

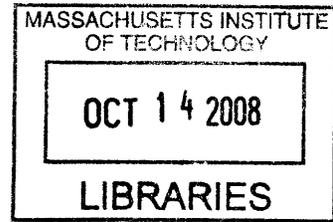
Syllabification and Syllable Weight in Ancient Greek Songs

by

J. D. Hill

B.A. Classics  
Amherst College, 1996

M.A. Classics  
University of Texas at Austin, 2002



Submitted to the Department of Linguistics and Philosophy in partial fulfillment of the requirements for the degree of

Master of Science in Linguistics  
at the  
Massachusetts Institute of Technology

September 2008

© Joseph David Hill. All rights reserved.

The author hereby grants to MIT permission to reproduce and to distribute publicly paper and electronic copies of this thesis document in whole or in part in any medium now known or hereafter created.

Signature of Author .....  
Department of Linguistics and Philosophy  
September 5, 2008

Certified by .....  
Donca Steriade, Professor of Linguistics  
Thesis Supervisor

Accepted by .....  
Irene Heim, Professor of Linguistics  
Department Head

ARCHIVES



# Syllabification and Syllable Weight in Ancient Greek Songs

by

J. D. Hill

Submitted to the Department of Linguistics and Philosophy on September 5, 2008, in partial fulfillment of the requirements for the degree of Master of Science in Linguistics

## ABSTRACT

This thesis is about phonetic events, phonetic representations, and the grammatical constraints on those representations, with respect to one particular phonetic dimension: time. It focuses on a process called *beat mapping*, whose clearest manifestation is in singing (as opposed to “ordinary” speech). This is the mapping of a sequence of syllables/segments onto a sequence of timing units or *beats*.

The empirical ground is provided by Ancient Greek musical scores. We analyze the way that sensitivity to syllable weight manifests itself in beat mapping. In Ancient Greek, the *musical quantity* of syllables (their duration, counted in beats) is tightly controlled by their type.

Taking this as a robust example of a weight-sensitive process, we set out to demonstrate that syllable weight is not about syllables, but about segments; this is contrary to what current theories of syllable weight assume (see Gordon 2004). We attempt to derive both syllable weight and syllable constituency itself from constraints on the beat mapping of segments.

This beat mapping grammar is developed within the general framework of Generalized Correspondence Theory (McCarthy and Prince 2005), and exploits certain properties of correspondence relations, notably non-linearity and reciprocity (bidirectionality). The mapping of segments onto beats *respects* their linear order but does not *reflect* them: it is a many-to-many mapping. Correspondence also provides the basis for a new definition of “syllable,” which rests on two things: the reciprocity of correspondence relations, and a principle of “salience matching” in mappings between non-homologous domains.

Thesis supervisor: Donca Steriade

Title: Professor of Linguistics



## Table of Contents

Chapter 1	Scope and Outline.....	7
1.1	Syllable weight .....	8
1.2	Textsetting .....	10
1.3	Musical quantity .....	14
1.4	Regulation of MQ by syllable type .....	20
1.5	Regulation of MQ by meter .....	23
1.6	The rest of the thesis .....	24
Chapter 2	Syllable MQ in Greek .....	27
2.1	A preliminary factorization .....	27
2.2	The structure of the musical notation.....	29
2.3	An example .....	31
2.4	Other sources of information on MQ .....	35
2.5	Counting polysemes.....	37
2.6	Controls .....	39
2.7	Interpreting short-vowel trisemes.....	42
Chapter 3	Beat Mapping .....	45
3.1	The problem.....	45
3.2	Representations and realizations .....	46
3.3	Constraints.....	51
3.3.1	Linearity .....	51
3.3.2	Parsing.....	52
3.3.3	Length.....	54
3.3.4	Sonority.....	55
3.3.5	Compressibility and alignment.....	58
3.3.6	Beat marking .....	61
3.4	The Greek beat mapping grammar .....	63
3.5	Cluster parsing .....	65
3.6	Segment MQ and syllable MQ.....	68
3.7	Vowel length.....	69
3.8	Observation: the weightlessness of onsets.....	72
3.9	Codas .....	73
3.10	Allophonic vowel lengthening.....	75
3.11	Excursus: evidence for allophonic vowel lengthening.....	78
3.11.1	Textual evidence .....	78
3.11.2	Experimental evidence.....	80
3.12	Consonant length.....	80
3.13	VV sequences .....	83
Chapter 4	Conclusion.....	87
Bibliography	.....	89



# 1 Scope and Outline

This thesis is about syllable weight in music: the phenomenon to be analyzed is the way that sensitivity to syllable weight manifests itself in grammars of singing,<sup>1</sup> specifically the way that syllable weight translates into musical duration. The thesis is based on and inspired by data from Ancient Greek songs. To my knowledge, the phenomenon has not been dealt with in detail in any language before.<sup>2</sup> The first task, then, is to identify and characterize the phenomenon precisely. That is one of two purposes of this chapter; the other is to provide an overview of the main topics and arguments in this thesis.

Syllable weight in music, and the analytical challenge it poses, has a bearing on several significant theoretical questions. I would like to mention three here, and give a brief indication of the answers I believe are best supported by the Greek evidence. Further discussion will be found in the sections of this chapter and in subsequent chapters.

(i) *The relation of music to “ordinary” speech* (or in architectural terms, the relation between the grammar of singing and “core” phonology): I will argue for a direct relationship between the timing units of singing (beats) and the timing units of speech. I will try to make the case for the strongest possible relationship: identity. I think it may well be that the phonetic representation of singing requires no proprietary (i.e., redundant for speech) representational

---

<sup>1</sup> By a grammar of singing, I mean essentially an extended grammar of speech, one that does all the things a grammar is normally taken to do, but also handles the interface between speech and music, i.e., the “singing interface.” Grammars, in generative linguistics, are mental objects studied indirectly, using the idealized approximations known as “languages.” To study grammars of singing generatively, we need to identify idealizations of them as well, or “singing languages.” These would be extended languages, then.

Languages are conventionally given proper names, e.g., “Ancient Greek.” It is perfectly appropriate to use the same proper names for languages and their singing-language extensions. But we will sometimes also use the terms “Ancient Greek singing,” “Ancient Greek vocal music” and “Ancient Greek songs” to specify the musical extension of Ancient Greek.

<sup>2</sup> It comes up in passing in Hayes and Kaun 1996, but in that study syllable weight is a sidelight—the language of study is English—and the main focus is the effect of phonological phrasing on musical duration.

levels at all;<sup>3</sup> here I will only try to make the case that the fundamental architecture of singing, beat structure, is not uniquely musical. However, since my empirical focus is squarely on singing, this argument is mostly implicit.

(ii) *The status of syllable weight as a theoretical construct*: I will develop an analysis of syllable weight phenomena that dispenses with syllable weight categories. Syllable weight effects will be derived from the way that segments (not syllables) are mapped onto timing units.

(iii) *The nature of syllabification*: In my analysis, syllable constituency emerges simultaneously with weight phenomena. In place of hierarchical syllable structure (e.g., [<sub>σ</sub> Onset [<sub>Rime</sub> Nucleus Coda]]), a definition of the syllable is proposed that is based on the logic of correspondence between segments and timing units.

The rest of this chapter is divided into “background” and “preview” sections. On background, syllable weight is introduced in 1.1, and I lay out my assumptions about the grammar of singing in 1.2–1.3. Then 1.4 summarizes the main task of this thesis, namely to account for the Greek pattern of syllable weight in music. In 1.5 we discuss the parallel role of meter. Finally 1.6 outlines the remainder of the thesis.

## 1.1 Syllable weight

*Syllable weight* (see Gordon 2004 for an overview) refers to the phenomenon whereby syllables of different shapes—e.g., C<sub>0</sub>V, C<sub>0</sub>VV,<sup>4</sup> C<sub>0</sub>VC, C<sub>0</sub>VVC—are treated differently or accorded a different status by a phonological process<sup>5</sup> in a given language. Typically, this differential treatment creates a division of syllables into two or three weight categories: light (L), heavy (H), and (sometimes) super-heavy (super-H); such a categorization is called a *syllable weight criterion*. There

---

<sup>3</sup> Even meter and harmony, the most distinctively “musical” elements of singing, have well-known natural-language analogs in the area of stress and tone.

<sup>4</sup> “VV” is a standard shorthand for “long vowel or diphthong.”

<sup>5</sup> The somewhat anachronistic term *process*, as I understand its current use, denotes a part of the grammar that has an integrated character, by virtue of controlling a specific phonological phenomenon, and that is identifiable cross-linguistically. Some examples are given below. In Optimality Theory (OT) terms, a process may be thought of as the set of constraints that govern a specific phenomenon; their ranking in a given language determines the shape the process takes in that language.

is no one universal weight criterion, and the category labels just given are acknowledged to have no universal meaning. Sometimes C<sub>0</sub>VC counts as H, sometimes as L. Sometimes the distinct category super-H is present (usually represented by C<sub>0</sub>VVC syllables), sometimes not.

Recent work has added an emphasis on the *process*-specificity of syllable weight criteria: not rarely, a given language employs different criteria for different processes (Gordon 2002, 2004). As it happens, Ancient Greek, from which we will draw our data, is taken to be one such language. But perhaps the most significant aspect of the variability of weight criteria is what is called *weight sensitivity*. This refers to the fact that a process shows discrimination among syllable types in one language, while that same process in another language shows none at all. Some languages show weight sensitivity in many processes, others only a few.

All this inter- and intra-language variability has been rightly seen as a challenge for theories of weight, especially those that treat weight as a measure of the structural complexity of syllables, e.g., “mora-counting” theories. In theories of this type, weight is expected to be stably determined for a given language, via parameter setting. (See, e.g., Broselow, Chen and Huffman 1997 for examples and references.) Gordon’s work, starting with Gordon 1999, promotes a more goal-oriented, phonetically driven account of syllable weight, in which what counts as a H or L syllable is a matter of process-specific phonetic desiderata and language-specific phonetic resources (i.e., the syllable inventory of the language).

One aspect of the theory of syllable weight that Gordon does not explicitly challenge is the foundational assumption that the input of weight-sensitive processes is syllabic. This thesis mounts a challenge to that assumption, though the challenge remains localized to Greek; Greek is offered as a demonstration case, one case where the hallmarks of weight-sensitivity seem better understood in segmental terms.

Gordon 2004 lists the following cross-linguistically identifiable processes as being weight-sensitive in at least some languages (see there for references): stress, tone, minimal word requirements, metrical scansion, compensatory lengthening, reduplication, syllable templatic restrictions. Ancient Greek is weight-sensitive in at least a subset of these: the first four (Steriade 1991). Three of the four use a common weight criterion, in which open syllables with short

vowels count as L and everything else is H, while for intrasyllabic tone placement, short-vowel syllables are L and long-vowel syllables are H.<sup>6</sup>

- (1) a. Greek Weight Criterion 1:   L = C<sub>0</sub>V       H = C<sub>0</sub>VVC<sub>0</sub> and C<sub>0</sub>VCC<sub>0</sub>  
 b. Greek Weight Criterion 2:   L = C<sub>0</sub>VC<sub>0</sub>   H = C<sub>0</sub>VVC<sub>0</sub>

The empirical results from Ancient Greek reported in Chapter 2 of this thesis allow us to add to both of these lists an additional process, which I will call *beat mapping*: the way that phonetic material is mapped onto beats. In Ancient Greek, syllable type controls the number of beats to which a syllable may correspond.

## 1.2 Textsetting

Beat mapping is an aspect of, but is not identical with, what is usually called *textsetting* in the literature.<sup>7</sup> On textsetting, see, among others, Halle and Lerdahl 1993; Halle 1999, 2003; Hayes 2005; Dell and Elmedlaoui 2008. Textsetting is defined by Hayes 2005 (p. 2) as “how lines of linguistic text are arranged in time against a predetermined rhythmic pattern.” This definition is correct, in my view, and illustrates how textsetting is really a set of processes, rather than just one. The reason that Hayes’s definition is a definition of textsetting, not of beat mapping, is its extraneous mention of meter (“a rhythmic pattern”). Beat mapping, I claim, is fundamentally independent of metrical pattern(s).

I propose to decompose textsetting into three distinct processes. These are all mapping processes, i.e., what they govern is correspondence relations. (I am

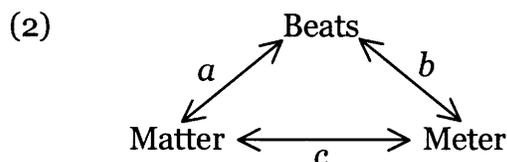
---

<sup>6</sup> A way to describe Criterion 1, in terms of conventional syllable structure, is as a “rime complexity” criterion (complex rime = H), while the more stringent Criterion 2 is a “nuclear complexity” criterion (complex nucleus = H).

<sup>7</sup> The term *textsetting* can be related to a term I previously used, *grammar of singing*, as follows: *grammar of speech* + *textsetting* = *grammar of singing*. That is, *textsetting* designates those processes of the grammar of singing that differentiate it from “core” phonology. It is an interface grammar, of sorts.

The term *textsetting* may invite at least one incorrect inference. *Setting* tends to imply a musical accompaniment, as well as (or even instead of) a vocal melody. But textsetting is really only concerned with the musical structure of phonetic representations; accompaniment, if present, might provide hints about this structure, but should not be mistaken for it. The human capacity to make music in groups is a highly significant fact, one that is surely relevant to an inquiry into the principles of music, but it is not what textsetting is about.

assuming the general framework of Generalized Correspondence Theory, on which see McCarthy and Prince 1995.) The correspondence relations they govern are those indicated by the double-sided arrows in the following triangular diagram:



The corners of this diagram are shorthand labels for what I take to be the fundamental contributors to the phonetic representation of singing. I will explain these immediately below. The correspondences between them I refer to simply as matter–beat correspondence, meter–beat correspondence, and matter–meter correspondence (arrows *a*, *b*, and *c* respectively). Beat mapping is a subprocess of matter–beat correspondence. (Note that beat mapping belongs to the one side of the triangle that doesn’t touch meter.)

I have already used “beat” and “timing unit” as synonyms earlier in this chapter. The first term in ordinary usage denotes a musical timing unit, so my collapsing of the two is consonant with the hypothesis I stated at the outset: that they are the same. Let me make explicit here, in three paragraphs, my understanding of beats; I will expand on this topic in the next section.

It is helpful to recall what is obvious: the distinction between phonetic events, which are physical things, and their mental representations. Phonetic representations are what I take the outputs of phonological derivations to be (whether these are expressed as an Optimality Theory (OT) tableau or an *SPE*<sup>8</sup>-style derivation of a Surface Representation from an Underlying Representation): a form of mental representation that is directly related to phonetic implementation, that embodies all the influence over/sensitivity to properties of phonetic events that phonology can have.<sup>9</sup> A beat is an element of phonetic

---

<sup>8</sup> *The Sound Pattern of English* (Chomsky and Halle 1968).

<sup>9</sup> As far as I know, no current theory of phonology treats the output as a phonetic event. This includes the “phonetically driven” approach to phonology, exemplified by, e.g., Gordon’s work on syllable weight, whose distinction from other approaches is its output-oriented approach to grammatical constraints on representations. As for this thesis, several of the constraints in

representation—a very basic element—whose physical correlate is just a point in time. A sequence of beats represents a sequence of points in time.<sup>10</sup>

Regarding this physical correlate, an important way that singing events differ from ordinary speech events is that the beats tend to be realized at a very even rate in time. The spacing between realizations of beats could be described in terms of an ideal rate, a *tempo*, which determines the temporal interval between beats, along with a range of deviation, which specifies the degree of strictness with which the tempo is enforced. For singing, this range tends to be on the low side. Whatever else may be said about the relative strictness of tempo in singing compared to speech, two important points seem clear: (i) A strict tempo is a fact about the realization of beats in a particular mode, not about the beats themselves. (ii) A practical effect of a strict tempo is that it makes the need for beats in the representation of musical speech much more obvious—at least to the analyst, if not to speaker-listeners—than in the case of non-musical speech, since it gives the cyclicity of the mental representation a clear physical correlate. We may say that strictness of tempo contributes to the *recoverability* (in this dual sense) of the sequence of beats, as a layer of phonetic representation unto itself.

While the physical correlates of beats are points in time, I believe their fundamental role in phonology is not to serve as measures of duration, but rather to organize and coordinate gestures. I believe their realization as points in time is more or less inevitable, and that the relative spacing of these points, when tempo comes with a high enough range of deviation, is determined by natural properties of phonetic gestures, which need not be part of the beat mapping representation.

Going back now to the diagram in (2), the label “beat” is on one level and “matter” and “meter” on another. This is intentional (though I do not want to put too much stress on the asymmetry). The first label refers to the most basic level of textsetting structure, the level of beats. This level can be thought of as basically invariant; there is nothing distinctive about one beat vs. another, or one sequence

---

Chapter 3 favor or disfavor representations on the basis of properties of their likely physical outcomes, while others are addressed to non-physical properties like computational complexity.

<sup>10</sup> Contrary to one common usage, beats do not represent musical events like drumbeats or toetaps. Such events are somewhat analogical to time points, however, and therefore helpful: the intervals of time they occupy (all events occupy time) are relatively brief, so they approximate the more idealized notion of beats as time points.

of beats vs. another (other than its length). The other two elements of textsetting are where variety and choices arise.

The less self-explanatory term of the two, “matter” (a reappropriated traditional term), is an oversimplification, an umbrella term for those elements of singing whose specific content is arbitrary from a structural point of view. There are basically two of these: the words (or let us say a phonological representation, a series of segments structured in some way) and the tune (a series of “notes,” pitch specifications, also structured in some way).<sup>11</sup> The oversimplification is that we are ignoring the tune; I leave as an open question what would change in (2) if we took it into account.<sup>12</sup> Since we are ignoring the tune, we can basically identify beat mapping with matter–beat correspondence.

The more familiar of the terms is “meter,” but it has been used in various senses.<sup>13</sup> I will adopt an entirely general definition. Meters are abstract patterns of alternating prominence; their fundamental principles are alternation and repetition. As pure patterns, they can be realized in various ways, without ceasing to be the same pattern.<sup>14</sup> It appears incorrect—partly on conceptual grounds, but also on empirical grounds—to tie meter to any one mode of realization (vocal music, non-vocal music, non-musical poetry) or phonetic dimension. Two common ways for metrical patterns to be realized phonetically are by translating the units of abstract prominence into units of stress/intensity (e.g., the meters of

---

<sup>11</sup> By “structured in some way,” I have in mind the prosodic hierarchy, on the one hand, and musical grouping structure (Lerdahl and Jackendoff 1983, Katz 2007) on the other.

<sup>12</sup> If we removed the words and left the tune, we would still have a musical score, just not a *vocal* score. In fact, we could theoretically replace the words with some mental representation of tuba-playing events, and get a tuba score. Notice that from the external point of view, songs-as-artifacts can be played on any instrument and retain their identity as “the same song.” The same is not true for the tune. In this respect, the tune is more on a par with meter than with words.

<sup>13</sup> My thinking on the place of meter in textsetting was much clarified by the analysis of Tashlhiyt Berber in Dell and Elmedlaoui 2008, though they do not explicitly take the position I take. What Dell and Elmedlaoui show is that in singing, meter does not inevitably interact with the temporal structure of the score. In Berber songs, the patterning of the linguistic matter is clearly distinct from the temporal patterning. Dell and Elmedlaoui do not explicitly refer to the latter as “meter,” but others would, e.g., Lerdahl and Jackendoff 1983. As I see it, a distinctive property of Tashlhiyt Berber singing is that it is polymetrical, i.e. it involves more than one meter, with separate modes of realization.

<sup>14</sup> According to M. Halle 1987 (cited in J. Halle 2003), there is even at least one case of meter being realized in the visual shape of the written text of a poem (Psalm 137 in the Bible).

English poetry) or into beats (e.g., the meters of Greek poetry and singing). The latter is the only one that will concern us.

We have now introduced each of the three corners of the textsetting triangle in (2). These mental elements of singing may be thought of as jointly determining a phonetic representation of singing. I will use the term *musical score* to refer to such a phonetic representation. Actually I will use this term in a somewhat flexible way: not only for phonetic representations of singing per se—these are mental objects, the true object of study for generative textsetting analysts—but also for the socially communicated externalizations of such representations—these are abstractions that manifest themselves in, e.g., written musical texts.<sup>15</sup> Formal depictions of musical scores will be developed on an as-needed basis, starting in the next section.

Having explained the place of beat mapping within a general theory of textsetting, I now want to address how beat mapping manifests itself in Greek, as a weight-sensitive process. First, we need to expand on the quantitative aspect of beat mapping and develop a formal depiction of it, so as to make the Greek data intelligible.

### 1.3 Musical quantity

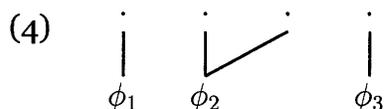
We now turn to the quantitative aspect of beat mapping. It is useful for this purpose to posit a derivative property of linguistic objects (i.e., elements of matter in a musical score), defined by the beat mapping relations they participate in: *musical quantity* (MQ). It is this property, we may say, that is regulated in a weight-sensitive manner in Greek beat mapping. MQ has a very simple definition, essentially “beat count”; this is stated explicitly in (3). As often, what is intuitively simple raises various questions on close inspection.

- (3) Musical quantity =  
       number of beats occupied (by a particular linguistic object  $\phi$ ,  
       e.g., a syllable or segment) in a musical score.

---

<sup>15</sup> This is exactly the same idealization involved in studying grammars via the idealized approximation of languages (see n. 1).

We can represent MQ formally according to the following schema, using a series of dots<sup>16</sup> to represent a series of beats, a series  $\phi_1 \dots \phi_n$  to represent a series of linguistic objects, and association lines between them to represent correspondence:



This is intended as a representation in which  $\phi_1$  and  $\phi_3$  have MQ 1 and  $\phi_2$  has MQ 2. With the representation adopted in (4), we can derive the MQ of each object by counting the number of distinct beats in correspondence with it, or the number of association lines projecting from it. The interpretation of beat “occupancy” as correspondence<sup>17</sup> has significant consequences, to which we will return shortly.

Having introduced the property MQ, I would like to identify and discuss four properties of this property, which bear on the empirical evaluation of the model being proposed. I will call these “matter-neutrality,” “discreteness,” “phoneticness,” and “non-linearity.”

*Matter-neutrality:* MQ as defined is not a property of any particular class of linguistic object. Just as words, syllables, and segments all have phonetic duration, they may all, in principle, have MQ.<sup>18</sup> Whether we actually define MQ for each of these classes of object depends on whether we have evidence that the grammar is *directly* controlling MQ at that level.<sup>19</sup> Such evidence might be quite

<sup>16</sup> The standard way to depict musical scores in studies of textsetting (e.g., Hayes and Kaun 1996, the only study I know of in which the MQ of phonetic objects plays a central role) is in the form of metrical grids. I must deviate from this practice because, as explained in the previous section, I am introducing a distinction between beats and metrical positions.

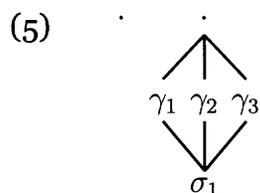
I should mention here that dots are used by Steriade 1991 as a representation of weight units (e.g., moras). The difference between weight units and beats (timing units) will be clarified as we proceed.

<sup>17</sup> Taking the term “occupy” more seriously would mean interpreting beats as weight units.

<sup>18</sup> In fact, MQ is not even a specifically linguistic property at all; we could easily speak of the MQ of a particular pitch event in a tune played on the piano. Since this thesis is specifically concerned with *vocal* music, it will ignore this degree of generality.

<sup>19</sup> Note that this is really two separate questions, which kinds of MQ will be defined and which will be controlled. Defining types of MQ is a matter of representations, controlling them is a matter of constraints. Some kinds of MQ could, in theory, be defined but not regulated, either universally or because of a particular constraint ranking.

hard to come by; consider a situation like the following, in which  $\sigma_1$  stands for a syllable and  $\gamma_1, \gamma_2, \gamma_3$  its constituent segments.



Assuming (mostly for graphical convenience) that correspondence is a transitive relation,<sup>20</sup> it is easy to confirm that all four objects  $\sigma_1, \gamma_1, \gamma_2, \gamma_3$  each have MQ 1, since they all correspond to exactly the same beat. Suppose that MQ 1 for each of  $\gamma_1, \gamma_2, \gamma_3$  was a direct result of grammatical constraints. It is fairly easy to posit an indirect reason why  $\sigma_1$  cannot have MQ 2: a rule that prohibits syllables from from mapping directly to beats, without also mapping to a segment. Similar reasoning could apply in reverse as well: in fact, assuming transitivity of correspondence is enough to prevent any constituent segment of an MQ 1 syllable from having MQ 2, since every syllable node automatically corresponds to all the beats that its constituent segments correspond to.

The main point here is that there is no obvious *a priori* reason to regulate MQ as a property of segments or syllables or both. The question must be settled empirically. Now, given a description of the Greek facts as “regulation of syllable MQ by syllable type,” one would think that regulating syllable MQ would be both necessary and sufficient. But in fact, the main point I hope to make in this thesis is this: *to capture how syllable MQ is regulated in Greek, the regulation of segment MQ is an indispensable factor, whereas adequate analyses that ignore syllable MQ exist.* I present one such analysis in Chapter 3.

I now turn to the other three properties of MQ.

*Discreteness:* MQ is a quantitative property—a measure—and specifically a discrete one: it is representable as a numeral. In this it differs significantly from duration, which is a non-discrete measure, whether we are talking about absolute or relative duration. Beats are an infinitely partial representation of time, and MQ is a correspondingly coarse measure of duration.

---

<sup>20</sup> I.e., if  $\alpha$  corresponds to  $\beta$  and  $\beta$  corresponds to  $\gamma$ , then  $\alpha$  corresponds to  $\gamma$ . I take syllable constituency to imply a correspondence relation.

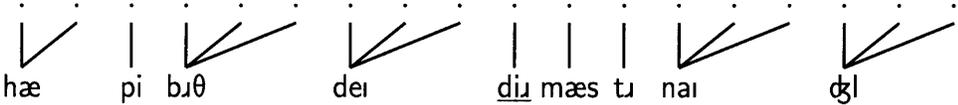
Duration, as a dense measure, is isomorphic to the inherently dense dimension it measures, the dimension of time. MQ, if we regard it as a measure of time, is clearly not isomorphic in this sense. This observation is closely tied to the fact that MQ is a measure over representations, with only an indirect connection to actual time.

*Phoneticness:* If MQ is not a physical fact, neither is it an invariant property of either syllables or segments. This variability is what demonstrates that we are dealing with a surface representation.

Consider syllable MQ. Here MQ is evidently a property of tokens rather than types. In the familiar “Happy Birthday” song, the words of the third line vary depending on whose birthday it is, while the tune stays constant. Here are some words that can be used to sing the third line:

- (6) a. Happy birthday, dear Nigel  
 b. Happy birthday, dear Master Nigel  
 c. Happy birthday, Deermaster Nigel

Fluent participants<sup>21</sup> who know the “Happy Birthday” song know that with each of these texts there is only one way to sing the line. With (6a), the underlined syllable has MQ 3, as shown in (7a). With the variants in (6b) and (6c), which are homophonous with each other, the “same” syllable as before has MQ 1, as in (7b).

- (7) a.   
 b. 

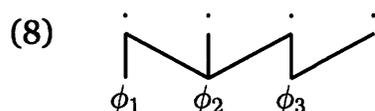
There is a sense in which the underlined syllables are the same object—/dir/—and a sense in which they are distinct objects—say, [dir]<sub>1</sub> and [dir]<sub>2</sub>. Clearly, MQ is only a (constant) property of the latter.<sup>22</sup>

<sup>21</sup> I take this term from Dell and Elmedlaoui 2008, who introduce it as a musical analog for *native speaker*. It refers to someone who has normal competence in a particular musical idiom.

<sup>22</sup> Note, however, that the MQ of an object is as persistent as the musical score in which it is embedded. Musical scores have a peculiar communicability, and a remarkable tendency to

The fact that MQ is a “surfacey” property is clearly shown by the fact that it cannot be equated with underlying segment length and/or syllable weight. It suffices to observe that these two phonological contrasts are binary (in Greek, at least), whereas the number of distinct MQs is unlimited. In fact, we saw just now that a single H syllable (/dir/) can have more than one MQ in English, and we will soon see that syllable MQ is also variable in Greek for long vowels and for syllables whose vowel is long. Since MQ cannot be identified with either underlying length/weight or duration, I claim that we need a three-way distinction between segment length/syllable weight, physical duration, and mediating between them, MQ. The task is to show that MQ assignment interprets underlying distinctions in a rule-governed way.

*Non-linearity:* Finally, MQ as defined is a non-linear measure of quantity, which is another respect in which it differs from duration. This is because it is defined in terms of correspondence, which *a priori* may be non-linear. Consider the following schematic score, which contains 4 beats:



With respect to this score,  $\phi_1$  has MQ 1,  $\phi_2$  has MQ 3, and  $\phi_3$  has MQ 2. If we were to add these all together (for some reason) we would get 6. From an intuitive point of view, this seems paradoxical, since there are only 4 beats in total. Duration is a more intuitive concept: it is an inherently linear measure of time, so the duration of parts can be expected to add up to the duration of the whole.<sup>23</sup>

If there were a one-to-one or one-to-many mapping of matter to beats (as, for example, in (4)), then the sum of MQs would always be equal to the total beat count, and we could say we had a linear measure of quantity. But in a correspondence-based theory, linearity has to be stipulated. I argue that we

---

become social artifacts (songs). This communicability seems to set musical scores apart from garden-variety phonetic representations.

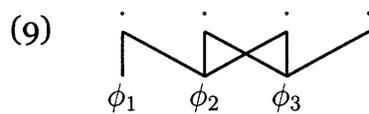
<sup>23</sup> Though only if the parts are assumed to be non-overlapping. This tends to be the assumption in grammatical representations, though we know it is not true physically. More recent theories of quantity, notably Steriade 2008, have exploited overlap in interesting ways. I have taken from this study the notion of compressibility of clusters as a factor in onset complexity (see 3.3.5).

Contrast, as well, the scenario in (5), where the MQs of the constituent segments definitely do not add up to the MQ of the whole syllable:  $1 + 1 + 1$  does not equal 1.

shouldn't stipulate it: the grammatical regulation of MQ in beat mapping exploits the intrinsic many-to-many potential of correspondence theory. In particular, beat mappings with the many-to-many shape in (8) will be argued to exist.

This is the major substantive difference between our interpretation of beats and a more traditional use of discrete units in theories of syllable and segment quantity: namely, weight units such as moras. Many-to-many correspondence between moras and segments would gut moraic theory.<sup>24</sup>

It should be noted that non-linearity also implies scores like the following are possible, in principle:



There is one more association line in (9) than in (8). Now  $\phi_3$  has MQ 3, and the diagram is getting very hard to read; association lines are now crossing, while before they were only touching. My proposal will rule out scores like (9) using a definition of (non-)linearity that applies specifically to mental representations, but this can wait till Chapter 3.

This concludes the list of properties of MQ. Throughout, we have been contrasting MQ with duration (whether as a physical property or a property of isomorphic representations). The point of the list boils down to this: MQ has very different properties from duration, and is not an isomorphic representation of it. Hence the hypothesis:

- (10) MQ is the mental correlate of physical duration. Duration is not encoded *per se* in phonetic representations.

Phonetic representations, full-fledged, must include all the cognitive resources a speaker has to influence the physical properties of her utterances, and to evaluate the physical properties of utterances she perceives. Since we know

---

<sup>24</sup> Like our approach to quantity, moraic theory employs discrete units, but by contrast predicts a fairly direct relationship between quantity and duration. See Broselow, Chen and Huffman 1997 for an experimental implementation of this approach, and see Gordon 2002 for a response.

that speakers' control<sup>25</sup> is quite finely tuned in general, phonetic representations must be correspondingly rich. The question is whether a representational device like MQ, which is more impoverished than duration in one respect—it is discrete, it can't do fractions—and richer in another respect—it is non-linear—has the right properties to account for whatever evidence we can muster about the way that, or the degree to which, speakers control duration.

I propose to address that question empirically only in the specific domain of Greek musical speech. Turning the hypothesis in (10) into a viable hypothesis of phonetic control of duration would obviously mean answering the question for non-musical speech as well. If affirmative, it would entail that a musical score, far from being a “foreign body” linguistically, is actually just a socially communicable, richly specified version of the phonetic representations that facilitate all speech.

#### 1.4 Regulation of MQ by syllable type

Without further ado, we now turn to our empirical focus, regulation of MQ in Ancient Greek. Ancient Greek vocal music actually furnishes evidence of two distinct kinds of regulation of MQ: by syllable structure, and by metrical structure. The first is the main focus of this thesis, and the data on it is presented in detail in Chapter 2 and analyzed in Chapter 3. The second is an important counterpoint to the first, but cannot be dealt with fully. In this section and the following one I will briefly outline the main facts about these two kinds of MQ regulation.

The basic Greek pattern we will be analyzing is in (11). Note that the pattern is presented as a syllable MQ pattern. The notation “2, 3, 4, ...” indicates that long-vowel syllables have variable MQ with a lower bound of 2 and, in principle, no upper bound (the highest *attested* MQ in the extant corpus of scores is 6).

(11)	Syllable type	MQ	Criterion 1	Criterion 2
	C <sub>o</sub> V	1	L	L
	C <sub>o</sub> VCC <sub>o</sub>	2	H	L

---

<sup>25</sup> I use the verb and noun *control* to denote both articulatory control over, and perceptual sensitivity to, phonetic variables.

$C_0VVC_0$	2, 3, 4, ...	H	H
—	—	L	H

The syllable types are also categorized, in the two rightmost columns, according to two different weight criteria, namely, the Greek criteria given earlier in (1) (repeated here as (12)).

- (12) a. Greek Weight Criterion 1:  $L = C_0V$        $H = C_0VVC_0$  and  $C_0VCC_0$   
 b. Greek Weight Criterion 2:  $L = C_0VC_0$        $H = C_0VVC_0$

Many empirical issues arise in establishing the pattern in (11), but I defer these to Chapter 2. (Unfortunately, the physical evidence is in a far from optimal state of survival.) I will mention only the principal issue: there are cases of  $C_0VC$  syllables with MQ 3. These contradict the claim that such syllables are limited to MQ 2. I will suggest that these cases have a special explanation, tied to a particular kind of coda consonant, and that they are not genuine exceptions.

The pattern in (11) appears to represent the workings of a process that aligns syllables with beats in a quantity-sensitive manner—mapping linguistic quantity onto MQ. If so, what is particularly striking about this process is that it seems to employ a non-binary syllable weight criterion: it treats three different kinds of syllables three different ways in terms of potential MQ. The other known weight-sensitive processes in Greek phonology use a binary criterion, one of the two given in (12).<sup>26</sup>

On the other hand, this non-binary criterion can be analyzed as a binary composite of the two binary criteria. One category consists of what both Criterion 1 and Criterion 2 call L—let us abbreviate these two “Lnesses” as  $L^{G1}$  and  $L^{G2}$ —, another category consists of what is both  $H^{G1}$  and  $H^{G2}$ , and another consists of what is  $H^{G1}$  but  $L^{G2}$ . The fourth logically possible category,  $L^{G1}$  but  $H^{G2}$ , happens to be empty.

To account for the effects of Criterion 1 in Greek beat mapping, we could write a language-specific constraint like the following:<sup>27</sup>

<sup>26</sup> Non-binary weight criteria are, however, found in other languages (Steriade 2002).

<sup>27</sup> Formatting note: in this thesis, the names of grammatical constraints are enclosed in a box.

- (13) Criterion 1/MQ  
 $L^{G1}$  syllables have MQ 1,  $H^{G1}$  syllables have MQ > 1.

Notice that this constraint is fully satisfied by the pattern in (11), that is, it describes the pattern in an accurate if coarse-grained way.

To implement Criterion 2, we might write, for example:<sup>28</sup>

- (14) Criterion 2/MQ  
 $L^{G2}$  syllables have as small an MQ as possible, preferably MQ 1  
 (assess 1 penalty for MQ 2, 2 penalties for MQ 3, ...).

Suppose we assume that the goal of beat mapping is to optimally satisfy both Criterion 1/MQ and Criterion 2/MQ, stipulative and language-specific as they are.<sup>29</sup> To find out which is more important, we have only to ask what happens when they conflict. The only time these two constraints conflict is in the case of  $C_0VCC_0$  syllables. Since these are  $H^{G1}$ , Criterion 1/MQ requires them to have MQ > 1, whereas, since they are  $L^{G2}$ , Criterion 2/MQ would prefer them to have MQ 1. In fact, they always have MQ 2, which is less than optimal from the Criterion 2/MQ's point of view, but has the crucial advantage of satisfying Criterion 1/MQ. Anything higher than MQ 2 for  $C_0VCC_0$  would incur higher

---

<sup>28</sup> As one alternative to (14), which requires MQ minimality for short-vowel syllables, we could briefly entertain a constraint based on the observation that all the short-vowel syllable types are invariant, while the long-vowel types are variable:

- (i) Criterion 2/MQ  
 $L^{G2}$  syllables have invariant MQ,  $H^{G2}$  syllables have variable MQ.

In combination with Criterion 1/MQ, this would ensure that  $C_0V$  always has MQ 1 while the MQ of  $C_0VCC_0$  ranges from 2 to infinity. However, it fails to correctly set MQ 2 for  $C_0VCC_0$  syllables; it would be equally satisfied with, say, invariant MQ 5 for those. This shows that the stronger restriction of MQ minimality is needed, as elaborated on forthwith.

<sup>29</sup> Both constraints explicitly favor MQ 1 for  $C_0V$  syllables. Once would be sufficient, so we could actually pare down Criterion 1/MQ to say simply “ $H^{G1}$  syllables have MQ > 1” (leaving  $L^{G1}$  unmentioned). There is no reason to inquire whether there are any conceptual or empirical reasons to favor this leaner formulation, since the current formulation is for expository helpfulness only.

penalties from  $\boxed{\text{Criterion 2/MQ}}$  without gaining anything with respect to  $\boxed{\text{Criterion 1/MQ}}$ .<sup>30</sup> This motivates the following constraint ranking:

(15)  $\boxed{\text{Criterion 1/MQ}} \gg \boxed{\text{Criterion 2/MQ}}$

The principal goal of this thesis is to tell essentially that story, but in a non-stipulative way. Why should just these particular MQs be favored for these particular syllable types? Why should these constraints exist, and why should they be ranked this way?

I will argue that the seemingly arbitrary content of the constraints as they stand obtains a rational basis when interpreted in terms of underlying properties of the constituent segments: sonority, and contrastive length. The constraint conflict in (15) will resurface, but in much altered form.<sup>31</sup>

### 1.5 Regulation of MQ by meter

Quite independently of the way MQ is regulated by syllable type, the metrical patterns that are a near-ubiquitous feature of Ancient Greek songs are an important additional regulatory factor, albeit a somewhat indirect one.

While the first type of regulation is about achieving an appropriate mapping between syllable type and beat count, the second type of regulation is about realizing an abstract pattern of alternation in beats. In my analysis, meter affects the MQ of syllables only indirectly.

Here are the basic facts from a practical point of view. In Greek songs, typically and by default, the alternation pattern that a song's meter imposes creates strong *positions* (S), which are sequences of beats that are two beats long, alternating with weak (W) positions, which are singleton sequences. Each of these positions must—again, by default—correspond to a single syllable. The result is that W syllables have MQ 1 and S syllables have MQ 2. As we saw in the previous section, every Greek syllable type is compatible with one of these two MQs.

---

<sup>30</sup> Thus, the invariance of MQ for all  $C_0VC_0$  syllables (both  $C_0V$  and  $C_0VCC_0$ ) receives a unified explanation from our  $\boxed{\text{Criterion 2/MQ}}$ . Cf. previous note.

<sup>31</sup> As  $\boxed{\text{Sonority monotonicity}} \gg \boxed{\text{Segment length}}$ : see 3.10.

Sometimes, however, the default is not observed. The most significant case is the genre that West 1992 calls “spondaic tempo,” which is typified by an absence of C<sub>o</sub>V syllables. In this genre, the metrical patterns stay the same—S alternating with W, either in a binary fashion or some other fashion—but their mapping onto beats is altered, so that instead of creating two-beat S positions and one-beat W positions for syllables to fill, they create four-beat S positions and 2-beat W positions. If this mapping process is separate from that of beat mapping, we might expect the beat mapping pattern in (11) to continue to hold even when the metrical mapping changes. This will have an interesting consequence: C<sub>o</sub>V syllables will be systematically absent, because they need one-beat positions to fill. That is what is predicted, and the prediction is confirmed (West 1992). Spondaic tempo shows vividly that meter does not influence the MQ of syllable types in Greek.

There are both positive and negative empirical consequences for us metrical regulation of MQ. On the negative side, when the default MQ 1/MQ 2 alternation pattern is observed, which is most of the time, the distinct MQ potentials of short-vowel H and long-vowel H syllables are, so to speak, neutralized. Both syllable types are limited to MQ 2, which artificially collapses the ternary pattern given in (11) into a binary one. In short, with the default metrical mapping, L = W, H = S, and that’s the end of the story.

To attest the full pattern, realizing the MQ elasticity of long-vowel syllables, we are crucially dependent on songs or parts of songs where the default metrical mapping is not observed, i.e., where metrical positions of three or more beats are available. Such data is limited, in an already limited corpus.

On the positive side, the fact that we can tease apart these two distinct kinds of MQ regulation in a single corpus has considerable potential for clarifying the overall structure of textsetting and the interaction of correspondences. I regret that I cannot flesh out the textsetting triangle (2) more in this study.

## 1.6 The rest of the thesis

The rest of the thesis, as mentioned along the way, is organized as follows:

Chapter 2 is a detailed presentation of the Greek MQ data.

Chapter 3, the theoretical core of the thesis, provides a constraint-based analysis of Greek beat mapping.

Chapter 4, the concluding chapter, suggests some avenues for future research.



## 2 Syllable MQ in Greek

The purpose of this chapter is to document certain facts about the attested MQs of the different Greek syllable types. The facts to be established were summarized in (11) in Chapter 1 above, and are repeated here.

(1)	Syllable type	MQ	Criterion 1	Criterion 2
	$C_0V$	1	L	L
	$C_0VCC_0$	2	H	L
	$C_0VVC_0$	2, 3, 4, ...	H	H

This pattern will be corroborated statistically (in a fairly informal way—no tests of statistical significance have been performed) using data on syllable MQ obtained through a manual search of the corpus of extant Greek musical scores.

Understanding the nature of the data requires laying out a certain amount of philological background. More theoretically inclined readers, who are not interested in the methodological basis for making determinations of fact about the phenomena of corpus languages with no extant speakers, may wish to skip the bulk of this chapter, 2.2–2.5 (perhaps stopping to look at the example in 2.3).

As already mentioned in 1.4, there is one significant hitch in the data: the existence of some apparent  $C_0VCC_0$  tokens with MQ 3. These examples are the special focus of Hill (in progress), the main point of which is summarized in 2.7.

### 2.1 A preliminary factorization

The pattern in (1) may be factored into a set of minimum and maximum MQs. Such a factorization will help us clarify which aspects of the pattern are “new” and which are not, which in turn will bring into focus what the present chapter needs to accomplish in terms of documentation.

- (2) Minimum MQs:
- a.  $C_0V$   $\geq 1$  (trivial minimum: greater than zero)
  - b.  $C_0VCC_0, C_0VVC_0$   $\geq 2$  (“anti-minimality”)

- (3) Maximum MQs:
- |    |            |          |                |
|----|------------|----------|----------------|
| a. | $C_0V$     | $\leq 1$ | (“minimality”) |
| b. | $C_0VCC_0$ | $\leq 2$ |                |
| c. | $C_0VVC_0$ | none     |                |

Three observations on this factorization:

(i) The fact that the maximum is equal to the minimum for  $C_0V$  and  $C_0VCC_0$  is another way of saying that these syllable types are quantitatively invariant.

(ii) All short-vowel syllable types have a maximum MQ; long-vowel syllable types do not.

(iii) One of these maxima, the lowest one (3a), which applies to  $C_0V$  syllables, combines with one of the minima, the highest one (2b), which covers  $C_0VX$  syllables, to create a quantitative disjunction between L and  $H^1$  syllables. L syllables show “MQ minimality” and H syllables show “MQ anti-minimality,” in that L syllables must be as small as (musically) possible and H syllables must be bigger than that.

Of these three empirical generalizations, the third—the minimality of L and the anti-minimality of H—is not new: it reflects the scholarly consensus among scholars of Ancient Greek music, and is confirmed by direct ancient testimony (see West 1992 for discussion and references). While all three generalizations require an explanation, only the first two generalizations are actually new facts.<sup>2</sup> Therefore this chapter, since its purpose is to establish the

---

<sup>1</sup> In this chapter, whenever we use the terms L and H, we mean  $L^{G1}$  and  $H^{G1}$ —weight according to Greek Weight Criterion 1. This is the predominant criterion in Greek.

<sup>2</sup> It may seem strange or striking that generalization (iii) should already be part of the scholarly record and (i) and (ii) not be, when the latter two as I have stated them are quite simple and straightforward (readable, even) compared to (iii). The reason for this state of affairs must be that (iii) is storable (and has generally been understood) in terms of syllable weight categories, while (i) and (ii) require reference to the segmental composition of syllables. The weight categories are part of the standard training for students of Greek, and second nature to any serious student of Greek poetry (of whom West is one), because they are both necessary and sufficient for poetic scansion. Interestingly, the category H is traditionally broken down into two subcategories, “long by nature” and “long by position.” This distinction is ancient, and it is simply the distinction between “ $C_0VVC_0$ ” and “ $C_0VCC_0$ .” One learns this distinction at the beginning of one’s training, but it is never useful in practice when learning to scan poetry, since Greek poetic meter treats all H syllables uniformly (as far as we know). Armed with this distinction, one could state generalization (ii).

empirical basis for the analysis to follow, will focus on the different treatment of different H syllable types, deriving the minima and maxima in (2b) and (3b–c) from data collected through a manual search of (transcribed facsimiles of) Greek musical scores. But first, a bit of background is necessary to explain how these texts are structured and interpreted.

## 2.2 The structure of the musical notation

A number of Greek musical texts are preserved on papyrus, parchment and stone. The standard comprehensive corpus is Pöhlmann and West 2001 (henceforth, P&W), which contains 61 documents.<sup>3</sup> Not all of these documents have both musical notation and words on them, and those that do range from small fragments to nearly complete long odes. It is a corpus constructed by chance, not rational design, and it is all we have.<sup>4</sup> It is a heterogeneous corpus in several respects: style of notation, genre, social context, physical context, and time (the documentary record of P&W spans several centuries, from the fifth century BC until early Christian times). Yet even while the corpus ranges over all these variables, the basic rules of correspondence governing MQ apparently remain stable, since the corpus taken as a whole yields consistent results.<sup>5</sup> The musical

---

<sup>3</sup> West 1992 provides more accessible versions of the more complete and/or more important texts. The matter is transliterated into Roman characters and translated.

<sup>4</sup> It should be mentioned that the manuscript tradition which preserves the canonical works of classical literature includes a number of musical texts: all the “lyric poets” (Pindar, Simonides, Bacchylides, etc.), all the choral lyric passages of Attic drama (Aeschylus, Sophocles, Euripides, Aristophanes), to name a few big ones, represent compositions that are every bit as musical as the compositions in the P&W corpus. Unfortunately, this canon preserves only the words of these compositions, not the music, either because the music was never written down or because it was lost. The P&W corpus is therefore the place to start studying Greek MQ, but the canonical works have the potential to provide additional data, if it is possible to make secure inferences about the musical setting of the preserved text.

<sup>5</sup> I am glossing over some historical linguistic issues here. The time period of the texts happens to have been a period of rapid linguistic change in Greek (the *koine* or common period), and some of the changes that are known to have taken place by late Roman/early Christian times would certainly have impacted MQ: first and foremost, the loss of contrastive vowel length (see Allen 1974). Other eventual changes also relevant: replacement of the polytonic accent (H, LH and HL on the accented syllable) with a uniform stress accent; loss of diphthongs, through smoothing (/ai/ > /e/) and fricativization of labial offglides (/au eu/ > /av ev/); simplification of certain consonant clusters (especially /sd/ > /z:/ > /z/).

The texts yield a coherent analysis only if one assumes that the phonology underlying them is quantity-sensitive and includes contrastive vowel length—in fact, that words have the same quantitative profile that they do in Classical Greek. I follow West 1992, and common

notation is also susceptible to a unified description. My description relies primarily on West 1992.

The richest type of musical text contains three parallel lines, with association between symbols on separate lines being implied by vertical alignment (sometimes rather approximate). Typically, the top line contains *quantity symbols*, which indicate the duration in beats of the note or sequence of notes, and thereby, indirectly, the MQ of a syllable. The next line contains pitch symbols (letters of the Greek alphabet, like our *A B C D E F G*), and the bottom line is the matter. Sometimes the quantity notation is absent altogether, whereas there are no texts that possess quantity notation without pitch notation. Since we are concerned with MQ, the texts that furnish us with usable evidence are those that have some quantity notation. The standard symbols are as follows:

— = *diseme* = MQ 2

⌊ or ⌋ = *triseme* = MQ 3

⌌ = *tetraseme* = MQ 4

(A *pentaseme* symbol is also known from ancient commentators, but not directly attested in use.) These symbols are only found associated with Hs. The fact that Ls universally go unmarked in the quantity notation is logical, since their MQ is not only invariant but also minimal, i.e., identified with the basic/atomic rhythmical unit.

The names *diseme* ‘two-sign’, *triseme* ‘three-sign’, and so on, are traditional. Although these terms properly denote the quantity symbols themselves, I will sometimes use them to refer to syllables that have the designated MQ. Also, I will refer to trisemes, tetrasemes, etc. (but not disemes) collectively as *polysemes*, which will be a convenient way of referring to (H)

---

philological practice, in transcribing these non-Classical texts using Classical Greek sound values; I do not agree with this choice in principle, but notably, it creates no practical difficulties and avoids certain uncertainties.

The corpus is undoubtedly “linguistically conservative” from the point of view of the late *koine*, even “Classicizing,” but it is hard to say how natural or artificial that conservatism is. A degree of artificiality, at least literacy, may be inferred from etymological spelling: where there is more than one grapheme with the same sound value, the writer’s choice is usually etymological and usually correct.

At any rate, whatever degree of historical distance there may be between the texts and the quantity-sensitive system they witness, they are our earliest and best witnesses to it.

syllables with an MQ above the minimum of 2 (the corpus attests MQs as high as 6). The most common attested type of polyseme is the triseme, though it is much less common than the diseme.

### 2.3 An example

The most pristine example of a musical text that is available to us is the Song of Seikilos (P&W #23; West 1992 #13), which a certain Seikilos had inscribed on his gravestone.<sup>6</sup> A glossed transcription of this inscription is given in (4).<sup>7</sup> The trilinear text—quantity symbols, notes (*A, B, C#',* etc.), and words—has been divided into four lines, each glossed and freely translated. Words are divided into syllables (joined by hyphens) in order to make vertical alignments easier to see;<sup>8</sup> note that word boundaries may fall within a syllable in Greek (Steriade 1982). The absence of some quantity symbols in some places will be explained a couple pages from now.

#### (4) **The Song of Seikilos** (transcript)

—	┘		—						
<i>A</i>	<i>E'</i>	<i>E'</i>		<i>C#'</i>	<i>D'</i>	<i>E'</i>	<i>D'</i>		
h'o-	son	z-dɛ:s		p'hai-			nu:		line 1
	how.long	you.live		shine					
	<i>However long you're alive, shine</i>								
—		—		—		—	┘		
<i>C#'</i>	<i>D'</i>	<i>E'</i>	<i>D'</i>	<i>C#'</i>	<i>B</i>	<i>A</i>	<i>B</i>	<i>G</i>	
mɛ:-	de-n	h'o-	lɔ:s	sy		ly:-	pu:		line 2
NEG		wholly		you		be.aggrieved			
	<i>Don't get annoyed at all</i>								

<sup>6</sup> Allen 1974 contains a drawing of this inscription.

<sup>7</sup> As mentioned in n. 5, I follow West 1992 and others in transliterating Greek musical texts using Classical Attic sound values—a distortion, but a practical move that causes no serious difficulties.

In the transcriptions, I omit accentuation, even though it is not predictable, because it is not relevant for us. It is also not recorded in the texts themselves; the location of accents is known from other sources. In the Song of Seikilos and several others, melodic structure can be seen to respect the contours created by the lexical pitch accent, a phenomenon of potential (separate) interest; see West 1992.

<sup>8</sup> In actuality, pitch and quantity symbols tend to be placed above the vowel, rather than the left syllable edge, as my transcription would suggest.

A	C#'	E'	<u>D'</u>	<u>C#'</u>	<u>D'</u>	C#'	A	B	G	
pro-s	o-	li-	go-n	es-	ti	to	z-dɛ:n			line 3
unto	little		is			the	to.live			
<i>Life is for a little while</i>										

A	C#'	B	<u>D'</u>	<u>E'</u>	<u>C#'</u>	A	A	<u>A</u>	<u>F#</u>	<u>E</u>	
to	te-	lo-s	ho	k <sup>h</sup> ro-	no-s	a-	pai-	te:			line 4
the	end		the	time		demands					
<i>Time demands its fee</i>											

One element of Greek musical notation that has not been mentioned yet, *pointing*, is represented in (4) as underlining of (sequences of) notes; the actual notation is a point or dot (called *stigma*) placed above a note or sequence of notes (or above the quantity symbol, if present). Pointing has a metrical significance: it marks the *arsis* or weak portion of a metrical constituent. The bearing this has on MQ in the Song of Seikilos will be explained below.

A musical score can be extrapolated from the text of (4), and is given in (5). The format of (5), and other scores in this chapter, differs somewhat from the format used in Chapters 1 and 3 (the theoretical chapters), being more like the standard metrical grids that textsetting analysts tend to use. This format is practical (it omits association lines, for example), and includes basic information about meter:<sup>9</sup> the locations of maximum metrical prominence, or *tactus*, which normally occur at a fixed rate relative to the beat. Starting at the top of (5), we have a beat cycle of 12 beats, numbered for reference (this cycle repeats), then the *tactus* pattern, indicated by ×. This song's rhythm is ternary, so the ×s come on every third beat. The notes and words from (4) are then vertically aligned to this temporal skeleton. Dashes (–) aligned with a beat indicate that the preceding syllable occupies that beat.

---

<sup>9</sup> We will not be analyzing meter formally in this thesis, but we will use it in this chapter as one piece of evidence for MQ.

(5) **The Song of Seikilos** (score)

1	2	3	4	5	6	7	8	9	10	11	12		
.	.	.	.	.	.	.	.	.	.	.	.	Beat	
x			x			x			x			Tactus	
<i>A</i>	<i>E'</i>		<u><i>E'</i></u>				<i>C#'</i>	<i>D'</i>	<i>E'</i>	<u><i>D'</i></u>			
h <sup>o</sup>	sonz	–	zε:s	–	–		p <sup>h</sup> ai	–	–	nu:	–	–	line 1
V	<b>VCC</b>	–	<b>VVC</b>	–	–		VV	–	–	<b>VV</b>	–	–	
<i>C#'</i>		<i>D'</i>	<u><i>E'</i></u>	<i>D'</i>	<i>C#'</i>	<i>B</i>	<i>A</i>			<u><i>B</i></u>	<i>G</i>		
mε:	–	de	n <sup>h</sup> o	lɔ:s	–	sy	ly:	–	–	pu:	–	–	line 2
<b>VV</b>	–	V	V	<b>VVC</b>	–	V	<b>VV</b>	–	–	<b>VV</b>	–	–	
<i>A</i>	<i>C#'</i>	<i>E'</i>	<u><i>D'</i></u>	<i>C#'</i>	<i>D'</i>	<i>C#'</i>	<i>A</i>			<u><i>B</i></u>	<i>G</i>		
pro	so	li	go	nes	–	ti	toz	–	–	dε:n	–	–	line 3
V	V	V	V	VC	–	V	VC	–	–	<b>VVC</b>	–	–	
<i>A</i>	<i>C#'</i>	<i>B</i>	<u><i>D'</i></u>	<i>E'</i>	<i>C#'</i>	<i>A</i>	<i>A</i>			<u><i>A</i></u>	<i>F#</i>	<i>E</i>	
to	te	lo	s <sup>h</sup> o	k <sup>h</sup> ro	no	sa	pai	–	–	te:	–	–	line 4
V	V	V	V	V	V	V	VV	–	–	<b>VV</b>	–	–	

Each syllable has been annotated according to its rime type (i.e., its syllable type, with the onsets omitted to save space).

I will now explain how this score was arrived at. The alignment to the beat cycle is based first and foremost on the disemes and trisemes, where present; these indicate that the associated syllable occupies, respectively, two or three beats. Syllables whose MQ is vouchsafed by a quantity symbol are boldfaced. The pitch symbols also provide information that is relevant to temporal alignment.

Note that every C<sub>0</sub>V syllable is mapped to exactly one pitch event, in contrast to C<sub>0</sub>VX syllables, which may be mapped to more than one. This indivisibility of C<sub>0</sub>Vs with respect to pitch is consistent with the claim that their MQ is invariantly one beat, given one further assumption: that one beat cannot host two pitch events. This indivisibility or atomicity of the basic counting unit is indeed a property of the normal style of Greek textsetting, of which the Song of Seikilos is an example. An “ornate style” (West 1992) arose in the later period (represented by higher-numbered texts in P&W’s catalog), one of whose features was, apparently, divisibility of the beat with respect to pitch. The basic rules of

MQ correspondence were not affected by this melodic elaboration; in other words, the beat remained indivisible with respect to matter.

But while every syllable gets at least one pitch symbol, not every C<sub>o</sub>VX syllable gets a quantity symbol: for example, according to the alignment given here, the 3-beat syllable p<sup>h</sup>ai in line 1 is missing a –, and in line 3, nes is missing a –. The standard interpretation (West 1992) of this sort of omission, which is common in the extant scores, is that quantity notation may be omitted when the syllable’s MQ is sufficiently indicated by the pitch notation. The syllable p<sup>h</sup>ai is mapped to three notes (C#, D, E) and therefore must be (at least) MQ 3, while nes- is mapped to two notes (C#, D) and therefore must be (at least) MQ 2.<sup>10</sup> This method of redundancy reduction is not obligatory, since the final syllable in the song (-te:) has both a triseme and three notes, and in line 2, -l̄:s has both a diseme and two notes.

With this much assumption and inference, what are the results? We did not begin by assuming that each of the four lines was isochronous, but that is the result we derive: each line occupies exactly 12 beats. Two more striking regularities emerge:

(i) The only beats in the 12-beat cycle that are invariably aligned to (the left edge of) a syllable are the tactus beats: 1, 4, 7 and 10.<sup>11</sup>

(ii) Notes marked by the stigme (underlined) turn out to be just those notes that occupy beats 4–6 and 10–12. Notes on beats 1–3 and 7–9 are pointless, therefore in the *thesis* or strong part of a metrical constituent.

This is not the place to give a proper metrical analysis of the Song of Seikilos, but in brief, the metrical organization of the 12-beat line seems to be as follows:

(6) [[1 2 3]s [4 5 6]w] [[7 8 9]s [10 11 12]w]

---

<sup>10</sup> How do we get from “at least 3” to “exactly 3”? This is apparently a sort of paralinguistic scalar implicature. When there is a divergence between the MQ of a syllable and what is implied by its pitch contour, this has to be explicitly indicated (for example, the final syllables of lines 2 and 3 (pu:, de:n), which have an MQ of 3 but only a 2-note contour). Where no such divergence is indicated, that is, when a quantity symbol is absent, Gricean reasoning leads to the conclusion that there is no divergence.

<sup>11</sup> I am indebted to François Dell for this observation, and further insights on the metrical organization of the Song of Seikilos, which I hope to make more use of some day.

The line is built up of four isochronous (three-beat) constituents. The left edge of each constituent is aligned with a syllable edge, and the constituents labeled W are those that are pointed. The fact that the score in (5) is *prima facie* metrically coherent is a welcome validation of the reconstruction.

More significantly for present purposes, the score in (5) conforms to the generalizations in (1). This song contains 1-, 2-, and 3-beat syllables, and the reader can verify that all the 3-beat syllables contain a long vowel (C<sub>0</sub>VVC<sub>0</sub>), all the 2-beat syllables are C<sub>0</sub>VX, and as already discussed, all the 1-beat syllables are C<sub>0</sub>V.

#### 2.4 Other sources of information on MQ

We have already mentioned that even in the absence of quantity notation, the pitch notation can furnish indirect information about MQ: if a syllable has *n* notes, it must have at least *n* beats.

In musical texts without a separate line of quantity notation, a triseme position may be indicated on the pitch line using the *leimma*  $\wedge$ , which increases the time value of the syllable it is associated with by 50% over its expected value. For example, if the leimma is attached to (a note attached to) a syllable whose expected (default) MQ is 2, then we infer MQ 3 for that syllable. Let us see an example. P&W #27 (Mesomedes, *Hymn to the Sun*) is composed of two similar kinds of lines, exemplified by (7) and (8).

(7) A D' E' E' E' E' E' F' D' F' E' (P&W #27.15)  
 po- ta- moi =de se-<sup>12</sup> t<sup>h</sup>en py- ro-s am- bro- tu:  
 rivers PTC your fire immortal  
*And the rivers of your immortal fire*

(8) A A A A D' A B, A G  $\wedge$  A (P&W #27.7)  
 k<sup>h</sup>i- o- nob- le- p<sup>h</sup>a- ru: pa- te-r A:- u:s  
 snow-eyed-GEN father-VOC Dawn-GEN  
*O father of white-faced Dawn*

The type in (7) is composed of 11 syllables, that in (8) of only 10 syllables. Note the leimma in (8), associated with a H syllable.

<sup>12</sup> No note is specified for this syllable. In such cases, it is assumed that the syllable is sung on the same note as the preceding syllable.

In this case an isochronous score is generated by, first, assuming that the MQ of H syllables defaults to 2, in the absence of quantity notation, and then taking the leimma as indicating MQ 3 for its syllable, compensating for the “missing” penultimate L. (Note, in passing, that the syllable so marked contains a long vowel, which has no MQ maximum and is therefore “legal” with MQ 3.)

(9)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
			x				x				x			x		Beat Tactus <sup>13</sup>
	po	ta	my:		de	se	t <sup>h</sup> em		py	ro	sam		bro	tu:		(7)
	V	V	VV		V	V	VC		V	V	VC		V	VV		
	k <sup>h</sup> i	o	nob		le	p <sup>h</sup> a	ru:		pa	te	ra:			u:s		(8)
	V	V	VC		V	V	VV		V	V	VV			VVC		

The first assumption is supported by variants of (7) and (8) in which the first two Ls are replaced by one H:

(10)	<i>A B,</i>	<i>C'</i>	<i>A</i>	<i>C'</i>	<i>C'</i>	<i>C'</i>	<i>C'</i>	<i>C'</i>	<i>D'</i>	<i>C'</i>						(P&W #27.12)
	ak-	ti:-	na	po-	lys-	tro-	p <sup>h</sup> o-n	am-	ple-	ko:n						
	beam			much-	turned			braiding								
	<i>Braiding your whirling rays</i>															

This H-for-LL substitution is a very common phenomenon in Greek metrics, known as resolution. Isochrony is preserved:

(11)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
			x				x				x			x		Beat Tactus
	ak	ti:		na	po	lys		tro	p <sup>h</sup> o	nam			ple	ko:n		
	VC	VV		V	V	VC		V	V	VC			V	VV		

These examples come from one of the most sparse texts in the corpus in terms of quantity notation. (Fortunately, the text is not fragmentary, or it would be difficult to say anything confidently about the song’s temporal structure.) In general, the more sparse the quantity notation in an Ancient Greek musical text,

<sup>13</sup> The tactus pattern of this song is a bit irregular, it involves a line-internal syncopation: one beat is dropped between the tactus beats at 11 and 14. Every other pair of adjacent tactus beats in the beat cycle is four beats apart: 3–7, 7–11, and 14–3 (pauses between lines are normally indicated in the Greek text if present, and this text contains no such indication).

the more predictable MQ is in the song that it records. The source of this predictability is metrical structure.

## 2.5 Counting polysemes

Having established what the material looks like, we will now turn to statistics. The numbers will bear out the MQ pattern in (1), with the caveat already mentioned: cases exist of MQ 3 in certain  $C_0VCC_0$  syllables. These are discussed in 2.7.

Interpreting ancient documents requires several different kinds of expertise, even more so when the documents' original users themselves relied on specialized knowledge (musical education), which has to be painstakingly reconstructed; in gathering my data, I have relied heavily on P&W's transcriptions and interpretations.<sup>14</sup> For each document, P&W provide a direct transcription (adding little or no information to what is contained in the document itself) and a reconstructed modern-style musical score based on it. I made use of both in my search for polyseme data.

A word about admission criteria: by the nature of the P&W corpus, the degree to which a given syllable's MQ may be taken as secure falls on a continuum from quite secure to quite uncertain. I have only counted examples of  $MQ > 2$  from reasonably fulsome textual contexts, and only those marked by a quantity symbol or a pitch contour of more than two notes.<sup>15,16</sup>

---

<sup>14</sup> I spent seven years in training as a classicist, during which time I got some experience in textual criticism and in studying meter. This gives me enough expertise to understand and, to some extent, evaluate what P&W do with their source material, but not to make any innovations. In particular, quibbling with particular details of transcriptions—is symbol X one letter or another letter, a rare metrical symbol or a stray mark—is out of the question, for technical reasons.

<sup>15</sup> I assumed in all cases that a pitch contour of  $n$  notes ( $n > 1$ ) on an H syllable indicated, in the absence of a quantity symbol, an MQ of exactly (as opposed to at least)  $n$ . For my purposes, I am not nearly as concerned about underestimating the actual MQ of syllables as I am about overestimating it. Nevertheless, in most such cases the “exactly” interpretation was reinforced by the metrical context.

<sup>16</sup> I made an exception to this rule for one document, P&W #27, the song from which the examples in 2.4 were drawn. I admitted from this song four cases of  $MQ = 3$  vouchsafed only by metrical parallelism, on the grounds that the text is complete and the metrical context is extremely simple and clear.

Without further preliminaries, I will now turn to Table 1, my main body of data. This table summarizes the distribution of polyseme tokens across the different syllable types in P&W, but it is broken into two parts: Table 1a covers polysemes in all songs but one, and Table 1b covers that song. Table 1a contains columns for counts of syllables with MQ 3, MQ 4, and MQ 6 (there are no other MQs above MQ 2 to report). Table 1b has columns for MQ 4 and MQ 6.

<b>MQ:</b>	<b>3</b>		<b>4</b>		<b>6</b>	
Total	41	100%	2	100%	2	100%
C <sub>o</sub> VV	32	78%	1	50%	1	50%
C <sub>o</sub> VVC:	3	7%	1	50%	1	50%
• C <sub>o</sub> VVN	• 2		—		• 1	
• C <sub>o</sub> VVS	• 1		• 1		—	
• C <sub>o</sub> VVT	—		—		—	
• C <sub>o</sub> VVR	—		—		—	
C <sub>o</sub> VC:	6	15%	—	—	—	—
• C <sub>o</sub> VN	—		—		—	
• C <sub>o</sub> VS	• 5		—		—	
• C <sub>o</sub> VT	—		—		—	
• C <sub>o</sub> VR	• 1		—		—	

**Table 1a.** Polysemic C<sub>o</sub>VX syllable types in the corpus, excluding P&W #50. There are no cases of complex coda to report.

<b>MQ:</b>	<b>4</b>		<b>6</b>	
Total	22	100%	3	100%
C <sub>o</sub> VV	11	50%	1	33%
C <sub>o</sub> VVC:	11	50%	2	66%
• C <sub>o</sub> VVN	• 6		• 1	
• C <sub>o</sub> VVS	• 4		• 1	
• C <sub>o</sub> VVT	—		—	
• C <sub>o</sub> VVR	• 1		—	
C <sub>o</sub> VC:	—	—	—	—
• C <sub>o</sub> VN	—		—	
• C <sub>o</sub> VS	—		—	
• C <sub>o</sub> VT	—		—	
• C <sub>o</sub> VR	—		—	

**Table 1b.** Polysemic C<sub>o</sub>VX rime types in P&W #50. Again, there are no complex codas to report.

In both tables, the numbers are broken down into syllable types, in hierarchical fashion: the total at the top of each column is what the three major categories C<sub>o</sub>VV, C<sub>o</sub>VVC, and C<sub>o</sub>VC add up to, and then each of those categories is broken

out by the major class category of the coda C (nasal, fricative, stop, liquid). The percentages next to each of the three columns are taken from the total at the top.

A brief note about the division of Table 1 into two parts: P&W #50 is a major contributor of MQ > 3 data. What is special about P&W #50 is that it is composed entirely of H syllables; the genre it belongs to, “spondaic tempo” (West 1992), was briefly described in 1.5. The reason for dividing the table in two is so as not to prejudge the question of whether P&W #50’s special metrical properties mean that matter-to-beat correspondence works differently in this song than in the others. But I contend that it does not, that the data in Table 1b is of a piece with that in Table 1a. That, at any rate, is the unmarked assumption.

The only truly unexpected fact in Table 1, from the point of view of the description in (1), is the existence of 6 C<sub>o</sub>VC tokens with MQ 3. This is only 15% of the MQ 3 total, so preliminarily, at least, this looks like underattestation. Curiously, 5 of these 6 are C<sub>o</sub>VS tokens. We will return to this fact in 2.7. Note that there are no C<sub>o</sub>VC tokens at all with MQ 4 or MQ 6.

C<sub>o</sub>VVC trisemes also seem to be quite poorly attested compared to other triseme types, only 7% of the total; compare this to C<sub>o</sub>VVC tetrasemes, which comprise a full 50%.

What explains these two anomalies? Most of the possible answers fall under the headings of “because of chance” and “because of grammar.” We want to know which are which, and we want the statistics to tell us. We would also like to know what the “because of grammar” answers actually are.

In order to develop a more precise interpretation of the attested pattern, we need to first ask how the frequencies in Table 1 deviate from expected frequencies. We can then make reasoned inferences about which gaps (and near-gaps) in Table 1 are due to chance and which are due to grammar.

The answers I will give: the depressed frequency of C<sub>o</sub>VVC trisemes is grammatically insignificant; and MQ 3 for C<sub>o</sub>VC is only allowed in special circumstances, controlled by the segmental composition of the coda.

## 2.6 Controls

For the expected relative frequencies of different H syllable types, there are two different categories of control data to choose from: from outside the P&W corpus,

and from inside it. Looking outside first, I recorded all the H syllables in two randomly selected passages drawn from the Greek canon: a prose passage (Herodotus 2.137) and a passage of “lyric poetry,” i.e., song (Aeschylus, *Agamemnon* 681–736). The results are in Table 2, broken down in the same way as before.

	Herodotus		Aeschylus			
Total H syllables	185	100%		212	100%	
C <sub>0</sub> VV	94	51%		88	42%	
C <sub>0</sub> VVC	20	11%		42	20%	
C <sub>0</sub> VC:	71	38%	100%	82	39%	100%
• C <sub>0</sub> VN	26	14%	37%	39	18%	48%
• C <sub>0</sub> VS	24	13%	34%	24	11%	29%
• C <sub>0</sub> VT	14	8%	20%	11	5%	13%
• C <sub>0</sub> VR	7	4%	10%	9	4%	11%

**Table 2.** Distribution of H syllable types in a prose excerpt (Herodotus 2.137) and a musical excerpt (Aeschylus, *Agamemnon* 681–736). The respectably high frequency of C<sub>0</sub>VC among H in both prose and song lyric contrasts with the low frequency of C<sub>0</sub>VC trisemes.

In addition to indicating each number’s share of the total H syllable count, we also give a percentage breakdown for the different C<sub>0</sub>VC subtypes. The reason for this will become apparent shortly.

In both passages, the C<sub>0</sub>VV and C<sub>0</sub>VC syllable types are both well represented, C<sub>0</sub>VV (51% and 42%) being modestly more frequent than C<sub>0</sub>VC (38% and 39%), while the C<sub>0</sub>VVC type is relatively sparse. It is less sparse in the Aeschylus passage (20%, vs. 11% in Herodotus), but still the least frequent of the three types.

Relative frequencies of the different C<sub>0</sub>VC subtypes are also consistent across the two passages. In both, C<sub>0</sub>VN is the most frequent, followed by C<sub>0</sub>VS, C<sub>0</sub>VT, and C<sub>0</sub>VR. The percentage of C<sub>0</sub>VS (the type of 5 of our 6 C<sub>0</sub>VC trisemes) relative to all C<sub>0</sub>VC is around 30%.

In control data taken from the P&W corpus itself, the picture is similar. By far the majority of H syllables in the P&W corpus are disemes, and MQ 2 is the one MQ that we *know* all H syllables can have, so this is a suitable control. I took a partial sample consisting of all syllables in the first 28 documents that are

disemes according to P&W's transcription, and whose syllable structure was clear. The results are given in Table 3.

<b>MQ:</b>	<b>2</b>		
Total disemes	522	100%	
C <sub>0</sub> VV	278	53%	
C <sub>0</sub> VVC	89	17%	
C <sub>0</sub> VC:	155	30%	100%
• C <sub>0</sub> VN	46	9%	30%
• C <sub>0</sub> VS	39	7%	25%
• C <sub>0</sub> VT	39	7%	25%
• C <sub>0</sub> VR	31	6%	20%

**Table 3.** Syllable type breakdown of all H syllables in P&W #1–#28 interpreted by the editors as disemes. Most of the tokens lack any explicit indication of their MQ. A few cases of complex coda were found, and skipped.

As Table 3 shows, the relative frequency ordering of C<sub>0</sub>VV, C<sub>0</sub>VVC and C<sub>0</sub>VC is the same in P&W as in the Herodotus and Aeschylus controls: C<sub>0</sub>VV (53%), C<sub>0</sub>VC (30%), then C<sub>0</sub>VVC (17%). Note that the frequency of VVC in disemes falls in between its frequencies in those two sources.

As for relative frequency among VC subtypes, we again find agreement with Herodotus and Aeschylus. The order is still C<sub>0</sub>VN, C<sub>0</sub>VS, C<sub>0</sub>VT, C<sub>0</sub>VR, although C<sub>0</sub>VN and C<sub>0</sub>VS are somewhat less preponderant than in those texts.

Against this backdrop of control data, it becomes evident that the relatively poor representation of C<sub>0</sub>VVC trisemes in Table 1 (7%) is due to a combination of (a) the relatively low frequency of C<sub>0</sub>VVC in Greek (10–20%), and (b) chance anomaly, since the frequency of both C<sub>0</sub>VVC disemes and C<sub>0</sub>VVC tetrasemes is no lower than we would expect based on control frequency. (Indeed, there even appears to be something of a preference for C<sub>0</sub>VVC when MQ > 3, since C<sub>0</sub>VVC frequency for MQ = 4 and MQ = 6 is well above the control frequency. This could be due in some way to the absence of C<sub>0</sub>VC from these positions; at any rate, there is no evidence that C<sub>0</sub>VV is avoided in these positions.)

## 2.7 Interpreting short-vowel trisemes

While the control data just given appears to do away with any significant concerns about the frequency of C<sub>0</sub>VVC polysemes, it also, more importantly, places the C<sub>0</sub>VC triseme data from Table 1 in a fresh light. All things being equal, we would expect C<sub>0</sub>VN trisemes to be the most frequent among them, followed by C<sub>0</sub>VS, C<sub>0</sub>VT, and C<sub>0</sub>VR. We would also expect C<sub>0</sub>VC to be better represented as a whole among the trisemes: about 30–40%. This is not what we find. According to Table 1, only about 15% of trisemes are C<sub>0</sub>VC, and these, with one exception, are C<sub>0</sub>VS. This, then, is genuine underattestation of C<sub>0</sub>VC trisemes. At the same time, there can be little doubt that the C<sub>0</sub>VS triseme cases, at least, are real, not anomalies or lapses, and so must be grappled with if we want to adhere to the description of the facts in (1). It really does appear that some C<sub>0</sub>VC subtypes are grammatical with MQ 3, while others are ungrammatical.

In Hill (in progress), I give an account of the C<sub>0</sub>VC triseme tokens that reconciles them with the claim of (1) that C<sub>0</sub>VC has invariant MQ 2. The solution I propose is as follows: apparent cases of C<sub>0</sub>VC with MQ 3 are actually cases of MQ 1 plus MQ 2. C<sub>0</sub>VC is parophonologically (i.e., phonetically, in a special context) split into two syllables by aspiration: C<sub>0</sub>V<sub>1</sub><sup>h</sup>V<sub>1</sub>C. This is a L followed by a H, each with their expected MQs. This solution may seem far-fetched, but it effectively addresses two facts: the strikingly uneven attestation of the different C<sub>0</sub>VC subtypes as trisemes—5 out of the 6 have /s/ as coda, the sixth has /r/—and the underattestation of C<sub>0</sub>VC trisemes as a whole.

In a word, why /s/ (and possibly /r/)? One possibility would be intrinsic duration of the coda C. But /s/ and /r/ are at opposite ends of the spectrum in this respect. We do not, of course, have firsthand data on Ancient Greek phonetics, but typically, fricatives like /s/ have relatively long duration (especially voiceless ones; Greek /s/ is noncontrastive for voicing), while coda liquids' duration is typically short. For example, in a study of segment duration in Italian CVC<sub>1</sub>C<sub>2</sub>V words, McCrary Kambourakis (2007: 136) finds that the average duration of C<sub>1</sub>, when parsed as a coda (including /r l n s k p/), ranges from 47 ms to 126 ms. The average duration of /r/ codas clustered at the bottom end of that range, 47–56 ms, and that of /s/ codas clustered at the top end, 112–126 ms.<sup>17</sup>

<sup>17</sup> Like in Greek, in Italian, Cs in coda position do not contrast in length. In other noncontrastive positions too, natural duration appears to win out. For example, the average duration of /r/ in

This data would support the hypothesis that MQ 3 is licensed for C<sub>0</sub>VS on the basis of the natural duration of /s/. On the other hand, it makes it very unlikely that MQ 3 could have been licensed for C<sub>0</sub>VR on the same basis. If our one C<sub>0</sub>VR triseme is actually grammatical, not a lapse,<sup>18</sup> then intrinsic duration of coda consonants cannot be the property that distinguishes between grammatical and ungrammatical VC trisemes.

An intrinsic duration story, therefore, commits us to rejecting the C<sub>0</sub>VR triseme as a lapse, a textual corruption, or some such thing. But as a methodological matter, positing errors to explain problematic data is a last resort. In this case a plausible alternative is available, the one I described in the second paragraph of this section.

What motivates the C<sub>0</sub>V<sub>1</sub><sup>h</sup>V<sub>1</sub>C parse is that it enables realization of a stray aspiration feature ([+spread gl]) which cannot be realized in coda position and, therefore, normally (outside of singing) fails to surface. Both /s/ and /r/ have a special relationship with aspiration in Greek, as documented in Hill (in progress).

If that account is on the right track, then the task of capturing the Greek MQ facts is considerably simplified. We can essentially ignore the C<sub>0</sub>VS (and C<sub>0</sub>VR) facts; C<sub>0</sub>V syllables are treated consistently one way, C<sub>0</sub>VCC<sub>0</sub> syllables another, and C<sub>0</sub>VVC<sub>0</sub> syllables another, as (1) claims. This is the kind of simplicity we expect of a syllable weight criterion: Gordon 2002 furnishes evidence that even very phonetically effective syllable weight criteria go unselected by languages because they are overly complex phonologically, requiring overly subtle reference to segmental features.

The one very important thing that the C<sub>0</sub>VS facts tell us about Greek MQ is that it is not abstract. It applies at a very “low” level of representation. The terms we use to capture it should therefore be phonetic.

---

stop-/r/ clusters (tautosyllabic in Italian) ranges from 49 to 52 ms (McCrary Kambourakis 2007: 136), and in stop-/s/ clusters (heterosyllabic in Italian) the /s/ range is 125–134 ms.

As for Italian /l/, the facts are fairly similar to those for /r/. In coda, the average duration ranges from 64 to 71 ms, and as the second member of a complex onset, it is 53–71 ms.

<sup>18</sup> Note that the overall low frequency of C<sub>0</sub>VR, both absolutely and relative to the other C<sub>0</sub>VC subtypes, means that having only a single triseme case is not particularly surprising. In fact, both C<sub>0</sub>VS and C<sub>0</sub>VR trisemes have about the same frequency, relative to trisemes as a whole, as they do in the control samples.



### 3 Beat Mapping

Having now given data to justify the basic pattern of Greek beat mapping, our goal in this chapter is to capture this pattern with a segment-based analysis.

#### 3.1 The problem

Recall the basic pattern:

(1)	Syllable type	MQ	Criterion 1	Criterion 2
	C <sub>o</sub> V	1	L	L
	C <sub>o</sub> VCC <sub>o</sub>	2	H	L
	C <sub>o</sub> VVC <sub>o</sub>	2, 3, 4, ...	H	H
	—	—	L	H

Our analysis must relate the facts about MQ in Greek to properties of segments rather than syllables, but it must also, more importantly, explain why the pattern is *prima facie* a syllable quantity pattern rather than a segment quantity pattern. The basic answer we will give is that syllable divisions (which emerge spontaneously, rather than by design) provide a measure of linearity to what is otherwise a highly non-linear (many-to-many) pattern.

Some relevant facts are easiest to state in syllabic terms, such as the familiar phenomenon of the weightlessness of onset consonants. The pattern is insensitive to the difference between for example, V, CV, and CCV syllables. The weightlessness of onsets is a stipulation based on the observed facts, but hierarchical syllable structure at least gives us the vocabulary to stipulate it: we can stipulate that weight is a property of rime. Similarly, multiple coda Cs have the same effect on weight as a singleton, and syllable structure rescues us again: it is the presence of a coda node, not coda Cs per se, that turns a short-vowel rime from L to H. As part of our task, we must provide alternatives to such forms of salvation.

While onsets are irrelevant to weight category assignment, alternate syllabifications of the same string have an accepted effect on weight. Consider

two hypothetical  $C_0VCCV$  strings for which the evidence indicates a difference in syllabification:

- (2) a.  $C_0VC_1|C_2V$   
 b.  $C_0V|C_3C_4V$

Such variation in the syllabification of  $C_0VCCV$  strings is a known feature of Greek phonology (e.g.,  $ap|ta$  vs.  $a|pra$ ). With these syllabifications, we expect, and find, a quantitative difference: MQ 2 for the first syllable in (2a), since it belongs to the  $C_0VCC_0$  category, and MQ 1 for the first syllable in (2b), since it is  $C_0V$ .

These considerations demonstrate that we must find a place for syllabification in our segment-based model, either in the representations (hierarchical syllable structure) or in the constraints: that is, we must either include syllable boundaries in our representations, and make our constraints sensitive to these boundaries, or we must write beat mapping constraints that somehow make the known syllable boundaries emerge. We are taking the latter course, incorporating the theory of syllabification into the theory of beat mapping. In the analysis to be presented, the proposed structural correlate of syllable boundaries (to the extent that they have one) is a certain discontinuity of correspondence, which emerges as a byproduct of the beat mapping process. Syllables themselves are given a correspondence-based definition.

### 3.2 Representations and realizations

Our basic representational assumptions about beat mapping were already laid out in Chapter 1: we assume that it involves ubiquitous many-to-many correspondence between segments and beats. What I want to do here, since several of the constraints I will define in the next section are “phonetically based” (referring to properties of phonetic events for their rationale), is to make explicit my assumptions about how the representations relate to the events, i.e., what kind of control they exert over the events. Beat mapping constraints remain constraints on correspondence (representations), not on phonetic outcomes (events) *per se*, so the assumptions stated in this section are of relevance only insofar as the rationales offered for constraints are stated in an outcome-oriented way.

One thing I will not try to account for here is how linearity reversals (association lines crossing), which are possible in principle, might be realized; a linearity constraint will rule these out for Greek singing (No reversal (beat mapping), 3.3.1).<sup>1</sup>

The central assumption is as follows: the phonetic correlate of correspondence between segments and beats is temporal alignment,<sup>2</sup> specifically left alignment (L-alignment). In the case of one-to-one correspondence of a segment with a beat, the phonetic interpretation is simple:



In the representation at left, both beats and segments are indexed (separately) for convenience. In the depiction of alignment on the right the symbol “|” represents aligned edges and “:” unaligned edges. The dot symbol is used in a different sense than on the left, denoting a point in time rather than an abstract timing unit.

Turning now to cases of non-linear correspondence: both one-to-many and many-to-one correspondence make complete realization of correspondence as L-alignment impossible. I assume that in all such cases, the realization is such as to maximize that correlation.

Consider the simplest case of one-to-many correspondence, a single segment mapped to two adjacent beats. As explained in Chapter 1, this is how beat mapping interprets contrastive segment length, which is ultimately realized in durational contrast. This is a clear case where the correlation between correspondence and alignment inevitably breaks down, since we have two time

<sup>1</sup> A role they could play is in the analysis of metathesis, especially long-distance metathesis, but Greek musical texts furnish no evidence on this.

<sup>2</sup> This is in line with the historical development of Generalized Correspondence Theory from Generalized Alignment Theory (see McCarthy and Prince 1995), but I am using the term “(L-) alignment” in a strictly physical sense, whereas it is sometimes used to mean (initial-to-initial) correspondence.

points looking for something to L-align with and only one event for them to share.<sup>3</sup>



In this case, I assume L-alignment is with the first beat, but that the segment's duration is now required to extend at least to the second beat, if not past it. It does not L-align with the second beat. On the other hand, while its onset does not *coincide* with that second beat, it does precede it, rather than following it. Being early is better than being late. More importantly, while its *onset* does not coincide with the second beat, another part of it does. There is, then, a partial achievement of L-alignment even in this case; this is, I assume, the reason for the prolongation requirement.

In the other case where a perfect correlation between correspondence and L-alignment is impossible, the correlation is again, I assume, maximized. This is many-to-one correspondence, i.e., correspondence of a string of segments to a single beat. Unless the segments are physically capable of being fully L-aligned with *each other* (a possibility we will set aside, though compare 3.3.5), at least one of them will have to be misaligned with the beat.

---

<sup>3</sup> Perhaps this inevitability is not intrinsic. Theoretically, the segment can be realized twice, with L-alignment both times. This kind of multiple realization is how reduplication would probably be analyzed, following McCarthy and Prince 1995, if we applied our system to it. Notably, reduplication typically does not consist of a single segment adjacent to itself. The problem with multiple realization here, then, must be adjacency. The Obligatory Contour Principle (OCP) prohibits identity under adjacency; it can be interpreted, for this case, as a realizational principle, prohibiting multiple realization under adjacency and thus indirectly requiring prolongation instead. (There might a purely representational OCP as well. I know too little about it to have any opinion.)

<sup>4</sup> There is no way, in principle, for the beat mapping process to alter this input order. As a mapping process, all beat mapping can do with respect to linearity is determine whether segment *x* maps onto an earlier beat than segment *y*, or the same beat, or a later beat. Changing the input to a different input is something that no phonological process can do, according to basic principles of OT (in particular, the principle of Richness of the Base obliges processes to accept all possible inputs).

Let us call segments mapped to a shared beat *tautomoraic*. For cases of tautomoraicity, I assume what happens is that there is a sort of competition for first place, whose winner may be determined by two main factors. Only the winner of this tautomoraic alignment competition will have its actual temporal onset determined grammatically; all the losers will have theirs determined relative to it, on an utterance-specific basis.

The two factors are the linear sequencing of the segments and the location of significant acoustic landmarks in the sequence's realization.

I assume the segment string has a linear order in the input, computationally distinct from its mapping onto beats.<sup>4</sup> By default, one expects the initial segment in the sequence to L-align with the beat, rather than a non-initial segment. That is, there is an intuition that linear precedence translates into precedence for L-alignment.



The source of this intuition isn't completely obvious. If salience in linear order is to be recruited as a selection principle, both initial and final position are equally salient, so it seems just as logical to stipulate the final segment as the winner as to stipulate the initial. However, the L-ness of L-alignment makes initial alignment look less like a stipulation. Note that by L-aligning the initial segment with the beat, we also L-align the whole segment sequence with the beat, as if it were a constituent; and indeed, as the set of segments corresponding with a beat, this sequence has a natural constituency. If we were R-aligning instead of L-aligning, it would make more sense to select the final segment rather than the initial segment as the winner.

Supposing that linear precedence determines the winner, the actual temporal onset of each of the non-initial segments is not encoded grammatically (note again the use of the “:” symbol). Therefore, they come as soon as possible after the point of L-alignment. Why is “as soon as possible” a reasonable assumption? To put it differently, why do we expect the duration of all the segments in the sequence, other than the final one, to be minimized? Because this

has the effect of minimizing the misalignment of the non-initial segments, hence maximizing the correlation between correspondence and alignment.

The other factor in the L-alignment competition, beside linear salience, is acoustic salience. Given a string of tautomoraic segments  $\phi_1 \phi_2 \phi_3$ , it might be the case that one transition in the sequence makes a particularly good acoustic landmark, marked by some particularly abrupt change in overall intensity, formant frequencies, or whatever. For example, in a tautomoraic sequence [dãn], the transition from [d] to [ã] is relatively distinctive, compared to that from [ã] to [n]. In general, CV transitions are more distinctive than VC transitions, and CC and VV transitions are generally even less distinctive. The most distinctive transition in the tautomoraic sequence (if it is also sufficiently distinctive to override linear salience) might be selected for L-alignment with the beat at the expense of the other transitions, and of the initial segment's onset:



Once again, I assume there is a pressure to minimize the duration of all the non-final segments in the sequence, for the same reason as before: to minimize the misalignment of all segments with the beat. This time, though, it is not a uniformly leftward pressure: it includes rightward pressure on the left edge of  $\phi_1$ .

These two factors, linear salience and acoustic salience, might play simultaneous roles in the L-alignment competition. For example, if there are two equally and/or sufficiently distinctive transitions, the earlier one might be selected for L-alignment at the expense of the second one, since it has an advantage in the precedence category.

These factors could have an indirect influence on beat mapping, and therefore have direct relevance for us. Constraints might exist favoring tautomoraic sequences that do well against one or the other of these criteria, or against both simultaneously: for example, sequences in which a salient acoustic landmark is at the left edge, or relatively close to it. We will propose such constraints in 3.3.6.

## 3.3 Constraints

I will now propose a set of beat mapping constraints, divided into six categories. The first and second categories are linearity and parsing; these are properties of mappings between domains, in this case, between a sequence of segments and a sequence of beats. The next three categories refer to properties of segments or segment sequences: contrastive length, sonority, and compressibility. The sixth category, beat realization, looks at beat mapping from the other end, that of beats and their needs.

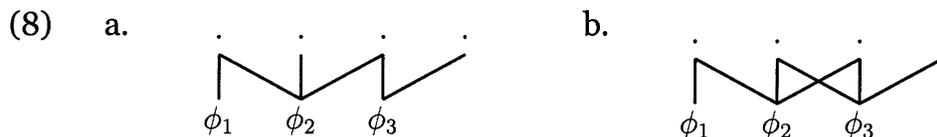
In the shorthand names of these constraints, the difference between “ $\rightarrow$ ” and “ $\Rightarrow$ ” is significant, and possibly idiosyncratic.

- (7) a.  $x \rightarrow y$  (*x*-centric correspondence)  
 Assess a penalty for any *x* that is not in correspondence with *y*.  
 b.  $x \Rightarrow y$  (exhaustive *x*-centric correspondence)  
 Assess a penalty if *x* corresponds to anything more, less, or other than *y*.

“ $\rightarrow$ ” can be pronounced as “corresponds at least to,” and “ $\Rightarrow$ ” as “only corresponds to.” (Bidirectional arrows are not used.)

## 3.3.1 Linearity

As mentioned in Chapter 1, we would like to permit non-linearity (many-to-many correspondence) of the sort in (8a), while ruling out the kind in (8b):



The kind of non-linearity seen only in (8b), reversal, is a severer kind of non-linearity than the kind seen in (8a), and this severer kind is targeted by the following constraint (Steriade, class notes):

- (9) No reversal (beat mapping)  
 If  $seg_1$  and  $seg_2$  are in correspondence with  $beat_1$  and  $beat_2$ , respectively, and  $seg_1 \preceq seg_2$ , then  $beat_1 \preceq beat_2$ .

The symbol “ $\leq$ ” means “precedes or is simultaneous with.” Assuming that both the segment string and the beat string are linearly ordered, “simultaneous with” means in practice “is identical to.”

Note that stricter enforcement of linear mapping would require precedence to be directly *reflected* in correspondence, which it is not in (8a), any more than in (8b); it is only *respected* in (8a). If beat mapping had to reflect precedence, the mapping of segments onto beats would be one-to-one; in (8a), it is many-to-many. Forcing the linear sequencing of two domains to be reflected in the correspondence relations between them is the job of a Match precedence constraint or constraints (Steriade, class notes).<sup>5</sup> No such constraint is active in Greek beat mapping.

### 3.3.2 Parsing

- (10) Max (beat mapping)  
Every segment corresponds to a beat.
- (11) DEp (beat mapping)  
Every beat corresponds to a segment.

These are familiar OT parsing constraints, which are generalized in Correspondence Theory beyond their original use in input–output correspondence.<sup>6</sup> For beat mapping, Max (beat mapping) ensures that no segment of the matter is left out by the beat mapping process. The practical effect of this constraint depends on the interpretation of beat mapping as a process. We take it to be a crucial part of the representation of speech events, identical with gestural timing. If so, then Max (beat mapping) means “give every segment a place in the temporal planning of the utterance”—in effect, “pronounce every segment” (just like the original Max).

---

<sup>5</sup> The constraints could also be written in such a way as to allow one-to-many beat mapping but not many-to-one, or vice versa.

<sup>6</sup> Their names are anachronistic, appropriate only for the special case of input–output correspondence. Originally, “Maximize the input in the output” was a way of saying “don’t delete anything,” and “Don’t Epenthesize” meant “don’t insert anything.” As the phrasing of our particular instance of these constraints reflects, they are really the same constraint, with reversed directionality.

The  $\boxed{\text{DEp (beat mapping)}}$  constraint can be interpreted as something like a constraint against pauses. Enforcement of this constraint has a benefit in terms of recoverability of song structure. The representations to which these constraints apply are finite, consisting of a string of beats with a string of segments mapped onto it. These strings/pairs of strings are probably to be understood as corresponding to (though grammatically distinct from) structural units, e.g., lines, periods, stanzas, musical groups, metrical cola. Requiring at least one segment for every beat ensures the “fullness” or continuity of the representation. This quality may act as a structural cue to the integrity of the structural unit.<sup>7</sup>

Note that this constraint, just like  $\boxed{\text{Max (beat mapping)}}$ , is purely a representational constraint, and does not require each beat to be physically realized by some perceivable boundary. That is a stronger constraint in its effect, which will be introduced in 3.3.6.  $\boxed{\text{DEp (beat mapping)}}$  is also not a constraint that penalizes silence *per se*. It is, on the one hand, stronger than that: it is violated by a structurally empty beat even if, in the realization, a preceding segment happens to be prolonged long enough to fill it. It is also weaker, in that it does not penalize, say, voiceless stops, which involve periods of silence;  $\boxed{\text{DEp (beat mapping)}}$  is indifferent to the specific features of segments.

In addition to these two parsing constraints, which are beat mapping constraints *per se*, it will also be crucial to have the following:

- (12)  $\boxed{\text{Max (IO)}}$   
Every correspondence relation  $\langle \text{beat}_i, \text{seg}_j \rangle$  in the input has a correspondent in the output.
- (13)  $\boxed{\text{DEp (IO)}}$   
Every correspondence relation  $\langle \text{beat}_i, \text{seg}_j \rangle$  in the output has a correspondent in the input.

These are nothing other than the “original”  $\boxed{\text{Max}}$  and  $\boxed{\text{DEp}}$ ; input–output relations are interpreted in Correspondence Theory as a special case of correspondence. The only wrinkle is that in the grammatical evaluation of beat mapping, for which the present constraint statements are customized, the input

---

<sup>7</sup> Compare Hayes and MacEachern 1998 on the role of pauses as boundary-marking devices, which is the other side of the coin. Boundary marking inserts/leaves empty beats at right edges, overriding  $\boxed{\text{DEp}}$ .

portion of the input–output correspondence relation is itself a set of correspondence relations (graphically represented by association lines). These constraints, then, evaluate a representation of beat mapping and favor faithfulness to it, specifically by penalizing deviations from it.

Keeping track of correspondence relations between segments and beats from input to output and vice versa can be tricky, because beats are not very distinctive objects. For the most part, I will deem there to be a violation of  $\boxed{\text{Max (IO)}}$  or  $\boxed{\text{DEp (IO)}}$  only if the *number* of correspondence relations differs in the input and the output. For example, if segment 1 and segment 2 map to two separate beats in the input but share a beat in the output, this will generally not be penalized by  $\boxed{\text{Max (IO)}}$  and  $\boxed{\text{DEp (IO)}}$ , because the two associations in the output can be analyzed as corresponding to the two associations in the input.

### 3.3.3 Length

In the 1st century BCE, Dionysius of Halicarnassus (*De Compositione* 15; quoted in Sturtevant 1922) attempted to derive the quantity of syllables from the quantity of their constituent segments, and likewise for other properties of syllables and segments.<sup>8</sup> In the same spirit, the following constraints control the way beat mapping interprets underlying segment length contrasts.

- (14)  $\boxed{[- \text{long}] \Rightarrow 1 \text{ beat}}$   
For every  $[- \text{long}]$  segment, assess one penalty for each beat, above 1, that is in correspondence with it.
- (15)  $\boxed{[+ \text{long}] \rightarrow 2 \text{ beats}}$   
For every  $[+ \text{long}]$  segment, assess a penalty if it is not in correspondence with at least 2 beats.

I will sometimes refer to these two constraints jointly as  $\boxed{\text{Segment length}}$ .

These constraints are deduced empirically, not from any *a priori* considerations. Their stipulative nature suggests a novel hypothesis about what length distinctions really mean: specifying a segment as  $[- \text{long}]$  is a way of

---

<sup>8</sup> “Since the letters show many variations, not only in their length and shortness but also their resonance, ... it is inevitable that the syllables consisting of them [that is, pure-vowel syllables] or woven from them should preserve the separate force of each as well as the joint force of all that comes about as a result of their being juxtaposed and blended.” (my translation)

prescribing MQ minimality for it, and [+long] specifies anti-minimality. Minimality means MQ 1, and anti-minimality is MQ > 1.<sup>9</sup> I will keep the traditional label for the feature in question, but we could imagine renaming it [ $\pm$  minimal]: [-long] = [+minimal] and [+long] = [-minimal].

Notice that these constraints do not make reference to the difference between C and V segments. Greek has contrastive length in both. The representational device of MQ allows us to give a unified description of the implementation of underlying segment length contrasts, at least in this language.

My implementation of Dionysius's approach to syllable quantity takes a radical form: syllable MQ is directly determined by vowel MQ, which is, in turn, largely (though not entirely) determined by the above length constraints.

### 3.3.4 Sonority

The most basic element of the syllable-based description of Greek beat mapping in (1) is the distinction between C and V segments. This distinction can be interpreted in terms of a sonority threshold. Vs are those segments that have "enough" sonority for certain grammatical purposes, while Cs are all the rest. Bringing sonority into the discussion is inevitable, since it is clearly an important property in syllable structure, and we are trying to replace syllable structure with beat structure. The sonority scale I will assume is the following, with the C/V threshold of Greek indicated by a horizontal line.

---

<sup>9</sup> One would think the *minimal* MQ would be MQ 0, not MQ 1. We could, indeed, rewrite the first constraint in a stronger form,  $[-\text{long}] \Rightarrow 0 \text{ beats}$ , and let a parsing constraint rule out MQ 0 (namely  $[\text{Max}]$ ; see 3.3.1). If we reidentified MQ minimality in this way, we would want to do the same for anti-minimality, thus,  $[+\text{long}] \rightarrow 1 \text{ beat}$ . To do the work of forcing [+long] segments to have MQ 2 or greater, we could invoke a distinctiveness constraint (see Flemming 2006), such as:

- (i)  $[\text{Minimum Distance } ([\pm \text{long}]/\text{MQ})]$   
Assess a penalty if MQ of any [-long] segments is equal to, or greater than, the MQ of any [+long] segment.

This constraint would, however, cause successive violations of  $[-\text{long}] \Rightarrow 0 \text{ beat}$  to have an incremental effect on [+long] segments, forcing them to be longer and longer. This prediction is disconfirmed. (In some cases, [-long] segments have MQ 2—see 3.10—and in that case, the [+long] segments do not obligatorily have MQ 4.) My conclusion is that the limiting case of minimality (to the extent that minimality is truly the relevant property) is MQ 1, not MQ 0.

(16)	Sonority scale (Greek):		
	1.	p <sup>h</sup> t <sup>h</sup> k <sup>h</sup> p t k	(voiceless stops)
	2.	b d g s	(voiced stops; fricatives)
	3.	m n	(nasals)
	4.	r l	(liquids)
	<hr/>		
	5.	i y u	(high vowels) <span style="float: right;">C</span>
	6.	a ε ɔ e o	(non-high vowels) <span style="float: right;">V</span>

Following Parker 2002, 2008, I assume the true sonority scale is universal, but sonority thresholds are particular partitions of it; I leave it open whether the threshold given here is valid for all sonority-sensitive processes in Greek or only for beat mapping and some others.

All the following constraints refer to sonority in context, not the sonority of individual segments in isolation. Except for the first constraint, which is fundamental, all these constraints are recontextualizations or replacements of classic syllable structure constraints.

- (17) Beat → V  
 Assess a penalty for every beat not mapped to a segment that is (i) a sonority peak and (ii) a V (of sonority level 5 or 6).

This constraint requires each beat to count among its correspondents a V whose sonority is higher than that of its neighbors. For the data we will be considering up until 3.13, condition (ii) is sufficient; all the Vs we will see will also be sonority peaks. The only time Vs are not sonority peaks in Greek is when they occur in sequence. Actually, apart from that configuration, conditions (i) and (ii) pick out virtually the same class in Greek.<sup>10</sup> The nuances are taken up in 3.13, including some refinements of the notion “sonority peak” being used broadly here.

I propose to interpret Beat → V as a salience-matching constraint.<sup>11</sup> Being a sonority peak (and a V) confers, obviously, salience in sonority. Beats are also peaks of a sort. Phonetically, they are realized as mere points in time, but points

<sup>10</sup> There are some sonority peaks that are not Vs, for example, the /s/ in /ks#p/.

<sup>11</sup> Another interpretation is more focused on singing: it starts from the observation that singing involves a tune, a sequence of tones. These need TBUs to be realized on, so Beat → V could be seen as, in effect, Beat → TBU. Such a constraint would, perhaps, not apply in non-musical speech. But a TBU is defined solely by a sonority threshold, whereas we will show in 3.13 that sonority peaks are also essential.

made salient by alignment with salient transitions (see 3.3.6). Structurally, they can be seen as a trivial sort of metrical position, and beat sequences as a trivial sort of meter; metrical positions can in turn be modeled as abstract prominence peaks. (Cf. the discussion of meter in 1.2.)

With this interpretation of  $\boxed{\text{Beat} \rightarrow \text{V}}$ , its meaning is “map beats *qua* prominence peaks onto vowels *qua* sonority peaks.” We might expect such a foundational principle of correspondence between two domains to be rigidly observed, and this expectation is fulfilled.<sup>12</sup>

In the three sonority constraints that remain, reference is made to the linear order of tautomoraic strings; see 3.2 above on the realization of these.

- (18)  $\boxed{\text{Onset}}$   
A V is preceded by a tautomoraic C.<sup>13</sup>

There is no shortage of possible rationales for this constraint. I will assume a phonetically based one, based partly on aerodynamics: an initial constriction, on release, gives the vowel a dynamic boost that allows it to achieve maximum sonority relatively quickly.<sup>14</sup> As to why this constriction needs to be tautomoraic/tautosyllabic in order to achieve this effect—this is the real question—I assume it is because the effect requires tight coordination of the two gestures, and that this requires tautomoraicity. This is a reasonable assumption in light of the hypothesis that beats are basic units of gestural coordination.<sup>15</sup>

---

<sup>12</sup> The complementary principle, “map vowels onto beats,” if it exists, is masked by the less specific parsing principle  $\boxed{\text{Max (beat mapping)}}$  (see 3.3.2 above), which requires every segment to map onto a beat, and which is undominated in Greek beat mapping.

<sup>13</sup> Note that this constraint does *not* require every beat to have an onset, not even in light of  $\boxed{\text{Beat} \rightarrow \text{V}}$ . A V may occupy more than one beat.  $\boxed{\text{Onset}}$  only requires that every V have an onset in its first beat.

<sup>14</sup> This general line of explanation correctly accounts for the preference for low-sonority onsets over high-sonority ones; a stop, for instance, gives a bigger boost than a nasal.

<sup>15</sup> If not for this factor—closeness of articulation—one might have predicted the opposite preference—a *heteromoraic* preceding C, not a tautomoraic one—on the following grounds: as described in 3.2, in the realization of tautomoraic sequences, there is a pressure to minimize the duration of the non-final segments, of which there is only one in a tautomoraic CV sequence, the C. But a shorter constriction means less time for air pressure to build up, which means less aerodynamic effectiveness. By contrast, if C and V are heteromoraic (and adjacent), C is not subject to duration reduction, because it is final in its sequence.

The interpretation of No Coda that I propose has a different name, because it is somewhat general:

- (19) Beat  $\Rightarrow$  X<sub>0</sub>V  
The sequence of segments associated with a beat is V-final.

Note that this constraint is similar to Beat  $\rightarrow$  V: whereas that constraint requires a peak V for every beat, this one requires a beat-final V for every beat.

This constraint also has a realizational basis. Recall from 3.2 that the final segment in a tautomoraic sequence has a special status vis-a-vis any non-final segments: it is the only segment not targeted for duration minimization by the pressure to achieve alignment. This gives the final segment a unique degree of durational openness. Beat  $\Rightarrow$  X<sub>0</sub>V states a sonority threshold on that final segment, specifically that it must be a vowel.

Finally, I posit a constraint that penalizes sonority contours on beats. This constraint may have more to do with computational complexity than acoustics:

- (20) Sonority monotonicity  
The segments associated with a beat, in their linear order, form a sonority rise, fall or plateau.

Sonority monotonicity is an implementation/replacement of the Sonority Sequencing Principle (SSP). The SSP says that sonority decreases as you go from the interior of a syllable to its edges.

### 3.3.5 Compressibility and alignment

What principle determines the different syllabifications of intervocalic consonant clusters, with the resulting difference in weight? Whatever it is, we will want to incorporate it into our system. Recall the basic facts from (2):

- (21) a. C<sub>0</sub>VC<sub>1</sub>|C<sub>2</sub>V      (e.g., Greek ap|ta)  
b. C<sub>0</sub>V|C<sub>3</sub>C<sub>4</sub>V      (e.g., Greek a|pra)

The first parse is a heterosyllabic parse of the cluster, the second a tautosyllabic parse. As before, we will reinterpret tautosyllabicity as tautomoraicity.

Two basic answers to this puzzle have been proposed: sonority (Steriade 1982) and *compressibility* (Steriade 2008). Both assume that the fundamental question is, what principle determines the well-formedness of complex onsets?

The sonority-based explanation says that a complex onset must be a sufficiently steep rise, i.e., it must be characterized by steadily increasing sonority with a certain rate of increase from one segment to the next. This account works pretty well for Greek, but extending the notion of sufficient steepness to other languages has proven problematic (Steriade 2008).

Steriade's more recent proposal is that complex onsets must be compressible: the members of the onset must be perceptually recoverable even with substantial gestural overlap, which is taken to be a general phonetic characteristic of complex onsets. The reason that non-compressible clusters have an effect on weight (they make a H syllable on their left) and compressible clusters don't is attributed to the durational difference that derives from (non-)compressibility.

In a way, it doesn't matter what answer we choose. We know independently that *something* chooses the two parses of the two sets of intervocalic clusters, and we have a way of interpreting those two parses in terms of beat mapping. We could just use a placeholder constraint "Syllabification" to represent the missing principle.

Nevertheless, I will adopt the compressibility approach, because, among other things, there is a natural role for compressibility in the system being developed.

We ended 3.2 with a discussion of linear salience and acoustic salience as factors in the realization (L-alignment) of tautomoraic sequences, and a suggestion that there might be representational constraints on the makeup of tautomoraic sequences based on what potential they have for maximizing the correlation between correspondence and L-alignment. I will set aside the possibility of constraints that privilege either linear salience or acoustic salience independently,<sup>16</sup> and propose a single family of constraints based on harmonizing

---

<sup>16</sup> As far as I can tell, such constraints would be either irrelevant for Greek singing, or trivial. A linear salience constraint would be trivial because it could not meaningfully discriminate between any two tautomoraic sequences: every such sequence has an initial segment, and that is all linear

the two kinds of salience: specifically, minimizing the durational disparity between the left edge of the initial segment—the most linearly salient point—with the point of CV transition, what I take to be the most salient transition acoustically.

Minimizing this durational disparity means minimizing the duration of the onset, i.e., the beat-initial  $C_0$  sequence. This implies a preference hierarchy of tautomoraic  $C_0V$  sequences, based on the duration of  $C_0$ . The lowest degree of disparity is of course zero; the best tautomoraic sequences, from this point of view, are V-initial. (Provided that this V is preceded by a C, even a heteromoraic C, its left edge counts as a salient transition.) Obviously that inherently conflicts with Onset.

(22)  $V > CV > CCV$  (compressible CC)  $> CCV$  (non-compressible CC)

Compressibility's role in defining this preference hierarchy is natural. In terms of duration, compressible CC onsets provide an additional degree of disparity between simple onsets and non-compressible CC onsets.

Implementing this preference hierarchy as an inherently ranked family of markedness constraints, we get:

(23) Beat  $\rightarrow$  CCV (non-compressible CC)  $>>$   
Beat  $\rightarrow$  CCV (compressible CC)  $>>$   
Beat  $\rightarrow$  CV

Interestingly, the influence of this preference hierarchy on realization is independent of what specific realizational strategy is actually chosen: alignment based on linear salience, as in (5), on acoustic salience, as in (6), or on some average of the two. The L-alignment point will in any event fall within the space defined by those two points of salience. Whether it falls at the left edge, the right edge, or somewhere in between only determines which point of salience it

---

salience means. As for acoustic salience, certainly some sequences have more distinctive transitions in them than others, but I have not found a pure role for such variance.

deviates from more and which less; the *total* amount of deviation from these points of salience is constant, defined by the distance between them.<sup>17</sup>

Before we leave this topic, let us note one key difference between the older sonority-based approach to cluster syllabification and the newer approach that we have adopted. This has to do with the scope of the theory of syllabification. The sonority-based approach (Steriade 1982) was more ambitious in its scope. Not only were complex onsets to be governed by a steep rise principle, but complex codas were to be symmetrically governed by a steep fall principle, and in combination with a principle of exhaustive parsing, this provided an explanation for the ill-formedness of certain strings, like \*VCCCCCCCCCV. They could not simultaneously satisfy both steepness principles, which resulted in unparsed segments.

But Steriade 1999 argues that such ill-formed strings need not and should not be accounted for in terms of syllable structure at all, but rather in terms of phonotactics. Comparative evidence supporting this view comes from Greek dialectal variation, both synchronic and diachronic (Steriade 2008): the syllabification rules change from dialect to dialect while the phonotactics stay exactly the same. I adopt this position as well, which means that my system does not need to worry about inputs like \*VCCCCCCCCCV. They are ruled out independently by phonotactic processes. In practical terms, we need only consider as inputs to matter–beat correspondence those strings of segments that are actually found in the Greek words and phrases in our musical texts. In that respect, our explanatory burden is much reduced.

### 3.3.6 Beat marking

Unlike segments, beats have few inherent properties; structurally, they are just anchors or slots for elements with some substance to them. Their main need is a realizational need: they want to be realized as temporal landmarks, and the only way for beat mapping to control this is by arranging L-alignment with a segment. While in 3.3.5 we dealt with L-alignment from the segmental point of view, now

---

<sup>17</sup> A different way of describing the effect of the prominence hierarchy is in terms of vagueness: a smaller interval between the linear salience point and the acoustic salience point approximates the point of alignment—again, wherever it may fall—with greater precision (less vagueness) than a larger interval.

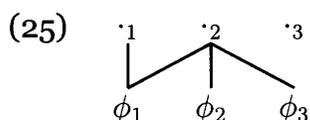
we implement the beat's own interest in L-alignment. In macro terms, one can think of the need for beat marking from the listener's point of view: if too many beats aren't realized, the basic tempo will be lost, and with it the rhythm. As before, we are interested in the impact of this realizational priority on representations.

As discussed in 3.2, L-alignment has a specific representational prerequisite: not only that a beat has a corresponding segment, but also that that segment does not correspond with the previous beat.

- (24) Beat marking  
Every beat corresponds to a fresh segment.

The term *fresh* segment, relative to a particular beat, is shorthand for a segment that doesn't correspond to the previous beat.<sup>18</sup> A segment that does L-align with that previous beat: it is a stale segment. *Beat marking* denotes correspondence between beats and fresh segments.

In cases of many-to-one correspondence that involve more than one fresh segment, Beat marking is multiply satisfied, and this suggests looking for more specific versions of the constraint. We can turn again to the properties of linear salience and acoustic salience for help. Consider the following beat mapping from the point of view of beat 2:



For beat 2,  $\phi_1$  is stale, but both  $\phi_2$  and  $\phi_3$  are fresh. L-alignment of either of the latter with beat 2 will satisfy Beat marking. To choose between the two segments, we might posit a constraint that says “Every beat corresponds to a fresh segment that is not preceded by any tautomoraic fresh segments.” This is an elaboration of Beat marking based on linear salience. But it is a vacuous elaboration. What it

---

<sup>18</sup> The constraint Onset can now be described in a different way than before: Vs do not want to be both fresh and initial at any beat. If they are fresh, they prefer to be non-initial (have an onset C), and when they are stale (as when they are long and get mapped onto a second beat), they don't mind being initial.

says is that among the fresh segments a beat corresponds to, one of them comes before the others. This is always the case, when there are any fresh segments at all.

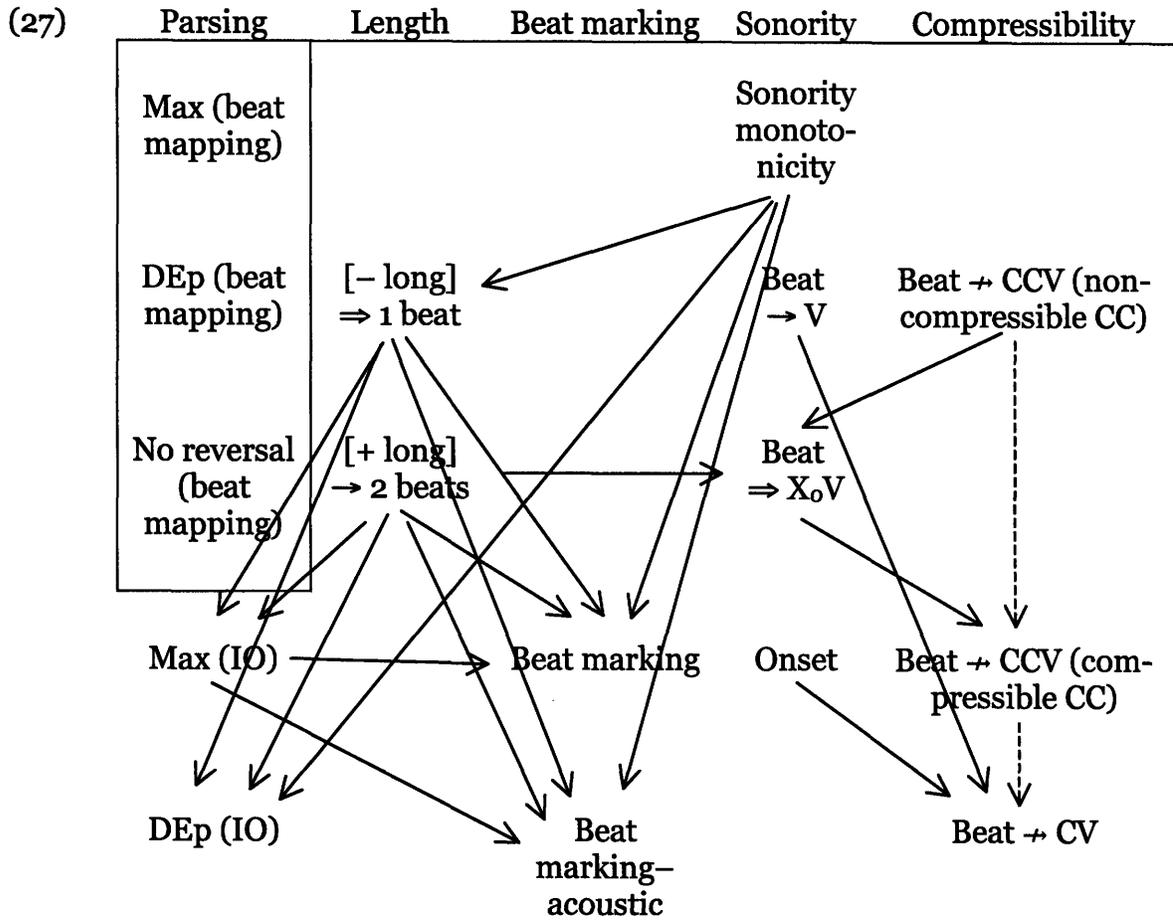
On the other hand, there is a non-vacuous elaboration in terms of acoustic salience:

- (26) Beat marking—acoustic  
Every beat corresponds to a fresh V that is immediately preceded by a C.

This constraint requires the representation to make available a CV transition (not necessarily an actual tautomoraic CV *sequence*—cf. Onset) for each beat. This doesn't force acoustic salience to determine the actual L-alignment point, but it facilitates that. Note that this constraint is violated every time a vowel maps onto two adjacent beats, since the second beat does not have any fresh V to correspond to (unless it has a second V mapped to it as well, which is possible). But that second beat is all right according to plain Beat marking as long as it has a following fresh segment (whether C or V).

### 3.4 The Greek beat mapping grammar

The following composite ranking of the above constraints will generate the attested pattern of weight sensitivity in beat mapping (1). The left column contains constraints that are undominated. The solid arrows indicate rankings that are explicitly supported by constraint conflict, while the dotted arrows indicate inherent rankings by strength among related constraints.



The undominated constraints Max (beat mapping), DEp (beat mapping), and No reversal (beat mapping) do not have any arrows attached to them in the above summary, and are enclosed in a box. This is because I treat them as providing representational ground rules, above the fray of constraint interaction: exhaustive parsing is obligatory in both directions, and non-linearity/many-to-many correspondence is tolerated only as long as the linear order of the inputs is respected. We will ignore candidate beat mappings that are non-starters due to these ground rules: mappings with unassociated beats, unassociated segments, and crossing association lines. See 3.3.1 and 3.3.2 for examples of permitted and prohibited types of mappings.

Also, for the beat portion of the input, we will always silently select a beat string of the appropriate length: cardinality is the only non-constant property of

this string, and we assume the grammar makes freely available strings of all cardinalities.

What we will now do is develop ranking arguments by going through cases, showing how the MQs of syllables and the syllables themselves emerge simultaneously in beat mapping. Our method for motivating constraint rankings will be constraint demotion: we will begin by assuming that all constraints are unranked with respect to each other, and then demote those constraints that disadvantage the winners we want (i.e., constraints that penalize the winner more than they penalize at least one loser). The test of this approach is whether it yields a consistent ranking.

### 3.5 Cluster parsing

Let us begin by establishing how our grammar will encode the syllabification of intervocalic consonant clusters. The basic pattern, in Greek, is a|pa a|pra ap|sa. That is, singleton C and compressible CC clusters are assigned to the onset, and all other clusters (non-compressible and partly compressible) are divided between coda and onset. We will set aside heterosyllabic clusters until 3.9, and the limiting case of VC<sub>o</sub>V, namely VV, will be dealt with in 3.13.

We interpret tautosyllabicity of adjacent segments as tautomoraicity. The first task is to show that p in apa comes out as tautomoraic with the following vowel: the third candidate in the tableau below. In fact, this candidate is highly favored by most of the relevant constraints.<sup>19</sup> Multiple motivation is not surprising in a typological universal.

---

<sup>19</sup> In the tableau, the “!” symbol is used to mark the fatal violation for each loser, as usual. When the fatal violation falls somewhere in a group of mutually unranked constraints, its precise identity is unknowable/arbitrary. In such situations, I treat the entire unranked group as a single column, counting violations from left to right arbitrarily within the group until the fatal number is reached. In the present tableau, the fatal number for the first group of four columns is 2.

	Beat → V	Sonority monotonicity	Beat ⇒ X <sub>o</sub> V	Onset	Beat mkg.– acoustic	Beat → CV
$\begin{array}{c} \cdot & \cdot & \cdot \\   &   &   \\ a & p & a \end{array}$	*		*!	**	**	
$\begin{array}{c} \cdot \\ \diagdown \\ a & p & a \end{array}$		*		*!		*
$\begin{array}{c} \cdot & \cdot \\   &   \\ a & p & a \end{array}$				*	*	*
$\begin{array}{c} \cdot & \cdot \\ \diagdown &   \\ a & p & a \end{array}$			*	*!* <sup>20</sup>	*	

For now, we make a substantial simplifying assumption, namely that each segment has MQ 1: it enters into only one correspondence relation with a beat. Recall that this is what Segment length demands for contrastively short segments, so we are assuming our segments are short and that Segment length is never violated. Segment length will be our second order of business (see 3.7); it is violated only in one special case, which does not apply here (see 3.9).

In the tableau, we have demoted Beat → CV and Beat marking–acoustic. The key ranking that selects a|pa over ap|a (the fourth candidate) is:

$$(28) \quad \text{Onset} \gg \text{Beat} \rightarrow \text{CV}$$

Beat → CV is the most stringent member of the family of output-oriented constraints that aims at minimizing the duration of onsets; it requires an onset of duration zero. The higher-ranked Onset prevents onset minimization from being a zero-sum equation.

We also see that a strictly linear mapping—the first candidate, in which the intervocalic C is tautomoraic with nothing—is ruled out by undominated Beat → V.<sup>20</sup> This constraint, in combination with Max (beat mapping), which

<sup>20</sup> This, the “faithful” candidate, is technically harmonically bounded by the fourth candidate, but is nevertheless included in the tableau. With the faithfulness constraints we have, all four candidates are equally faithful to the input, technically. To correct this, we would need to encode

forces both Cs and Vs to map onto a beat, effectively requires all Cs to be tautomoraic with a V. This is the case even though the linear mapping avoids a violation of  $\boxed{\text{Beat} \rightarrow \text{CV}}$ , unlike the winner. Hence the following ranking:

(29)  $\boxed{\text{Beat} \rightarrow \text{V}} \gg \boxed{\text{Beat} \rightarrow \text{CV}}$

Tautomoraic CV sequences (which have inevitably imperfect alignment, per 3.3.5) cannot be avoided if it means failing to map a beat onto a sonority peak.

Also,  $\boxed{\text{Sonority monotonicity}}$  has the effect of preventing sonority peaks—the non-adjacent Vs in VCV—from being tautomoraic with each other, as in the losing second candidate. This candidate outperforms the winner on one constraint,  $\boxed{\text{Beat marking-acoustic}}$ , and is otherwise tied with it. It satisfies  $\boxed{\text{Beat marking-acoustic}}$  by crowding all three segments into one beat, thus ensuring that there are no beats that lack a fresh CV transition. Hence the crucial ranking is:

(30)  $\boxed{\text{Sonority monotonicity}} \gg \boxed{\text{Beat marking-acoustic}}$

Now let us consider a compressible intervocalic CC cluster. The account of V|CV division just given should extend naturally to V|CCV, and it does:

	Sonority monotonicity	Beat $\Rightarrow$ X <sub>0</sub> V	Onset	Beat $\rightarrow$ CCV (comp.)	Beat $\rightarrow$ CV
$\begin{array}{c} \cdot \quad \cdot \\ \diagdown \quad   \\ \text{a} \quad \text{p} \quad \text{r} \quad \text{a} \end{array}$	*	*!	**		
$\begin{array}{c} \cdot \quad \cdot \\ \diagdown \quad \diagdown \\ \text{a} \quad \text{p} \quad \text{r} \quad \text{a} \end{array}$		*	*!		*
$\begin{array}{c} \cdot \quad \cdot \\   \quad \diagdown \\ \text{a} \quad \text{p} \quad \text{r} \quad \text{a} \end{array}$			*	*	*

---

faithfulness to the set of correspondences entered into by individual beats/segments in the input representation. These would be  $\boxed{\text{Ident(ity)}}$  constraints.

(All candidates perform equally with respect to  $\boxed{\text{Beat} \rightarrow \text{V}}$ , which is omitted.) The first candidate is a non-starter, since both of its beats lack onsets and the first one even has two sonority peaks (a and r). The two serious contenders perform equally with respect to  $\boxed{\text{Onset}}$ , which allows another constraint to break the tie:  $\boxed{\text{Beat} \Rightarrow \text{X}_0\text{V}}$ , our implementation of  $\boxed{\text{No Coda}}$ . This requires the demotion of  $\boxed{\text{Beat} \rightarrow \text{CCV (compressible CC)}}$ , the less stringent cousin of  $\boxed{\text{Beat} \rightarrow \text{CV}}$ . The crucial ranking, then:

(31)  $\boxed{\text{Beat} \Rightarrow \text{X}_0\text{V}} >> \boxed{\text{Beat} \rightarrow \text{CCV (compressible CC)}}$

As for non-compressible clusters, we will defer these to 3.9, since they trigger marked outcomes.

### 3.6 Segment MQ and syllable MQ

At this point, I would like to state a hypothesis which is consistent with the two derivations seen so far:

(32) Syllable MQ Hypothesis

The MQ of syllables, as deduced empirically, is always equal to the MQ of the syllable nuclei, because no tautosyllabic material occupies a beat that the nucleus does not also occupy.

In the four  $\text{C}_0\text{V}$  syllables in the derivations in 3.5, all of which have MQ 1, the vowels also have MQ 1.

This hypothesis says that syllables have the same structural quantity as their vowels. This implies a structural correlate for “syllable,” one that is inherently quantified:

(33) Structurally, a *syllable* consists of a set of segments and beats in correspondence, where the set of beats consists of all the beats in correspondence with one vowel, and the set of segments consists of all the segments in correspondence with all those beats.

This is a definition of the syllable that is grounded in the inherent reciprocity of correspondence relations: a member of the set of segments picks out a set of beats, which in turn picks out a set of segments.

The definition is met by all the winning candidates in 3.5. But of course, we have hardly tested the definition *or* the hypothesis so far, since we are still operating with a temporary stipulation of MQ 1 for all segments. Let us get rid of this stopgap measure now, at least for vowels.

### 3.7 Vowel length

Recall three facts:

(i) Greek has segment length contrasts in both C and V.

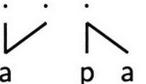
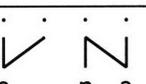
(ii) Segment length requires MQ 1 for short segments and MQ > 1 for long segments, regardless of whether segments are C or V. There is an asymmetry between short and long here: MQ is fixed for short segments but variable for long segments.

(iii) For MQ purposes, there is no distinction between sharing a beat and having it to yourself: both types of correspondence contribute to MQ in the same way, by definition.

With this in mind, let us add Segment length to the mix. In this section we will only deal with V length contrasts, while continuing to pretend that all Cs are short and therefore must have MQ 1. C length contrasts implicate heterosyllabicity (long Cs are heterosyllabic), a phenomenon we defer to the next section.

In the following tableaux, input representations (and not output representations) are annotated with an indication of underlying segment length. The symbol “:” means that a segment is lexically specified as [+ long], and its absence means the segment is [– long]. First we will look at an ungrammatical input representation, then a grammatical one.

Here is an example in which the input MQ of the Vs violates Segment length.

			$[-\text{long}]$ $\Rightarrow 1 \text{ beat}$	$[\text{+long}]$ $\rightarrow 2 \text{ beats}$	Max (IO)	DEp (IO)	Beat marking	Beat mkg.- acoustic
	*!	*					*	**
		*!			*			*
	*!					*	**	***
					*	*	*	**

We demote four constraints, en masse: the input–output faithfulness constraints and the beat marking constraints. Both pairs of constraints tend to conflict with Segment length, since they have their own criteria for segment MQ. The faithfulness constraints want to preserve input MQ, while beat marking tends to favor MQ 1 for all segments; segments are no longer fresh once they correspond to a second beat. The higher ranking of Segment length means that underlying length contrasts are directly represented in the output. (Segment length is not undominated, though, as we will see in the next section.)

(34) Segment length >> Max/DEp (IO), Beat marking, Beat marking–acoustic

Note that in the input as well as in all the output candidates, the lone C has MQ 1, as required for a short segment.

Now let us consider a grammatical input. The point here is to show the role of the faithfulness constraints, specifically Max (IO), in preserving the variable MQ of long vowels. The input contains a long V with MQ 4.

	 a: p a	[+ long] → 2 beats	Max (IO)	Beat marking	Beat marking-acoustic
 a p a				**	***
 a: p a	*!	**			*
 a p a		*!	*		**

The beat marking constraints favor MQ reduction, whereas we want to let MQ for long Vs range freely above 1. Ranking Max (IO) above beat marking achieves this aim.

(35) Max (IO) >> Beat marking, Beat marking-acoustic

Before concluding the treatment of V length, let us confirm and amplify something that we already established in 3.5, to do with Sonority monotonicity.

	 a: p a	Sonority monotonicity	Max (IO)	Beat marking	Beat marking-acoustic
 a p a		*!		*	**
 a: p a				**	***
 a p a			*!	*	**
 a: p a	*!	*			*

From an input that violates Sonority monotonicity, we obtain the same winner as in the previous tableau, where it was the faithful candidate. The winner is actually equally faithful (as far as IO parsing is concerned), but performs better on Sonority monotonicity, on the one hand, and worse on beat marking on the other. Selecting it as the winner means demoting beat marking, just as in 3.5. This time, both Beat marking and Beat marking–acoustic are implicated, not just the latter.

(36) Sonority monotonicity >> Beat marking, Beat marking–acoustic

We have now derived the part of the syllable MQ pattern (1) that applies to open syllables with simple vowels: MQ 1 for C<sub>0</sub>V and MQ 2 or greater for C<sub>0</sub>V:. In both cases, syllable MQ = vowel MQ, partially confirming the Syllable MQ Hypothesis in (32) and validating the syllable definition in (33). What remains of the pattern, then, involves closed syllables and diphthongal nuclei, and we will take each in turn. First, though, I would like to claim a triumph.

### 3.8 Observation: the weightlessness of onsets

It is well known that onsets are irrelevant to syllable weight, but explanations of this fact tend to be on the arbitrary side; for example, the claim that weight is calculated for syllable rimes, not for syllables as a whole, is actually just a restatement of the fact to be explained. I would like to suggest that we have just derived this fact—that the so-called weightlessness of onsets is just their failure to make any impact on syllable MQ, which we have derived as a consequence of the constraint Beat → V. This constraint forces Cs toglom onto Vs (be tautomoraic with a V), making their presence or absence irrelevant to overall MQ. What facilitates this glomming, in turn, is No Reversal (beat mapping), or rather, the absence/inactivity of any stronger constraint on linearity of correspondence, plus Max (beat mapping), which forces Cs to find a beat to correspond with.

It is true that this claim of success does not take into consideration the difference between CV and VC tautomoraicity: both types of sequences are equally satisfactory from the point of view of Beat → V, which suggests that we ought to be dealing not with weightlessness of onsets but with weightlessness of consonants, period. In fact, I argue that weightlessness of consonants is the normal state of affairs. (Note that all consonants, codas as well as onsets, are

weightless under Greek Weight Criterion 2, the criterion used in contour tone distribution; see 1.4.) In the next section, we will deal with the “paradox” of weightless codas; once the solution is in place, the apparent contribution of some codas to syllable weight will be isolated as a special case.

### 3.9 Codas

An interesting fact about the pattern in (1), and indeed about Greek syllable weight as a whole, is that the presence or absence of a coda makes a difference to syllable weight only if the vowel is short. To repeat (1):

(37)	Syllable type	MQ	Criterion 1	Criterion 2
	C <sub>o</sub> V	1	L	L
	C <sub>o</sub> VCC <sub>o</sub>	2	H	L
	C <sub>o</sub> VVC <sub>o</sub>	2, 3, 4, ...	H	H
	—	—	L	H

If the vowel is long or a diphthong, the MQ range is the same regardless of whether there is a coda or not. This seems counterintuitive: if a coda contributes an invariant amount of MQ (exactly 1 beat’s worth) to its syllable when the vowel is short, why should that change when the vowel is long? Why is it not the case that MQ is systematically higher for C<sub>o</sub>VVCC<sub>o</sub> than for C<sub>o</sub>VV, yielding an MQ range of “3, 4, 5 ...” instead of “2, 3, 4 ...”?

The interpretation of length as MQ solves this puzzle. Actually, the intuition just described is based on a commonsense view of length as duration, which ought to add up in a cumulative fashion, whereas MQ is a non-linear measure of time (see 1.3 for discussion of this point). There is no problem, in general, with segments sharing a beat. Since Cs cannot occupy a beat on their own, our segment-based approach clearly predicts the same syllable MQ for C<sub>o</sub>VVCC<sub>o</sub> as for C<sub>o</sub>VV. (We predict no difference between single and multiple coda consonants either, any more than between simple and complex onsets; we will return to complex codas below.)

Let us check the grammaticality of MQ 2 for a C<sub>o</sub>VVC syllable, say, pa:p. Since this syllable has a coda, the tableau should include Beat ⇒ X<sub>o</sub>V, our implementation of No Coda. In fact, we will embed this syllable in a sequence pa:pta, in order to see how non-compressible CC clusters (pt is such a cluster),

which are heterosyllabic, get apportioned to beats. So we should also include the appropriate compressibility constraints. We will present pa:p|ta to the constraints as an illicit input, pa:|pta.

	Beat → CCV (non-comp.)	DEp (IO)	Beat marking	Beat marking- acoustic	Beat ⇒ X <sub>0</sub> V
 <p>p a: p t a</p>	*		*!	*	
 <p>p a p t a</p>				*	*
 <p>p a p t a</p>		*	*!	**	*

As desired, we get pa:p|ta, and despite the coda, there is no special problem with MQ 2 on the first syllable. In fact, the third candidate, which is just like the winner except it expands the first syllable to MQ 3, is harmonically bounded by it, doing worse on both faithfulness and beat marking.

The ranking that gets us the heteromoraicity of non-compressible clusters is this one:

$$(38) \boxed{\text{Beat} \rightarrow \text{CCV (non-compressible CC)}} \gg \boxed{\text{Beat} \Rightarrow \text{X}_0\text{V}}$$

This ranking slots in with one established earlier (3.5):

$$(39) \boxed{\text{Beat} \Rightarrow \text{X}_0\text{V}} \gg \boxed{\text{Beat} \rightarrow \text{CCV (compressible CC)}}$$

The composite ranking  $\boxed{\text{Beat} \rightarrow \text{CCV (non-compressible CC)}} \gg \boxed{\text{Beat} \Rightarrow \text{X}_0\text{V}} \gg \boxed{\text{Beat} \rightarrow \text{CCV (compressible CC)}}$  summarizes the claim that non-compressible CC clusters are bad enough as onsets to justify making them heteromoraic, overriding the prohibition on codas, but that other kinds of clusters are not.

What goes for intervocalic CC clusters goes equally for more complex clusters. For example, we derive the division pa:mp|tra (this cluster is grammatical in Greek: Steriade 1981) in the same way as pa:p|ta, since the only

differences are not significant to the relevant constraints. The compressible cluster *tr* is in the same class of permissible onsets as the singleton *t*, and as for stray consonants (codas), they glom onto *V* beats just as easily in groups as they do individually:

(40) 

### 3.10 Allophonic vowel lengthening

If consonants very generally make no contribution to MQ/weight, why do they seem to in the case of  $C_0VCC_0$  syllables? The reason is Sonority monotonicity, which prevents a stray consonant from glomming onto an MQ 1 syllable:<sup>21</sup>

 pan	Sonority monotonicity	[- long] ⇒ 1 beat	DEp (IO)	Beat marking	Beat marking- acoustic
 pan	*!				
 pan		*	*		*

This tableau highlights the imperative nature of the Sonority monotonicity criterion. It overrides Segment length, faithfulness and beat marking in one fell swoop.

(41) Sonority monotonicity >> [- long] ⇒ 1 beat, DEp (IO), Beat mkg.-acstc.

The claim that results is that the beat mapping of  $C_0VCC_0$  syllables (that is, the beat mapping of segment strings whose properties destine them to be  $C_0VCC_0$

<sup>21</sup> In this tableau and the next one, all candidates perform equally with respect to the coda constraint Beat ⇒ X<sub>0</sub>V, which is omitted for that reason, and because its ranking relative to the constraints in this tableau is undetermined. We have only ranked it with respect to the compressibility constraints.

syllables) involves non-phonemic vowel length adjustment—that is, the fixing of vowel MQ by something other than Segment length.

This claim can be stated in a more general way: in the one special case where a C affects syllable MQ, it does so by affecting vowel MQ, and it does this indirectly, by triggering a repair of a Sonority monotonicity violation. This takes us straight back to the Syllable MQ Hypothesis (32), which says that syllable MQ = vowel MQ. If we are correct that even in the unique case of “weight-bearing” Cs—namely  $C_0VCC_0$  syllables—the equation still holds, then we have what is perhaps the best imaginable confirmation of the Syllable MQ Hypothesis.

The claim that vowel lengthening is implicated in the heaviness of  $C_0VCC_0$  syllables may seem *ad hoc*, but it turns out to have strong empirical support; this is provided in the next section (3.11).

Two points about the proposal require clarification. First about invariance:  $C_0VCC_0$  syllables have invariant MQ 2, whereas comparable syllables with long vowels rather than short vowels have open-ended MQ. We did not include any MQ 3 or MQ 4 candidate in the tableau above. This was because it would have been harmonically bounded by the winner: all of the winner’s constraint violations are only exacerbated by such a candidate, with no compensatory benefit. To see this more clearly, consider what happens when such a candidate is the input—it is remapped to an MQ 2 output.

	Sonority monotonicity	[- long] ⇒ 1 beat	Max (IO)	Beat marking	Beat marking- acoustic
 p a n		**!		*	**
 p a n		*	*		*
 p a n	*!		**		*

All of the constraint rankings in this tableau were independently arrived at.<sup>22</sup> We can therefore claim to have a grammar that captures the MQ invariance of C<sub>0</sub>VCC<sub>0</sub> syllables.<sup>23</sup>

The second point is actually a concern, which the astute reader will have spotted sooner than I did. It involves the range of applicability of Sonority monotonicity. The account we have just given of MQ 2 for C<sub>0</sub>VCC<sub>0</sub> syllables does not actually cover VCC<sub>0</sub> syllables, only C<sub>0</sub>CVCC<sub>0</sub> syllables. At least one initial C is crucial to creating the sonority contour that causes the MQ 1 parse to violate Sonority monotonicity, triggering the vowel lengthening repair. VCC<sub>0</sub>, on the other hand, respects monotonicity, and no repair is predicted.

There are two places that V-initial syllables can occur in Greek: absolute initial position, and word-internally after certain vowels (that is, word-internal hiatus is permitted depending on the identity of the vowels in contact). Everywhere else, rightward resyllabification applies as necessary to supply syllables with an onset (Steriade 2008). I will discuss the second environment, which I think is a more serious concern, in 3.13; here I will address domain-initial vowels.

First, a configuration that is restricted to absolute initial position is not necessarily a good basis for discrediting a model that makes correct predictions for all other positions. Second, in the case of Greek, there are empirical unknowns, reasons to doubt that the configuration in question is truly a sonority plateau rather than a rise. Not only is glottal stop epenthesis, or some other kind of laryngeal consonant epenthesis,<sup>24</sup> an entirely likely process in this

---

<sup>22</sup> On the other hand, we are relying for the first time on the gradient formulation we chose for [-long] ⇒ 1 beat (see (14) in 3.3.3): it punishes successive degrees of deviation from minimality. If not for this, that is, if [-long] ⇒ 1 beat punished all deviations from minimality equally, we would get a different result: the faithful candidate and the desired MQ 2 winner would tie on [-long] ⇒ 1 beat, and then Max (IO) would break the tie in favor of the faithful candidate.

The gradience of [-long] ⇒ 1 beat is, however, entirely natural.

<sup>23</sup> I will not attempt to account for the separate “super-H” status of C<sub>0</sub>VVCC<sub>0</sub> syllables in languages like Hindi-Urdu, since I know too little about the facts. In such languages it is possible that coda Cs, or even all Cs, have a degree of weightiness/rhythmic independence. The main point is that Cs are *uniformly* weightless in Greek, regardless of position in syllable structure.

<sup>24</sup> My own bet would be on [h] epenthesis—effectively aspiration neutralization in initial position, since Greek has contrastive /h/—but we don’t know and have no access to speakers. If some form of epenthesis is a correct hypothesis, then the grammatical relevance of this non-phonemic

environment (Parker 2008 classifies [ʔ] and [h] as Cs, in fact obstruents, for sonority purposes), but even if there are truly no phonetic segments in the initial position other than the V, there is still an initial period of silence, which might conceivably have a phonetic representation. In short, edge phenomena come with special uncertainties.

Lastly, as a hedge, I would like to observe that replacing Sonority monotonicity with some other constraint of equivalent effect—say, a constraint that penalizes tautomoraicity of a *fresh* vowel and a following C—would not change the essence of our story. The main points are (i) the effect on syllable MQ of Cs in a particular configuration is due to the vowel lengthening that occurs in that configuration, and not to any “weighty” properties of the Cs themselves, and (ii) this validates the Syllable MQ Hypothesis.

### 3.11 Excursus: evidence for allophonic vowel lengthening

The main evidence comes from the Greek musical texts themselves, specifically the evidence provided by the tune, which we mostly ignored in Chapter 2. Supporting phonetic evidence also comes from studies of living languages with quantitative properties similar to that of Greek.

#### 3.11.1 Textual evidence

In Greek musical scores, each beat is available to host a separate tone, including each tautosyllabic beat in syllables of  $MQ > 1$ .  $C_0VCC_0$  syllables are no exception to this. In the example in (42), whose score is in (43), we see a two-note contour on a CVC diseme: two beats, two notes. Notice that the coda C happens to be an obstruent in this case—a particularly poor TBU. (Compare this two-note  $C_0VT$  diseme with the  $C_0V$  syllables in this example, which uniformly lack contours.)

- (42)  $G\# G \wedge G\#$      $C\# \underline{D'B'}$      $G\# C\#$      $F\# C\#$     (P&W #18)  
 hai-    ma    ka- ta    k<sup>h</sup>-t<sup>h</sup>o- no-s    a- po[...  
 blood    down    ground-GEN    from  
*Blood down on the ground from ...*

---

segment in the evaluation of sonority monotonicity would be another illustration of the “phoneticness”/“surfacingness” of the relevant representations.



(46)	<i>C'D'</i>	<i>E<sub>h</sub>'</i>	<i>D'E<sub>h</sub>'</i>	(P&W #20.6)
	Deel-	p <sup>h</sup> i-	siin	
	CVC	CV	CVC	

In normal orthography, this word is <Delp<sup>h</sup>isin> ‘residents of Delphi’.

### 3.11.2 Experimental evidence

In general, we expect greater length in MQ to be reflected physically as greater duration. This goes for both phonemic length and allophonic lengthening.

There is some experimental evidence for this duration increase. Gordon (2002: 70) found that in Japanese and Finnish—two languages that are typologically similar to Greek in that they have contrastive vowel length and treat C<sub>0</sub>VCC<sub>0</sub> syllables as heavy—the duration of short vowels is substantially greater in closed syllables than in open syllables: 88.2 ms vs. 49.9 ms in Japanese, 95.9 ms vs. 75.8 ms in Finnish. These results are consistent with the claim that in Greek speech, a key durational correlate of weight in VC syllables is *vowel* duration.<sup>25</sup> This did not translate into the ability to host contour accents, but apparently did translate into the ability to host musical contours.

The existence of such evidence suggests that allophonic vowel lengthening might not have been a property of sung Greek only, but also of spoken Greek.

### 3.12 Consonant length

Just like (contrastive) V length (3.7), C length is interpreted in beat mapping in terms of MQ. Long Cs in Greek are always parsed partly as a coda and partly as an onset; now that we know how coda formation is regulated, we can complete the analysis of segment length. On the one hand, there is not much to say: the same Segment length constraints capture the behavior of both long Cs and long Vs, once their interaction with other constraints is taken into account. On the

---

<sup>25</sup> On the other hand, Broselow, Chen and Huffman 1997, looking at Levantine Arabic, a language with the same properties as Greek, Japanese and Finnish, found that short vowel duration was essentially invariant between closed and open syllables: 79.9 ms vs. 80.2 ms in one speaker, 65.0 ms vs. 68.0 ms in another, and 67.4 vs. 65.2 in a third. See Gordon 2002 for more discussion of this study.

other, integrating long Cs in our analysis motivates some new constraint rankings.

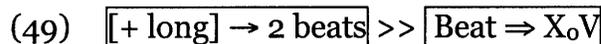
Long Cs normally only occur intervocalically in Greek. What kind of beat mapping must an intervocalic long C have? Since it is [+ long], Segment length says it must have at least MQ 2, if not greater. But since it is C, it must not correspond to any beats that do not also correspond to a V, per Beat → V. These two conditions ensure that MQ 2 is the only permitted MQ for long Cs:



Compare a (non-compressible) CC cluster, which is very similar; such a cluster also has invariant MQ 2.<sup>26</sup>



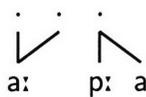
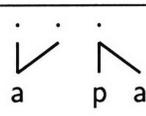
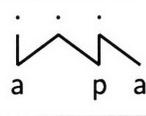
What dictates the MQ 2 parse for intervocalic pt is the compressibility constraint Beat ≠ CCV (non-compressible CC), outranking the coda constraint Beat ⇒ X<sub>o</sub>V. (See 3.5.) For intervocalic p:, what overrules Beat ⇒ X<sub>o</sub>V is instead the length constraint [+ long] → 2 beats. So we posit this ranking:<sup>27</sup>



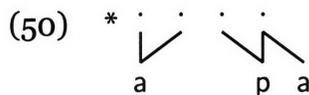
Let's see if it works on an ungrammatical input in which a [+ long] C has MQ 1. The winner, indeed, is unfaithful, satisfying the length constraint by violating the coda constraint.

<sup>26</sup> To the extent that syllables may have MQ in our system, so may clusters.

<sup>27</sup> With the opposite ranking, Beat ⇒ X<sub>o</sub>V >> [+ long] → 2 beats, and holding all other assumptions constant, we would expect intervocalic C length to be neutralized.

	[+ long] → 2 beats	DEp (IO)	Beat ⇒ XoV
	*!		
		*	*

There is a way to satisfy both the length constraint and the coda constraint, namely by tolerating a V-less beat, a violation of Beat → V:

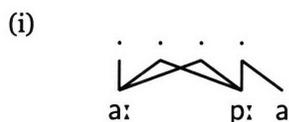


The fact that this is not allowed reflects the fact that Beat → V is a fundamental principle of Greek beat mapping, never violated.<sup>28</sup>

Note, finally, that the winning representation creates no problems for the Syllable MQ Hypothesis (32). Nor is it problematic from the point of view of the proposed structural definition of the syllable (33). The definition is repeated here:

- (51) Structurally, a *syllable* consists of a set of segments and beats in correspondence, where the set of beats consists of all the beats in correspondence with one vowel, and the set of segments consists of all the segments in correspondence with all those beats.

<sup>28</sup> The linearity constraint No reversal (beat mapping), which we have been taking for granted throughout, also has a role in deriving invariant MQ 2 for long Cs. A long C with MQ 3 or higher could share all its beats with Vs if association lines were allowed to cross, for example:



Consider again the representation in (47). The long C here is ambisyllabic: it belongs to two syllables at once. The first vowel corresponds to the first two beats, which correspond to the first two segments ap:. That is one syllable. The second vowel corresponds to the third beat, which in turn corresponds to p:a—the second syllable.

Unlike all the previous examples we have seen, the syllable boundary in this case is not represented by discontinuity of correspondence, i.e., a point where adjacent association lines do not touch. That discontinuity makes a visually intuitive structural correlate of “syllable boundary,” but as we see, it is not an invariant property of syllables, since there is such a thing as ambisyllabic segments.

The class of long Cs is actually coextensive with the ambisyllabic class in Greek. It is worth noting that undominated  $\boxed{\text{Beat} \rightarrow \text{V}}$  actually predicts this; if a long C must share all its beats with vowels, it must necessarily share them with separate vowels, one on either side.<sup>29</sup> It does not have to be intervocalic, though—it can also occur between a V and a following C, provided that it forms a compressible cluster with that C:<sup>30</sup> e.g., ek-knai|e:n ‘wear out’ (kn is a compressible cluster: Steriade 2008).

### 3.13 VV sequences

Lastly, I would like to glance at a problem whose solution I must leave for later research: the problem of vowels in contact.

When we introduced the fundamental sonority-based constraint  $\boxed{\text{Beat} \rightarrow \text{V}}$  in 3.3.4, we noted that its definition would not be fully exploited:

- (52)  $\boxed{\text{Beat} \rightarrow \text{V}}$   
 Assess a penalty for every beat not mapped to a segment that is (i) a sonority peak and (ii) a V (of sonority level 5 or 6).

All the Vs up to now have also been sonority peaks, rendering condition (i) redundant. The facts about vowel sequences suggest both motivating and refining

<sup>29</sup> Other languages possess tautosyllabic long Cs, e.g., Tashlhiyt Berber, a language famously endowed with consonantal nuclei (Dell and Elmedlaoui 2008). It is safe to say that this language, at least, requires a lower ranking of  $\boxed{\text{Beat} \rightarrow \text{V}}$  than Greek.

<sup>30</sup> Such non-intervocalic geminates only occur at morpheme boundaries in Greek.

this condition; I can only sketch these refinements here. First, let us sketch the empirical picture. I will briefly describe the segmental properties of  $V_1$  and  $V_2$  that seem to be relevant: sonority asymmetries, and contrastive length. Then I will state the MQ facts, which we already know. The puzzle is how to make the latter follow from the former.

Vowel sequences are the limiting case of  $VC_0V$  sequences (cf. 3.5). They are sometimes diphthongal, and sometimes heterosyllabic. Here is a simplified version of the distribution of these two parses (for more details, see, e.g., Smyth 1920: §§4–8, 46–76):

- (53) a.  $V_1V_2$  is a *diphthong* when  $V_1$  is non-high (sonority level 5) and  $V_2$  is high (sonority level 6):  
ai oi ei au ou eu
- b.  $V_1V_2$  is *heterosyllabic* when  $V_1$  is high and  $V_2$  is non-high:  
i|a i|o i|e y|a y|o y|e

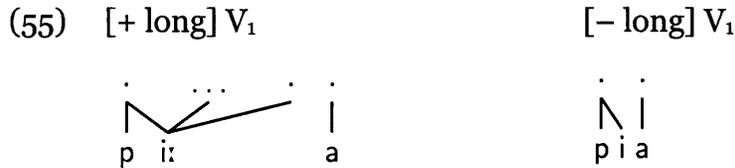
V length contrasts are attested in both the  $V_1$  and  $V_2$  positions in both the diphthongal and the heterosyllabic cases. There is one gap: no contrast, at least not overtly, between long and short  $V_2$  in diphthongs.

- (54) a. Diphthongs:  
ai oi ei au (ou) eu  
a:i o:i e:i a:u o:u e:u
- b. Heterosyllabic:  
i|a i|o i|e y|a y|o y|e  
i:|a i:|o i:|e y:|a y:|o y:|e  
i:|a i:|o i:|e y:|a: y:|o: y:|e:  
i:|o: i:|e: y:|a: y:|o: y:|e:

The syllable MQ facts are as follows. Syllables with diphthongal nuclei (54a) behave just like long-vowel syllables: they have flexible  $MQ > 1$ , regardless of whether  $V_1$  is [+ long] or [– long]. Meanwhile, heterosyllabic  $V_1V_2$  (54b) behaves just like  $V_1CV_2$ , the MQ of the two syllables being determined by the (contrastive) length of their vowels: if  $V_1$  is [– long], its syllable has MQ 1, and if it is [+ long], its syllable has  $MQ > 1$ .

Here are the representations that, it seems to me, are essentially forced on us by the above facts. The puzzle is how to make these representations follow from the properties just listed. In these representations, “...” is a wildcard

denoting *zero or more* beats. First, the heterosyllabic sequences. In these, the contrastive length of  $V_2$  raises no new issues, only that of  $V_1$ ; for concreteness, we will assume [- long]  $V_2$ .

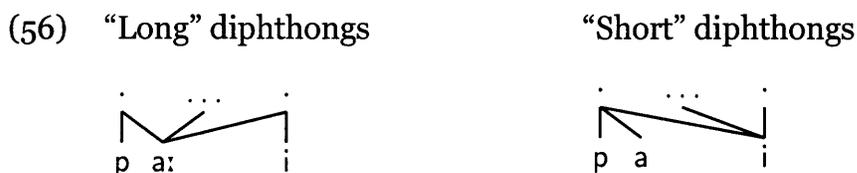


This pair of representations satisfies the definition of the syllable in (33) straightforwardly, as the reader can verify; both pi:|a and pi|a come out as two syllables. The main issue with these disyllabic sequences is that they currently violate Beat  $\rightarrow$  V.  $V_1$  in these sequences (both the long and the short version) is not a sonority peak, since it is followed by a higher sonority segment.

The solution in this case appears straightforward: define *sonority peak* so that it is only sensitive to the relative sonority of the preceding segment, not also the following one. On this revised definition, as long as a V is preceded by a lower sonority segment, whether a C or (in the case of a non-high V) a high V, it is a peak.  $V_1$  in the above depictions satisfies this asymmetric definition.

The other issue with these sequences is the fact that the second syllable lacks an onset, which enhances the doubts about Sonority monotonicity that we identified at the end of 3.10: supposing that we added codas to these second syllables, what would force allophonic vowel lengthening?<sup>31</sup>

Next, the diphthongs (54a), which seem more problematic:



<sup>31</sup> Perhaps the replacement constraint contemplated at the end of 3.10 could actually be motivated. This constraint would penalize tautomoraicity of a fresh vowel and a following C. Such a configuration might well violate a realizational minimum for the vowel, where it is non-final in its first beat and therefore subject to compression—snuffed at birth, as it were. This account does not rely on a preceding C at all, so it would apply to  $V_2$  in these heterosyllabic  $V_1V_2$  cases.

Both long and short diphthongs, we know, have unbounded MQ. In the case of short diphthongs—where  $V_1$  is subject to MQ minimality, by Segment length—the idea would be that  $V_2$ , being (for some reason) neither [+ long] nor [– long], picks up the slack. Otherwise it is not clear how such a diphthong could have unbounded MQ. Perhaps in the long diphthongs as well,  $V_2$  has unbounded MQ. But wherein, then, does the integrity of these syllables lie?

One possible answer is “so what?” The definition of the syllable that we proposed in (33), if discarded, would not change the fact that we have successfully derived virtually all the syllable MQ facts without reference to hierarchical syllable structure or even syllable boundaries.

But if we do not want to simply abandon the proposed definition, we might want to inquire more closely into what segments, exactly, the definition permits to define a syllable. As stated, it just says that every vowel does so. Perhaps a more refined criterion, along the lines of what we did above with Beat  $\rightarrow$  V, might lead us to reconstitute in our theory one of the most basic concepts of hierarchical syllable structure, that of the nucleus.

## 4 Conclusion

I will briefly describe what seem to me desirable avenues to pursue if a correspondence-based, segment-based, phonetically based, computationally discrete approach to syllables and syllable weight effects is to be deemed successful.

First, clearly, the model developed here must be tested on languages other than, and typologically different from, Greek.

Second, the applicability of the model to non-musical speech remains unclear. It is not clear, for example, what the model has to say about the process-specificity of weight criteria. In the particular case of Greek (see Chapter 1 for the facts), I suspect that the reason tone contour assignment shows a different pattern of weight than beat mapping, non-musical versification, etc., is because it's a different process: the layers that are corresponding are segments and tones, not segments and beats, and tones just have different needs than beats do. I suspect that tone is a “more lexical”/“more phonological” process than beat mapping is, with a less direct relation to the planning of utterances, and mutual completeness of parsing ( $\overline{\text{Max}}$  and  $\overline{\text{DEp}}$ ) is less of a priority than it is in beat mapping. Notice that the kind of tones that are part of textsetting tunes show different behavior than lexical tones: whereas a  $\text{C}_0\text{VCC}_0$  syllable can't host a lexical contour tone, it can host a “musical contour” (two notes: see 3.11.1). The tones of textsetting, perhaps, correspond to beats in addition to segments, and are in that sense “more phonetic” than lexical tones.<sup>85</sup>

Finally, I would emphasize that the overall picture of Greek textsetting as a triangular correspondence system of beats, matter and meter still remains to be drawn. An explicit model of how metrical patterning of the beat cycle interacts with the weight-sensitivity of beat mapping might very well lead in interesting directions, for example, with regard to the transitivity or non-transitivity of correspondence relations.

---

<sup>85</sup> Of course, they are different from lexical tones in other ways too: for one thing, they come in non-binary scales, as opposed to the binary H(igh)/L(ow) distinction.

## 4 Conclusion

On the empirical side, as I mentioned in Chapter 2, n. 4, the manuscript corpus of Ancient Greek lyric, sprawling in contrast with the ragged P&W corpus, remains an untapped source of data on Ancient Greek textsetting. It is my hope that the present study has contributed to the exploitation of that body of data.

## Bibliography

- Allen, W. S. (1974). *Vox Graeca*.<sup>2</sup> London: Cambridge University Press.
- Broselow, E., S.-I. Chen, and M. Huffman (1997). Syllable weight: convergence of phonology and phonetics. *Phonology* 14: 47–82.
- Browman, C. P., and L. Goldstein (1992). Articulatory phonology: an overview. *Phonetica* 49: 155–80.
- Chomsky, N., and M. Halle (1968). *The Sound Pattern of English*. New York: Harper and Row.
- Dell, F., and M. Elmedlaoui (2008). *Poetic Meter and Musical Form in Tashlhiyt Berber Songs*. Köln: Rüdiger Köppe.
- Flemming, E. (2006). The role of distinctiveness constraints in phonology. Ms., MIT.
- Gordon, M. (1999). *Syllable Weight: Phonetics, Phonology, and Typology*. Ph.D. thesis, UCLA.
- Gordon, M. (2002). A phonetically driven account of syllable weight. *Language* 78: 51–80.
- Gordon, M. (2004). Syllable weight. In *Phonetically Based Phonology*, ed. B. Hayes, R. Kirchner, and D. Steriade. Cambridge: Cambridge University Press.
- Halle, J. (1999). *A Grammar of Improvised Textsetting*. Ph.D. thesis, Columbia University.
- Halle, J. (2003). Constituency matching in metrical texts. Ms.
- Halle, J., and F. Lerdahl (1993). A generative textsetting model. *Current Musicology* 55: 3–23.
- Halle, M. (1987). A Biblical pattern poem. In *The Linguistics of Writing*, ed. N. Fabb, D. Attridge, A. Durant, and C. McCabe. New York: Methuen.
- Hayes, B. (2005). Textsetting as constraint conflict. Ms.
- Hayes, B., and A. Kaun (1996). The role of phonological phrasing in sung and chanted verse. *The Linguistic Review* 13: 243–303.
- Hayes, B., and M. MacEachern (1998). Quatrain form in English folk verse. *Language* 74: 473–507.

## Bibliography

- Hill, J. D. (in progress). Paraphonological syllable splitting in Ancient Greek singing. Ms., MIT.
- Jones, P. (2005). Positional faithfulness in Attic vowel contraction. Ms., UCLA.
- Katz, J. (2007). Optimal musical grouping. Paper presented at the conference on Music and Language as Cognitive Systems in Cambridge, UK, May 2007.
- Lerdahl, F. (2001). The sounds of poetry viewed as music. *Annals of the New York Academy of Sciences* 930: 337–54.
- Lerdahl, F., and R. Jackendoff (1983). *A Generative Theory of Tonal Music*. Cambridge, MA: MIT Press.
- McCarthy, J., and A. Prince (1995). Faithfulness and reduplicative identity. In *University of Massachusetts Occasional Papers in Linguistics 18: Papers in Optimality Theory*, ed. Jill Beckman, Suzanne Urbanczyk, and Laura Walsh Dickey, 249–384.
- McCrary Kambourakis, K. (2007). *Reassessing the Role of the Syllable in Italian Phonology: An Experimental Study of Consonant Cluster Syllabification, Definite Article Allomorphy and Segment Duration*. New York and London: Routledge.
- Ohala, J. J. (1992). Alternatives to the sonority hierarchy for explaining segmental sequential constraints.
- Ohala, J. J., and M. Ohala (1993). The phonetics of nasal phonology: theorems and data. In *Phonetics and Phonology*, vol. 5: *Nasals, Nasalization, and the Velum*, ed. M. K. Huffman and R. A. Krakow, 225–49. San Diego, CA: Academic Press.
- Parker S. G. (2002). *Quantifying the Sonority Hierarchy*. Ph.D. thesis, University of Massachusetts Amherst.
- Parker, S. (2008). Sound level protrusions as physical correlates of sonority. *Journal of Phonetics* 36: 55–90.
- Pöhlmann, E., and M. L. West (2001). *Documents of Ancient Greek Music*. Oxford: Clarendon Press.
- Prince, A., and P. Smolensky (1993). *Optimality Theory: Constraint Interaction in Generative Grammar*. New Brunswick, NJ: Rutgers University Center for Cognitive Science.
- Smyth, H. W. (1920). *Greek Grammar*. Cambridge, MA: Harvard University Press.
- Sommerstein, A. (1973). *The Sound Pattern of Ancient Greek*. Oxford: Blackwell.
- Steriade, D. (1982). *Greek Prosodies and the Nature of Syllabification*. Ph.D. thesis, MIT.

## Bibliography

- Steriade, D. (1988). Greek accent: a case for preserving structure. *Linguistic Inquiry* 19: 271–314.
- Steriade, D. (1991). Moras and other slots. *Proceedings of the Formal Linguistics Society of Midamerica* 1: 254–80.
- Steriade, D. (1999). Alternatives to syllable-based accounts of consonantal phonotactics. In *Proceedings of LP 1998*, ed. O. Fujimura, B. Joseph, and B. Palek, 205–45. Prague: Karolinum.
- Steriade, D. (2002). The syllable. In *The Oxford Encyclopedia of Linguistics*, ed. W. Bright.
- Steriade, D. (2008). Syllabic quantity in Ancient Greek: effects of cluster compressibility. Paper presented at the workshop on Consonant Clusters and Structural Complexity, July 31–August 2.
- Sturtevant, E. H. (1922). Syllabification and syllabic quantity in Greek and Latin. *Transactions and Proceedings of the American Philological Association* 53: 35–51.
- Vaux, B. (1998). The laryngeal specification of fricatives. *Linguistic Inquiry* 29: 497–511.
- West, M. L. (1992). *Ancient Greek Music*. Oxford: Clarendon Press.