
On this farm he had a cow, ee-i ee-i oh.

The last note of the phrase is each time lengthened indicating that the phrase is concluded. One can also see that gradation exists in FL, as the note ‘before the comma’ is each time lengthened compared to the preceding notes, but less than the final note of the phrase.[2]

In addition to rhythmic phenomena, intonation patterns are used to mark boundaries. In language intonation marks groups such as syntactic constituents and phonological phrases. In a similar way intonation marks, for example, the differences indicated in writing by full stops and commas. A full stop in a declarative sentence is often the equivalent of a strong pitch fall in prosody, while a comma is comparable to the intonation pattern in which the tone is suspended somewere ‘in between’, to indicate that the sentence is to be continued. In (18) this difference is reproduced abstractly.

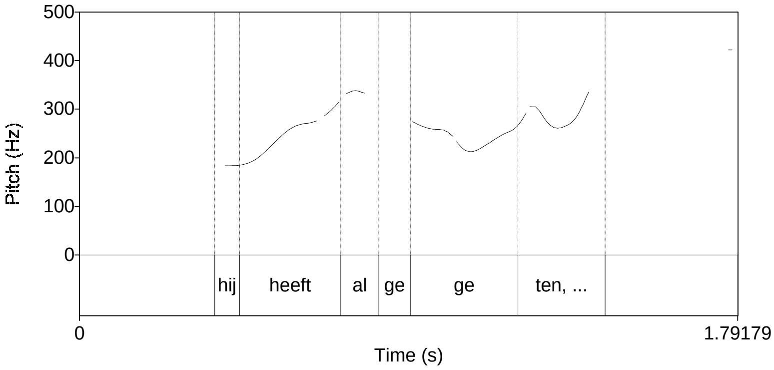
(18) Intonation patterns (Schreuder, 1999)

a. *Hij heeft al gegeten.* ‘He has eaten already.’



[2] Another common phenomenon for marking boundaries in both language and music is speed reduction at the end of phrases.

(18) b. *Hij heeft al gegeten, (maar hij wil toch nog een koekje.)*
‘He has already eaten, (but he still wants another cookie.)’

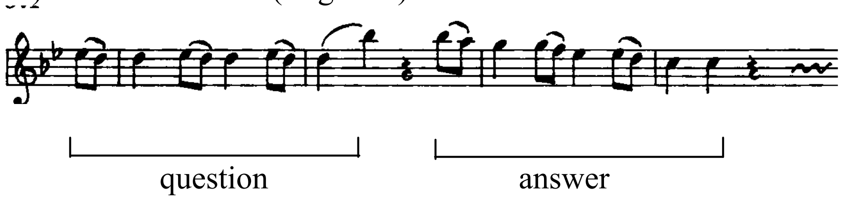


In (18a) the intonation contour moves downward to the end, and in (18b), the ‘comma intonation’, the tone is suspended in between. Thus in (18b) the sentence cannot be complete, something has to follow this boundary.

Intonation in music, called *phrasing*, makes the music ‘tell a story’, similar to the way intonation does in language. Phrases are formed in which tension is built up or reduced. This is properly comparable to ‘comma intonation’ and ‘full stop intonation’ in language: the comma indicates prolongation, the full stop completion.[3] A full stop is comparable to the ‘full cadence’ (the end of a phrase or piece) in music, i.e. the sequence of G-C in the key of C. Phrases and pieces prefer ending in the tonic, here C, mostly low. A comma is comparable to the ‘plagal cadence’, in which the phrase does not end in the tonic, but in the fourth tone of the scale, F in the key of C, so higher. It therefore does not sound completed, and another phrase, ending in the tonic, will ideally follow.

In (19) we show an example of phrasing: ‘question and answer’. One phrase (the answer) follows the other phrase (the question) and is also a reaction to it. Thus they can be very similar, except that the question concludes in a high tone and the answer in a low tone. An example of this is the first three measures of Mozart’s Symphony in G Minor, K. 550:

(19) Mozart K.550 (fragment)



This ‘question-answer intonation’ has the same way of marking grouping boundaries as the patterns of full stops and commas. Again it is very similar to the patterns appearing in language. Questions have the tendency to end ‘upward’, while answers, comparable to sentences with full stop, tend to show a strong ‘downward’ end pattern.

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[3] Lerdahl and Jackendoff describe the difference between intonation patterns expressing prolongation and intonation patterns expressing completion. Prolongation is worked out in the prolongation reduction of the pitch structure.

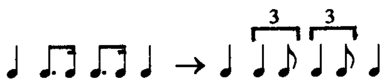
In this section, we showed that language and music have many similarities both on a representational level and in the area of the preference rules. It seems that output-oriented preference rules do not specifically hold for only one discipline. In the next section, we see that insights from music theory can be very useful in phonological issues.

3 Rhythmic variability

3.1 Triplet rhythm in music and language

In this section we assume that acquired insights from music theory can help us to describe some problematic cases of rhythmic variability in phonology. In the introduction of this paper the question was put forward whether the influence of a higher speaking rate leads to adjustment of the phonological structure, or whether we are only dealing with phonetic compression. Phonetic compression is mainly shortening and merging of vowels and consonants, with preservation of the phonological (rythmical and metrical) structure, and therefore it is less interesting where metre is the research object. In (20) we give an example of re-/misinterpretations of rhythm in accelerated or sloppy playing.

(20) Rhythmic restructuring: dotted notes rhythm → triplet rhythm



In (20), the ‘dotted notes rhythm’ (left of the arrow) is played as a triplet rhythm (right of the arrow). In the dotted notes rhythm the second note has a duration which is three times as long as the third, and in the triplet rhythm the second note is twice as long as the third. In fast playing it is easier to give notes the same length. Clashes are thus avoided and one tries to distribute the notes over the measures as evenly as possible, even if this implies a restructuring of the rhythmic pattern. In order for the beats not to come too close to each other in fast playing, the distances are enlarged, in order to avoid a staccato-like rhythm. In short, in fast tempos the musical equivalents of the Obligatory Contour Principle (OCP), a prohibition on adjacency of identical elements in language (McCarthy 1986), become more important.

In language we also find occurrences of clash avoidance. There is a preference for beats that are more evenly distributed over the phrase. In (21) we see that the distribution of strong syllables over the word *bijstanduitkeringsgerechtigde* ‘person entitled to social security’ in an andante tempo is different from the distribution in an allegro tempo. As in the music example in (20) the phrase gets a triplet-like rhythm at allegro-tempo. Gilbers (1987) notices that in fast speech the fourth syllable is stressed more than the third. In andante speech, however, the first syllable in *uitkering* gets more stress than the second.

(21) Rhythmic structure *bijstanduitkeringsgerechtigde* (Gilbers 1987)

a. andante	*bij stand*	*uit ke rings*	*ge rech tig de*
	s w	s s w	w s w w
b. allegro	*bij stand uit*	*ke rings ge*	*rech tig de*
	s w w	s w w	s w w

Neijt and Zonneveld (1982) and Van Zonneveld (1983) have argued that Dutch is a trochaic language. In OT terms this means that the constraints RHYTHMTYPE=TROCHAIC (RT=T), a foot consists of a strong syllable followed by a weak one, and FOOTBINARITY (FTBIN), a foot consists of two syllables (or two morae), are high in the constraint ranking for Dutch. The question now is how the triplet rhythm in (21b) can be accounted for. In the next subsection we will specify this.

3.2 *Triplet rhythm in trochaic Dutch*

Gilbers and Jansen (1996) formulate an elaborate OT grammar for Dutch stress patterns, partly based on Nouveau (1994), Van Oostendorp (1995) and Kager (1994). The relevant part for this paper is given in (22).

(22) Ranking for rhythmic base structure in Dutch

RT=TR ; FTBIN >> PARSE σ >> ALIGN PRWD >> ALIGN FT

This grammar enables us to describe the longer rhythmic patterns in (23).[4]

(23) Possible rhythmic patterns in Dutch for phrases with more than four σ's

a. (σ σ) σ (σ σ)
b. (σ σ) (σ σ) (σ σ)
c. (σ σ) σ (σ σ) (σ σ)
d. (σ σ) (σ σ) (σ σ) (σ σ)
e. (σ σ) σ (σ σ) (σ σ) (σ σ)

In the OT grammar PARSE-σ demands that syllables are parsed in a foot and FTBIN and RT=TR provide for the preference of trochaic feet. These constraints dominate PARSE-σ, which results in an unparsed syllable for every phrase of an uneven number of syllables. ALIGN-Σ demands that feet align with the right edge of the phrase. This constraint, however, would cause the unparsed syllable with an uneven number of syllables to align to the left edge of the phrase. This is avoided by a dominant alignment constraint which requires that the left edge of a phrase aligns with the left edge of a foot (ALIGN-PRWD: Align (PrWd, Left, Foot, Left). This constraint now ensures that a triplet pattern can only occur at the left edge of a phrase.

The ranking in (22) implies that the grammar does not enable us to describe the triplet pattern in (21b), because in that example the triplet pattern is carried through the whole phrase. The OT grammar will always prefer the structure in (23e) to that in (21b) for a nine-syllable phrase. After all the constraint ranking in Gilbers and Jansen (1996) leads where possible to a trochaic rhythmical basic pattern for Dutch phrases, like in *parallellogrammen* 'parallelograms', where s- and w-syllables nicely alternate. A compound like *bijstanduitkeringsgerechtigde* also gets – where allowed by morphological structure and difference in syllable weight – a trochaic pattern.

[4] For the sake of clearness we abstract away from the influence of syllable weight here, and thus we will depart from a sequence of light syllables.

However, there are languages in which the standard is a ternary rhythmic pattern. The dactyl pattern in (21b) is the default rhythmic pattern of prosodic words in languages like Estonian and Cayuvava: every s-syllable alternates with two w-syllables. Kager (1994) bases his analysis for patterns like those on *Weak Local Parsing theory* (Kager 1993; Hayes 1995): feet are at most binary and a ternary pattern is caused by an unparsed syllable between feet.[5] The constraint bringing about this effect is FOOT REPULSION: *ΣΣ (avoid adjacent feet), it is a kind of an OCP effect. FOOT REPULSION dominates PARSE-σ in languages like Estonian and Cayuvava. This constraint allows us to account for the alternative rhythmic structure for *bijstanduitkeringsgerechtigde* in (21b).

The basic assumption in OT is that constraints are universal. Because of the trochaic character of Dutch we have to assume that FOOT REPULSION is situated very low in the constraint ranking of Dutch, in any case it is dominated by FTBIN and PARSE-σ. In fast speech such a constraint ranking leads to a pile-up of many accents in a short period. Similar to the the music example in (20), a kind of mechanism now starts to work, demanding a longer interval between the accents. In order to avoid clashes beats are distributed over the phrase as evenly as possible. In a fast tempo one prefers the beats not to stand too close to each other in both music and speech. The distances between beats are enlarged, in order to avoid a staccato-like rhythm.

Evidently, we are not dealing with phonetic compression, but with restructuring, which can only be obtained by assuming a special constraint ranking for fast speech. In fast speech FOOT REPULSION (*ΣΣ) dominates PARSE-σ.

(24) Rhythmic variability and speech rate

a. andante ranking:

RT-TR ; FTBIN >> PARSE-σ >> ALIGN-PRWD >> ALIGN-Σ >> *ΣΣ

b. allegro ranking:

RT=TR ; FTBIN >> *ΣΣ >> PARSE-σ >> ALIGN-PRWD >> ALIGN-Σ

As a general rule we can conclude that in allegro rankings, for both language and music, markedness constraints and OCP-effects (*CLASH, *ΣΣ) are dominant, while in andante rankings CORRESPONDENCE constraints are far more important. Consider the different pronunciations of the word *tandpasta* 'tooth paste' in (25). In addition to clash avoidance there is a preference for assimilation in allegro styles. The functional explanation is that markedness constraints (ease of articulation) dominate correspondence constraints (ease of perception) in fast speech. Speaking fluently becomes more important and therefore unmarked structures from an articulatory point of view are preferred.

(25) Andante and allegro speech

	a. andante:	b. allegro:
tandpasta	[ ]	[ ]
	s s w	s w s

---

[5] Contrary to the analysis of ternary patterns like (s w) <w>, Dresher and Lahiri (1991), Selkirk (1980), and Hewitt (1992) propose ternary feet: (s w w). Dresher and Lahiri propose an extra parameter, in order to achieve a branching head of a binary foot. The resulting ternary feet violate FTBIN.

In the next subsection we will show that this observation is also valid for the OT analysis of other cases of rhythmic variability.

3.2.1 Trochaic rhythm versus dactylic rhythm

Consider the data in (26), exhibiting a secondary stress to the right in fast speech.

(26) Rhythmic variability

a. trochee	b. dactyl	
fototoestel	*fototoestel*	'photo camera'
s w s w	s w w s	
handenarbeid	*handenarbeid*	'manual work'
s w s w	s w w s	

data: *studietoelage, tijdsduurindeling, bijstanduitkering*
'study grant', 'division of time duration', 'social security'

The constraint ranking for andante speech (24a/27a) will prefer the sequence *(foto)(toestel)* as an optimal rhythmic pattern. Better than, for example, *(foto) toe (stel)*.[6] Given the allegro ranking in (24b/27b), however, this last option satisfies FOOT REPULSION, because the feet are separated from each other by an unparsed syllable.

(27) Restructuring in language

a. ranking in andante speech:

constraints → *fototoestel* candidates ↓	RT=TR	FTBIN	PARSE-σ	ALIGN-PRWD	ALIGN-Σ	*ΣΣ
☞ (fóto)(tòestel)						*
(fóto)toe(stèl)			*!		*	

b. ranking in allegro speech:

constraints → *fototoestel* candidates ↓	RT=TR	FTBIN	*ΣΣ	PARSE-σ	ALIGN-PRWD	ALIGN-Σ
(fóto)(tòestel)			*!			
☞ (fóto)toe(stèl)				*		*

Notice that in the ranking for andante speech the correspondence constraint PARSE-σ is higher ranked than in allegro speech. OUTPUT-OUTPUT CORRESPONDENCE (O-O CORR) constraints

[6] The syllable *stel* can form a foot on the base of its bimoraicity (*cf.* Gilbers and Jansen 1996).

relate the output to related outputs (*cf.* Burzio 1998; Jansen 1996).[7] The output *fótotòestel* with secondary stress on the penult is preferred, because of the correspondence with the related output *tóestel*. This output satisfies O-O CORR, whereas an output *fótotoestèl*, with final secondary stress violates O-O CORR. In the andante grammar, O-O CORR dominates the constraints which take care of OCP effects (*ΣΣ and *CLASH).

O-O CORR also requires that in the compound *zuidafrikaans* 'South African' the part *afrikaans* 'African' shows the same rhythmic pattern as the related output *afrikaans* (s w s) itself. This yields an optimal output for *zuidafrikaans* in the andante grammar with a clash in it: s s w s. In the allegro grammar, however, in which FOOTREPULSION dominates O-O CORR, the optimal structure is s w w s. O-O CORR is violated in order to satisfy FOOTREPULSION in the latter case.

(28) Restructuring *zuidafrikaans* (simplified tables)

a. andante

constraints → *zuidafrikaans* candidates ↓	O-O CORR	*ΣΣ
☞ (zuid) (a fri) (kaans) s s w s		*
(zuid a) fri (kaans) s w w s	*!	

b. allegro

constraints → *zuidafrikaans* candidates ↓	*ΣΣ	O-O CORR
(zuid) (a fri) (kaans) s s w s	*!	
☞ (zuid a) fri (kaans) s w w s		*

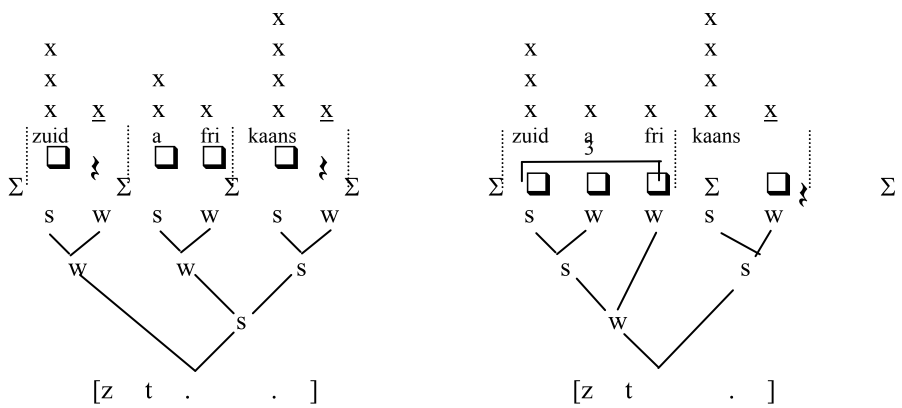
In the fast variant the number of strong beats or the number of feet is changed from three into two. Evidence for this restructuring is to be found in the reduction possibilities of this phrase. Generally reduction of a vowel to schwa is only possible in weak syllables. In the s s w s structure of *zuidafrikaans* (andante), *-a-* cannot be reduced. In fast speech, however, reduction is possible. This indicates the occurrence of restructuring, the second syllable fills a

[7] On the base of O-O CORR an explanation can be given in OT for the difference in rhythmic structure of the seven syllable words *sentimentaliteit* 'sentimentality' (s w w s w s) and *individualist* 'individualist' (s w s w w s). The subtle difference is caused by the satisfaction of the optimal outputs of both words to O-O CORR, whereby the initial triplet in *sentimentaliteit* is explained from the relationship with the initial triplet in the base *sentimenteel* 'sentimental' (s w w s) and whereby the initial trochee in *individualist* is explained from the relationship with the base *individueel* 'individual' (s w s w s). The reduction of the penultimate syllable in *individualist* is the result of the dominance of *CLASH in relation to O-O CORR.

weak position. This is only possible if the rhythm is simplified to a triplet, in which only the first note is strong. In the weak position reduction of the syllable *–a-* to schwa is possible. Notice that in the fast variant resyllabification is more likely to occur, giving the second syllable an onset: [:]. This realization violates O-O CORR, if we consider the base *afrikaans* (s w s). (29) illustrates this musical solution for a linguistic issue. The metrical restructuring is depicted by the grids and the tree structures.

(29) Restructuring *zuidafrikaans* (arboreal, musical and in grid form) (after Gilbers, 1987)

a. andante b. allegro



O-O CORR can also be in conflict with boundary marking alignment constraints such as RHYTHMIC HAMMOCK. In (30) variable outputs are given for *perfectionist* ‘perfectionist’ and *amerikaan* ‘American’.

(30) Conflicting constraints

Base:		Optimal candidate according to O-O-CORR:		Optimal candidate according to HAMMOCK:
perfect w s	→	*perfectionist* w s w s	→	*perfectionist* s w w s
amerika w s w w	→	*amerikaans* w s w s	→	*amerikaans* s w w s

data: *koloniseer* (base: *kolónie*) ‘colonize’ (base: ‘colony’), *piraterij* (base: *piráat*) ‘piracy’ (base: ‘pirate’), *grammaticaal* (base: *grammática*) ‘grammatical’ (base: ‘grammar’)

OUTPUT-OUTPUT CORRESPONDENCE prefers a pattern for *perfectionist* which agrees with the structure of the base *perfect*, in which the second syllable is stressed. In fast speech, however, secondary stress shift to the left is more likely to be observed, implying a violation of O-O CORR.[8]

(31) Restructuring *perfectionist* (simplified tables)

a. andante

constraints → *perfectionist* candidates ↓	O-O-CORRESPONDENCE	HAMMOCK
☞ w s w s		*
s w w s	*!	

b. allegro

constraints → *perfectionist* candidates ↓	HAMMOCK	O-O-CORRESPONDENCE
w s w s	*!	
☞ s w w s		*

The preference for satisfaction of boundary-marking constraints (Hammock) at the expense of violation of correspondence constraints (O-O Corr with the base *tandheelkundige* 'dentistry') can also be seen in the data in (32), which all show secondary stress shifts to the lefthand phrase boundary in fast speech.

(32) Rhythmic shifts to the left (Visch, 1989; Gilbers, 1988 a.o.)

```
a. andante                      b. allegro
                x                                 x
          x     x               x                 x
x         x     x               x       x         x
x    x    x     x               x    x  x         x
x    x    x  x x x              x    x  x  x x    x
```

tandheelkundige dienst *tandheelkundige dienst* 'dentistry service'

data: *aardrijkskundig genootschap* 'geographical association', *zevensnarige luit* 'seven-string lute', *speciale aanbieding* 'special offer'

[8] Constraints such as *CLASH also play a role in here. In the andante rankings *CLASH will also dominate O-O CORR, if we consider a derivation like *apparatuur* 'aparatus', in which O-O CORR is never satisfied with the base *apparaat* 'machine', 'apparatus', because the rhythmic pattern s w s s exhibits a clash.

As in music a faster tempo apparently does not always lead to ‘phonetic compression’, but it often leads to restructuring of the rhythm. Different registers prefer different rhythmic structures for the same phrase.

4 Conclusion

In this paper we showed that language and music have much in common with respect to psychological assumptions and structural properties. In both disciplines the ‘grammar’ imposes hierarchical structures on the sound signal. In both language and music, preference rules for ideal outputs indicate the head constituent and the dependent constituents of every part of the hierarchical structure. Together the preference rules or constraints indicate what is grammatical in language and which way of listening is optimal in music and in both theories the preference rules are soft and potentially conflicting, which gives the theories their power, because violable constraints can be defined very generally without exceptions and domain restrictions.

We showed that in music and language similar processes occur. There are examples of boundary-marking processes, such as final lengthening and phrasing in both disciplines. They should be seen as the result of satisfaction of so-called *generalized alignment* constraints.

Our conclusion is that a fast tempo in language and music can lead to restructuring of the rhythm. In fast playing and fast speech, the avoidance of clashes, for example, is more important than in slower rates. Therefore, we assume a special grammar for fast rate in language and music, in which constraints referring to the Obligatory Contour Principle (OCP), a prohibition on adjacency of identical elements (McCarthy 1986), take a more prominent position in the ranking. Every tempo and every style has its own ranking of constraints. In general, the faster the tempo the more markedness constraints dominate correspondence constraints.

In our view, the observation that language and music show so many similarities strengthens the hypothesis that the same structures and principles hold for all temporally ordered behavior (*cf.* Liberman 1975; Gilbers 1992). In addition we can refer to research by Lasher (1978), who describes patterns in ballet in a similar way to our description of language and music in this paper.[9] In her research of dancing patterns the main movements are also distinguished from dependent movements, for every part of the hierarchically structured research object. It is the way in which our brain works: our cognitive system structures the world surrounding us in a particular way in order to understand everything in the best way.

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[9] Bergesen (2001) and Mallen (2001) also use linguistic methodology in their analyses of paintings.

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