Relatively Optimal Textsetting

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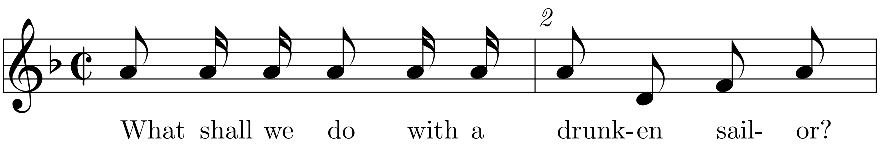
1 Introduction

The main problem of textsetting is to determine why certain musical settings of the same line of a poem are grammatical and others are not. For instance, imagine a person is singing a familiar tune, such as a Christmas carol, but is presented with the text of a verse she has never seen before – without any indication of where the syllables fall in the musical tune. Out of the many, many possible mappings of the new text to the known tune and rhythm, only a very small number actually “sound right” to the singer. Determining which of these mappings from a linguistic object to a musical one sound right is the problem of textsetting.

1.1 Notation

Before discussing this problem in more detail, we will need some new notation. Liberman (1975) introduced a system for representing metrical and musical patterns, called the grid. This system was expanded on by Jackendoff and Lerdahl (1983) in their book analyzing music in a generative system. The basic idea is that rhythmic patterns such as music and chanted poetry occur on the backdrop of a regular system of beats of varying strength. For instance, the traditional musical notation for the English folk song “What Shall We Do with a Drunken Sailor” is given below, followed by the grid notation for the same setting:




```
L(0)    x                           x                           x                           x
L(-1)   x             x             x             x             x             x             x             x
L(-2)   x      x      x      x      x      x      x      x      x      x      x      x      x      x      x      x
        |             |      |      |             |      |      |             |             |             |
        What          shall  we     do            with   a      drunk-        en            sail-         or?
```

Notice that the grid is separated into levels, with each level equally dividing the next higher level into two beats. According to Jackendoff and Lerdahl (1983), the most psychologically significant level is the *tactus*, labeled L(0) above

– this is the level where it would be most natural for someone to clap during the music.

A similar grid has also been proposed for linguistic stress (e.g., by Liberman (1975) as well). In this system, though, there is exactly one column per syllable, and the level above each syllable corresponds to its level of stress:

(1)

6	*								*	
5	*			*			*		*	
4	*			*			*		*	
3	*	*	*	*	*		*		*	
2	*	*	*	*	*	*	*		*	
1	*	*	*	*	*	*	*	*	*	*
	|	|	|	|	|	|	|	|	|	|
	What	shall	we	do	with	a	drunk-	en	sail-	or?

The syllables whose stress level extends above the horizontal line are those that count as accented in the systems by Halle and Hayes below. From now on, though, I will indicate linguistic stress with either an accent on stressed syllables, or a number above each syllable, indicating its stress:

(2)

6	3	3	5	3	2	5	1	6	1
Whát	shall	we	dó	with	a	drúnk-	en	sáil-	or

1.2 Systems of Textsetting

The main principle behind any system of textsetting is that linguistically strong syllables are somehow related to metrically strong beats, a principle Hayes and Kaun (1996) refer to as stress matching. There are (at least) two logically possible ways to implement this principle. First, you could simply require linguistically strong syllables to be set on metrically strong beats. This is the approach taken by Halle and Hayes. Second, you could consider the relative linguistic strengths of the syllables in a line of text and try to preserve these relationships in setting the syllables to music. This is the approach that I will pursue in this paper. To illustrate the difference, consider the following mis-setting:

(3)

L(0)			x	
L(-1)	x		x	
L(-2)	x	x	x	x
	4	0	1	0
	fá		ther	

You could either consider the setting incorrect because the strong syllable "fa" is set in a weak position and the weak syllable "ther" is set in a strong position or because the stress relationship "fa" > "ther" is reversed in the setting.

Halle (1999) was the first to propose an explicit algorithmic solution to the textsetting problem (following Halle and Lerdahl (1993)). In his system, syllables are divided into accented and unaccented syllables. First, the accented syllables are set from left to right on the strongest musical beats (level L(0)), then any unaccented syllables are set between the accented ones. The way this algorithm works ensures that there will never be a mismatch between syllable accent and strength of metrical/musical position: accented syllables will always be in the strongest (L(0)) positions (and never in weaker positions) and unaccented syllables will never be in the strongest positions, but always in weaker ones.[1]

Hayes's system, although more articulated than Halle's, still achieves stress matching by simply requiring accented syllables to be set on strong positions and unaccented syllables on weak positions. He achieves this through a system of constraints within an Optimality Theory system, as described in detail below.

This paper agrees with Hayes (2005) that the proper treatment of textsetting is by using Optimality Theory, but in the new system presented below, the emphasis for the stress-matching constraints is slightly different: instead of looking at single syllables, the stress-matching compares all pairs of syllables in the line. The important factor is whether the relative prominence between the two syllables of a pair is maintained when moving from linguistic prominence (i.e., stress level) to metrical prominence (i.e., beat strength).

The system using this idea of relative prominence is much simpler than Hayes's system – both in number of constraints and in ease of extending the system to new cases. It makes more accurate typological predictions about possible systems of textsetting. Finally, the new system, when extended to consider more levels of stress, improves dramatically in accuracy when run on the same corpus as Hayes's system.

1.3 Technicalities

Technically speaking, a line of a poem is an actual utterance of a particular sequence of words, including linguistic stress and phonological grouping information. In practice, however, there might be several ways to utter the same written line, caused by contrastive stress or other factors. Therefore, in the data below, each line is given just one set of linguistic stresses and I have for the most part ignored the phonological groups. A musical setting of such a line should include where each syllable of the line starts, how long it is held, and on which notes it is sung. However, following previous work, I will concentrate on the musical beats where each syllable starts. Last, the grammaticality of a textsetting should be tested empirically, just like the syntactic grammaticality of a sentence. I will mostly use empirical data below, but sometimes I will assume that attested (i.e., composed or transcribed) settings are grammatical as well.

2 Hayes 2005

Halle's system never allows stressed syllables in weak positions or unstressed syllables in strong positions. It turns out, however, that there are cases where

[1] Hayes's version of the algorithm does sometimes set unaccented syllables in L(0) positions.

such mismatches are required in order to create a grammatical output. Several such cases are discussed below in this section, but a quick example is that lines that leave three or more L(-2) positions empty in a row are strongly dispreferred, even if they fully fit within stress-matching parameters. To see how often such mismatches occur, Hayes (2005) tests Halle's strict algorithm against a corpus of 364 lines from English folk verse and finds that it only sets 84 of the lines correctly, or 23.1%. Hayes proposes that the textsetting problem requires a more flexible framework that allows some of the mismatches that Halle's algorithm avoids. The framework he suggests is Optimality Theory, a system of ranked constraints much used in phonology. In an Optimality Theory system, a higher-ranked constraint can prevent a lower-ranked constraint or constraints (such as stress-matching in this case) from being fully satisfied. Hayes proposes a set of constraints that uses the main intuition behind Halle's system, but includes other constraints, ranked both higher and lower than stress-matching constraints. Hayes's system can correctly set 257 of the lines in his corpus, or 70.6%. I will briefly discuss each part of his system below, and refer the reader to Hayes (2005) for further detail.

2.1 Stress Matching

Hayes's stress-matching constraints take the following form[2]:

(4) * ⟨Linguistic Prominence Level⟩ IN ⟨Metrical Prominence Level⟩

where

⟨Linguistic Prominence Level⟩ = NULL or STRESSLESS or STRESSED

⟨Metrical Prominence Level⟩ = S or M or W
(for Strong = L(0), Medium = L(-1), and Weak = L(-2))

So, for instance, *STRESSLESS IN S assigns a violation for every stressless syllable set in an L(0) position. An example like (3) above would incur violations for *STRESSLESS IN S ("ther" in an L(0) position) and *STRESSED IN M ("fa" in an L(-1) position). The constraints work together to determine the proper setting of a longer line of text:

		L(0)			x				x				x				x	
		L(-1)	x		x		x		x		x		x		x		x	
(5)	a.	L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
			|		|		|		|		|		|		|		|	
			I		wóoed		her		in		the		súm-		mer		tíme	

[2]Hayes assumes, along with Halle and myself, that the continuation of a syllable being chanted or sung during a beat still counts as a null. Only the position where the syllable begins to be sung/chanted counts as being set with that syllable.

```
      L(0)             x                   x                   x                   x
      L(-1)  x         x         x         x         x         x         x         x
b.    L(-2)  x    x    x    x    x    x    x    x    x    x    x    x    x    x    x    x
                       |         |         |         |    |    |         |         |
                       I         wóoed     her       in   the  súm-      mer       tíme
```

(6)

		*Null in S	*S-less in S	*S-ed in W	*S-less in W	*S-ed in M	*Null in M
☞	a.	0	1(“in”)	0	0	0	0
	b.	0	2(“I”, “her”)	0	1(“the”)	1(“wooed”)	1(1st pos)

Candidate (a) has an upbeat and (b) does not. As you can see from the tableau, (b) has an extra violation for *Stressless in S (“I”), *Stressless in W (“the”), *Stressed in M (“wooed”), and *Null in M (first position). In this way, Hayes’s constraints enforce the stress-matching for this line of text. Presumably, if the system were going to take into account more than two stress levels, it would need to add three such constraints (corresponding to the three relevant metrical levels) for each additional stress level handled.

2.2 Lapses

If these stress-matching constraints were enough, however, Halle’s system would be more successful. One place that strict stress-matching goes astray, as Hayes points out, is cases where the strict stress-matching setting leaves a lapse in the grid, which he defines as three or more unset metrical positions (on the L(-2) level). On the whole, settings with lapses are not grammatical in English folk verse – hence we want to find a way to prevent them. Since Hayes is using an Optimality Theory system, he can introduce a higher-ranked constraint, as we will see below, to prevent lapses in lines.

One case where Halle’s system derives outputs having lapses Hayes refers to as “consecutive stressed syllables,” where setting two accented syllables with no intervening unaccented syllables on two consecutive L(0) positions causes a lapse. This is also the most harmonic candidate with respect to Hayes’ stress-matching constraints above:

(7) (≈ Hayes (22))

```
L(0)             x                   x                   x                   x
L(-1)  x         x         x         x         x         x         x         x
L(-2)  x    x    x    x    x    x    x    x    x    x    x    x    x    x    x    x
       |         |                   |                   |    |    |    |    |
       *To       cóurt               yóung               máid-ens  I    was  bént
```

In order to only put accented syllables on L(0) positions, the algorithm leaves three L(-2) positions open between the accented syllables, causing a lapse. The preferred setting is in (8):

(8) (≈ Hayes (23))

```
L(0)              x                   x                   x                   x
L(-1)   x         x         x         x         x         x         x         x
L(-2)   x    x    x    x    x    x    x    x    x    x    x    x    x    x    x    x
        |         |         |         |         |         |         |         |
        To        cóurt     yóung     máid-     ens       I         was       bént
```

In (8), strict stress matching is violated (for instance the accented syllable "yóung" is set on an L(-1) position), but there are no lapses. Hayes proposes a constraint *Lapse, ranked higher than the stress-matching constraints, to derive this case and others like it:

(9) *Lapse – "violated whenever there are three empty grid positions in a row."

(10)

		*Lapse
☞	(7)	0
	(8)	2

Candidate (8) incurs two violations of *Lapse while (7) incurs none. Therefore, even though (7) is the best candidate according to the stress-matching constraints, (8) wins. As we will see below, a constraint based on relative prominence reduces the need for the *Lapse constraint, but does not eliminate it entirely.

2.3 Alignment Conditions

The other examples Hayes uses to motivate his system are cases where Halle's system does not respect the boundaries of the metrical grid. In one case, labeled by Hayes "squeezing the stressless syllables," too many stressless syllables fall between two stressed syllables, causing them to be set on a lower level than seen before: L(-3):

(11) (≈ Hayes (18))

```
L(0)              x                             x                   x                   x
L(-1)   x         x         x                   x         x         x         x         x
L(-2)   x    x    x    x    x         x         x    x    x    x    x    x    x    x    x    x
L(-3)                       x    x    x    x
        |         |         |    |    |    |    |         |         |
        *En-      quír-     ing  for  his  a-   lá-       dy,       Ó
```

The preferred setting is in (12), where the syllables are spread more evenly through the grid:

(12) (≈ Hayes (19))

```
L(0)              x                   x                   x                   x
L(-1)   x         x         x         x         x         x         x         x
L(-2)   x    x    x    x    x    x    x    x    x    x    x    x    x    x    x    x
        |         |         |         |         |    |    |         |         |
        En-       quír-     ing       for       his  a-   lá-       dy,       Ó
```

To handle cases like this, Hayes proposes a *Fill Extra Weak constraint to prevent syllables on this line:

(13) *Fill Extra Weak – "violated whenever a syllable is placed in an extra weak position"

(14)

		*Fill Extra Weak
☞	(12)	0
	(11)	2

As far as I can tell, however, this problem could also be thought of as an instance of the *Lapse constraint – since the examples shown also violate *Lapse.

Another line that exemplifies an alignment condition in a more straightforward manner is Hayes's "more than four stresses" case. Here, since there are more than four accented syllables, Halle's system requires the uses of a longer grid to satisfy the strict stress-matching constraint:

(15) (≈ Hayes (20))

```
L(0)          x           x           x           x      |
L(-1)  x      x     x     x     x     x     x     x      |
L(-2)  x  x   x  x  x  x  x  x  x  x  x  x  x  x  x  x   |
       |      |     |     |     |     |  |     |
       *I     pláced my   báck  a-    gáinst the  óld
L(0)          x           x
L(-1)  x      x     x     x
L(-2)  x  x   x  x  x  x  x  x
              |     |     |
              gár-  den   gáte
```

(The vertical line marks where the original grid ends.)

There seems to be a very large prohibition against going beyond the space allotted by the grid. The preferred way to set this longer line is:

(16) (≈ Hayes (21))

```
L(0)          x              x                 x              x
L(-1)  x      x     x        x        x        x      x       x
L(-2)  x  x   x  x  x  x     x    x   x    x   x  x   x    x  x  x
       |      |     |        |    |   |    |   |      |    |  |
       I      pláced my      báck a-  gáinst the óld  gár- den gáte
```

Once again, strict stress matching is violated minimally in order to satisfy the alignment to the boundaries of the grid. Hayes captures this with his *Run-On constraint:

(17) *Run-On – "violated whenever the syllables of a line [exceed] the allotted grid for that line."

(18)

		*Run-On
☞	(16)	0
	(15)	3

2.4 Strong Is Long

The last constraint in Hayes's system is Strong Is Long, defined as below:

(19) Strong Is Long – violated whenever a strong metrical position is filled with a note of short duration; violations are counted by subtracting the number of contiguous empty positions after the strong beat from the total possible number of positions before the next strong beat (namely, three).

This constraint favors settings where strong metrical beats are long – namely that the note in those positions extends for more than one L(-2) beat. I could not find an example from the corpus to motivate this constraint for Hayes's system, but see section 3.2.4 below for how it works in the new system.

2.5 Hayes's System

Haye's full list of constraints are listed below, in order of precedence. The stress-matching constraints have boxes around them, since these are the ones I will be discussing mostly below.

(20)
a. *Fill Extra Weak
b. *Run-On
c. *Lapse
d. *Null in S – violated whenever there is no syllable in a strong position
e. *Stressless in S – violated whenever there is an unaccented syllable in a strong position.
f. *Stressed in W – violated whenever there is an accented syllable in a weak position.
g. *Stressless in W – violated whenever there is an unaccented syllable in a weak position.
h. Strong Is Long
i. *Stressed in M – violated whenever there is an accented syllable in a medium position.
j. *Null in M – violated whenever there is no syllable in a medium position.

Near the end of his paper, Hayes suggests several ways to improve on his system, using techniques from the field of generative metrics. Of these suggestions, the one I will concentrate on most for the remainder of the paper is that constraints for textsetting ought to allow for multiple levels of stress and compare the relative stress of syllables instead of using an absolute scale. My system builds a single constraint for stress-matching based on this suggestion.

3 Relative Prominence

In this section, I will propose a replacement system for the stress-matching portion of Hayes's constraint set based on Correspondence Theory. The system centers around one single constraint, given below:

(21) RELPROM – assign one violation for every pair of syllables $\langle \sigma_1, \sigma_2 \rangle$ where σ_1 has a higher linguistic prominence than σ_2 but σ_2 has a higher metrical prominence than σ_1.

This constraint serves to preserve the relative prominence of syllables from one level (linguistic stress) to the next (strength of metrical position). To show how it works, consider (22) below. Two settings for the same line are shown, including Hayes and Kaun's stress levels (0 for no syllable, 1 for least stressed syllable, 4 for most stressed syllable). (24) shows the pairs of syllables from (22) that violate RELPROM.

(22) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	1	0	4	0	1	0	3	0	1	0	1	0	4	0	2	0
	One		night		she		came		to		my		bed-		side	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0	0	1	0	4	0	1	0	3	0	1	1	4	0	2	0
			*One		night		she		came		to	my	bed-		side	

(23)

		RELPROM
☞	a.	3
	b.	13

(24) a.

$$\left\langle \begin{array}{c} \\ x\\ x\\ 4\\ \textit{bed–} \end{array}, \begin{array}{c} x\\ x\\ x\\ 3\\ \textit{came} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 4\\ \textit{bed–} \end{array}, \begin{array}{c} x\\ x\\ x\\ 1\\ \textit{my} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 4\\ \textit{bed–} \end{array}, \begin{array}{c} x\\ x\\ x\\ 2\\ \textit{side} \end{array} \right\rangle$$

b.

$$\left\langle \begin{array}{c} \\ x\\ x\\ 4\\ \textit{night} \end{array}, \begin{array}{c} x\\ x\\ x\\ 1\\ \textit{One} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 4\\ \textit{night} \end{array}, \begin{array}{c} x\\ x\\ x\\ 1\\ \textit{she} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 4\\ \textit{night} \end{array}, \begin{array}{c} x\\ x\\ x\\ 1\\ \textit{to} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 4\\ \textit{night} \end{array}, \begin{array}{c} x\\ x\\ x\\ 2\\ \textit{side} \end{array} \right\rangle$$

$$\left\langle \begin{array}{c} \\ x\\ x\\ 3\\ \textit{came} \end{array}, \begin{array}{c} x\\ x\\ x\\ 1\\ \textit{One} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 3\\ \textit{came} \end{array}, \begin{array}{c} x\\ x\\ x\\ 1\\ \textit{she} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 3\\ \textit{came} \end{array}, \begin{array}{c} x\\ x\\ x\\ 1\\ \textit{to} \end{array} \right\rangle \left\langle \begin{array}{c} \\ x\\ x\\ 3\\ \textit{came} \end{array}, \begin{array}{c} x\\ x\\ x\\ 2\\ \textit{side} \end{array} \right\rangle$$

$$\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 1 & & 0 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \end{array} \right\rangle$$

$$\begin{array}{cccccccc} \textit{my} & & \textit{bed}- & \textit{One} & \textit{bed}- & \textit{she} & \textit{bed}- & \textit{to} \end{array}$$

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 2 \end{array} \right\rangle$$

$$\begin{array}{cc} \textit{bed}- & \textit{side} \end{array}$$

Notice that (22a) does incur three violations of RelProm, because "bed" is set on a weaker beat than "came," "my," and "side." However, (22b) has thirteen violations, shown above – much worse than (22a).

One immediately apparent advantage to RelProm is that it is one constraint that replaces six in Hayes's system. Furthermore, since RelProm does not directly refer to specific levels of stress, it easily allows for systems with an unlimited number of levels of stress. As it turns out below, the ability to distinguish between many levels of stress is where the new system provides its greatest empirical advantage over Hayes's system. Although the Hayes system could conceivably add more and more constraints for each new level of stress added, it is not immediately apparent how to order such a vast array of constraints: for instance, is it worse to have a level two syllable in an L(-1) position or a level three syllable in an L(0) position? It is also not clear whether such constraints would even correctly set the lines in question. Last, having so many constraints will run into a problem with typological predictions, as we will see below.

3.1 Specific Decisions

There are several subparts of the definition of RelProm that are purely arbitrary; they do not make any difference in which lines are set correctly. For instance, the definition above calls for checking pairs of syllables where one syllable is linguistically stronger than the other and investigating whether the same metrical relationship holds. However, if instead you were to pick pairs of syllables based on metrical prominence and check for relative linguistic stress, you would still be picking out the exact same syllables. Additionally, whether you consider pairs that have equal stress and equal metrical position or whether you do not consider these pairs (as done in the definition above), in theory there might be a difference, but in practice I have found that the results are statistically the same.

However one part of the definition is crucial: the fact that all pairs of syllables are compared. One might think that the relative prominence phenomenon is a local effect, so perhaps only adjacent or relatively near-by syllables need to be considered. However, the number of lines that are set correctly is quite low when only adjacent syllable pairs are considered. Even at a window of five syllables left or right, the following line is set incorrectly ((25) shows the correct and incorrect settings, (26) the tableau choosing the incorrect one, and (27) the violations for RelProm(5) – relative prominence only considering a five-syllable window):

(25) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	1	0	4	0	1	0	1	0	3	0	1	0	4	0	2	0
	And		Nel-		son		he		got		his		death-		stroke	

b.

L(0)			x				x				x				x		
L(-1)	x		x		x		x		x		x		x		x		
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
	0	0	1	0	4	0	1	0	1	0	3	0	1	0	4		2
			*And		Nel-		son		he		got		his		death-		stroke

(26)

		*Lapse	*Upbeat Mismatch	RelProm(5)	Strong Is Long
	a.	0	0	4	0
☞	b.	0	0	3	1

(27) a.
$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 1 \\ \textit{got} & & \textit{he} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 1 \\ \textit{got} & & \textit{his} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \\ \textit{death}- & & \textit{his} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 2 \\ \textit{death}- & & \textit{stroke} \end{array} \right\rangle$$

b.
$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \\ \textit{Nel}- & & \textit{And} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \\ \textit{Nel}- & & \textit{son} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \\ \textit{stroke} & & \textit{his} \end{array} \right\rangle$$

In the full system, the tableau and violations are as follows:

(28)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
☞	a.	0	0	6	0
	b.	0	0	8	1

(29) a.
$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 1 \\ \textit{got} & & \textit{he} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 1 \\ \textit{got} & & \textit{his} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 2 \\ \textit{got} & & \textit{stroke} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \\ \textit{death}- & & \textit{he} \end{array} \right\rangle$$

$$
\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \\ \textit{death}- & & \textit{his} \end{array} \right\rangle
\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 2 \\ \textit{death}- & & \textit{stroke} \end{array} \right\rangle
$$

b.
$$
\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \\ \textit{Nel}- & & \textit{And} \end{array} \right\rangle
\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \\ \textit{Nel}- & & \textit{son} \end{array} \right\rangle
\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \\ \textit{Nel}- & & \textit{got} \end{array} \right\rangle
\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 0 \\ \textit{stroke} & & \end{array} \right\rangle
$$

$$
\left\langle \begin{array}{ccc} & & x \\ & & x \\ x & , & x \\ 2 & & 1 \\ \textit{stroke} & & \textit{And} \end{array} \right\rangle
\left\langle \begin{array}{ccc} & & x \\ & & x \\ x & , & x \\ 2 & & 1 \\ \textit{stroke} & & \textit{son} \end{array} \right\rangle
\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \\ \textit{stroke} & & \textit{he} \end{array} \right\rangle
\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \\ \textit{stroke} & & \textit{his} \end{array} \right\rangle
$$

The bulk of the new violations that arise when you consider the relative prominence of the entire line come from comparing the last syllable ("stroke") with syllables as far back as the first syllable ("And"). This is about as far as you can get in the same line, both in terms of syllables and even if you were to move towards consider higher-level phonological or syntactic groupings. For instance, the only syntactic phrase that the first and last syllable are both in is the entire sentence.

As the window of syllables considered expands to the whole line (of length sixteen), the overall accuracy of the system increase as well:

(30)

Window:	1	2	3	4	5	8	12	16
	12.9%	65.4%	74.3%	76.1%	82.1%	87.9%	88.4%	89.3%

Such evidence strongly indicates that the problem of textsetting considers a domain including the entire line of text being set. This is further supported by anecdotal evidence from speakers reading lines of text for the first time. A speaker may begin with a straightforward setting for the first half of the line, and then realize halfway through that she has painted herself into a corner due to, for instance, the large number of syllables in the second half of the line. She may then reread the line with the proper setting taking into account the entire line of text.

3.2 Other Constraints

Since every line satisfies Hayes's *Run-On, I have imported it directly in my system. The case for adding the rest of the constraints is a little less obvious, so I discuss them on a case-by-case basis below.

3.2.1 *Fill Extra Weak

Hayes's *Fill Extra Weak constraint seems never to apply without incurring a *Lapse constraint in the examples examined for this paper. In most cases, *Fill Extra Weak-violating settings will also incur more RelProm violations. If you consider the two syllables set in L(-3) positions in (11), repeated below, they each will incur a RelProm violation for every unfilled L(-2) or higher position, of which there are nine, for a total of 18 extra violations:

(31) (repeat of 11):

```
L(0)               x                                   x                       x                       x
L(-1)  x           x           x                       x           x           x           x           x
L(-2)  x     x     x     x     x           x           x     x     x     x     x     x     x     x     x     x
L(-3)                          x     x     x     x
       |           |           |     |     |     |     |           |           |
       *En-        quír-       ing   for   his   a-    lá-         dy,         Ó
```

However, I can imagine a case where *Fill Extra Weak might be violated in a grammatical setting:

(32) "This line of text is unprecedentedly long."

(33)

```
L(0)               x                       x                       x                       x
L(-1)  x           x           x           x           x           x           x           x
L(-2)  x     x     x     x     x     x     x     x     x     x     x     x     x     x     x     x
       |     |     |           |           |     |     |     |     |     |     |           |
       *This line  of          text        is    un-   pre-  ce-   den-  ted   ly          long
```

(34)

```
L(0)               x                       x                       x                             x
L(-1)  x           x           x           x           x           x           x                 x
L(-2)  x     x     x     x     x     x     x     x     x     x     x     x     x     x           x     x
L(-3)                                                                                x     x
       |           |           |           |           |     |     |     |     |     |     |     |
       This        line        of          text        is    un-   pre-  ce-   den-  ted   ly    long
```

To me, (34) sounds much better than (33) – for stress-matching reasons – even though (34) has extra-weak syllables. Such a setting seems to happen exactly when RelProm and *Lapse are satisfied, so it seems to me that the best course of action is to eliminate *Fill Extra Weak entirely.

3.2.2 Lapse

In many cases, RelProm can distinguish between the setting with a lapse and the setting without. For instance in (7), repeated below, the setting with the lapse incurs more RelProm violations than the preferred setting:

(35) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	1	0	3	0	3	0	4	0	1	0	1	0	1	0	3	0
	To		court		young		maid-		ens		I		was		bent	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	1	0	3	0	0	0	3	0	0	0	4	1	1	1	3	0
	*To		court				young				maid-	ens	I	was	bent	

(36)

		RelProm
☞	a.	1
	b.	4

(37) a. $\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 1 \end{array} \right\rangle$

young *I*

b. $\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 1 & & 0 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 1 & & 0 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 1 & & 0 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 1 & & 0 \end{array} \right\rangle$

ens *ens* *was* *was*

The candidate with a lapse has two syllables in L(-2) positions and two empty L(-1) positions, for a total of four violations.

However, *Lapse is still needed in the new system, for cases like the following:

(38) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0	0	3	0	4	0	5	0	3	0	5	0	4	0	6	0
			She		walked		out		one		moon-		lit		night	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	4	0	0	0	5	0	3	0	5	0	4	0	6	0
	*She		walked				out		one		moon-		lit		night	

(39)

		RelProm
	a.	2
☞	b.	0

(40) a.
$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \\ \textit{walked} & & \textit{She} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \\ \textit{lit} & & \textit{She} \end{array} \right\rangle$$

Although (38a) is the real setting, (38b) is a better setting according to relative prominence – it just has a lapse.

A real test of RelProm would come in a system where stress-matching constraints outrank *Lapse. There, if only lapses allowed by RelProm appear, it would be more evidence for the RelProm constraint. See section 5.1 below for a system that might possibly show this.

3.2.3 *Upbeat Mismatch

There are several lines whose proper settings violate RelProm in order to avoid having two upbeat syllables that are relatively too strong locally. For instance:

(41) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	3	3	4	0	6	0	3	0	5	1	3	0	6	0
	But		as	she	turned		out,		I'd		bet-	ter	been		dead	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	3	3	0	4	0	6	0	3	0	5	1	3	0	6	0
	*But	as	she		turned		out,		I'd		bet-	ter	been		dead	

(42)

		RelProm
☞	a.	1
☞	b.	1

(43) a. ⟨ , ⟩

		x
	x	x
	x	x
	4	3
	turned	*as*

b. ⟨ , ⟩

		x
	x	x
	x	x
	4	3
	turned	*she*

Just according to RelProm, the two settings are equal; however Hayes and Kaun's consultants preferred (41a) is preferred, due to its upbeat structure. The constraint to distinguish them is formulated as follows:

(44) *Upbeat Mismatch – Assign a violation for an upbeat with two syllables of greater than or equal stress to the syllable in the first downbeat.

This is basically a magnification of RelProm at the boundary of the line.

3.2.4 Strong Is Long

Even with relative prominence and all the above constraints, there is still a preference for strong beats to contain long syllables. I have reformulated the constraint slightly in order to simplify it, but the basic ideas is the same:

(45) Strong Is Long – Assign one violation for every filled L(-2) position immediately following an L(0) position.

In the relative prominence system, this constraint actually makes a difference in many lines of text, which are tied based on the previously mentioned constraints. For instance:

(46) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	4	0	3	3	6	1	3	2	5	0	1	0	6	0
	O		where		are	you	go-	ing	to,	my	pret-		ty		maid	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	4	3	3	0	6	1	3	2	5	0	1	0	6	0
	*O		where	are	you		go-	ing	to,	my	pret-		ty		maid	

(47)

		*Lapse	*Upbeat Mismatch	RelProm
☞	a.	0	0	2
☞	b.	0	0	2

(48) a. $\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 3 & & 1 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \end{array} \right\rangle$

you *ty* *my* *ty*

b. $\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 3 & & 1 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \end{array} \right\rangle$

are *ty* *my* *ty*

The difference is in the setting of "are you" – whether it is directly after the strong metrical position (dispreferred) or leaves an empty position after the strong metrical positions (preferred).

3.3 Full System

The complete new system is as follows (in order):

(49) a. *RUN-ON
b. *LAPSE
c. *UPBEAT MISMATCH
d. RELPROM
e. STRONG IS LONG

Section (4) will examine the empirical advantages to this system, but first there are also some advantages of a more theoretical nature. First, as noted above, the RELPROM constraint does not refer to specific stress levels or metrical grid levels and therefore more easily allows a greater range of such levels. It also more directly captures the notion that stress is an inherently relative conception.

Second, if you consider a factorial typology of the constraints in Hayes' system, you would predict many, many unattested systems, with the individual constraints standing in different ranking relationships with one another. For instance, why shouldn't a system exist that is precisely the opposite, with weak syllables in strong positions – or something in between the two extremes? Even if you employed a meta-ranking whereby you could never get the complete reverse system, there is no a priori method of choosing the ranking of constraints comparing the two different scales involved: metrical prominence and linguistic prominence. For instance, you might restrict the typology to rankings where constraints concerning L(0) positions outrank constraints concerning L(-1), which in turn outrank constraints concerning L(-2) positions:

(50) *... IN S ⟩⟩ *... IN M ⟩⟩ *... IN W

Alternatively, you might restrict the typology to rankings where constraints concerning null syllables outrank constraints concerning stress-level one syllables, and so forth:

(51) *Null in . . . ⟩⟩ *1 in . . . ⟩⟩ *2 in . . . . . .

However, even Hayes's current system does not adhere to either of these metaranking strategies. His constraints seem to go in the following order of metrical positions:

(52) *. . . in S ⟩⟩ *. . . in W ⟩⟩ *. . . in M

Within each grouping by metrical position, there is a different order for linguistic strength. The question becomes even more murky when levels are added – for instance, which constraint should be higher ranked, *4 in W or *3 in M?

In the new system, the RelProm constraint is indivisible and hence could not lead to strange textsetting systems through reranking. However, this constraint could be reranked with respect to the other constraints, such as *Lapse and Strong is Long, predicting, among others, a system where it is more important to satisfy RelProm than *Lapse. Such a system is in fact exhibited in the work of Cole Porter, where lapses are often allowed – see section 5.1 below.

4 Experiments

4.1 Data

Hayes and Kaun (1996) gathered a corpus of 670 lines from collections of English folk verse. All these lines are set on the grid in (53):

	L(0)			x				x				x				x	
(53)	L(-1)	x		x		x		x		x		x		x		x	
	L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Both Hayes and Kaun separately coded the lines in the corpus for the stress level of each syllable on a scale from one to four, then worked out a compromise setting for the 8.8% of cases where they differed by one stress level and the 2.9% of cases where they differed by two or three. They transcribed ten native speakers chanting the lines as the the speakers felt was most natural. The 364 lines from Hayes (2005) are only lines from the larger corpus that have four beats (within a strophe of English folk verse, couplet endings are often truncated to three beats). Of these four-beat lines, Hayes (2005) only included those where at least four consultants agreed on what the correct textsetting should be. It is this smaller corpus that I used for my experiments.

4.2 Procedure and Results

To test against this corpus, I wrote a computer program in the Java programming language that reads in the Hayes (2005) corpus and implements the general Optimality Theory evaluation procedure. I coded Hayes's constraints and my constraints separately in order to test them in the computer program and be able to play with the rankings of the constraints. The program generates all possible settings of a given line of text to the grid given in (53) where all the syllables are set within the grid and the syllables remain in the correct order; this approach effectively enforces *Run-On as the highest ranking constraint in the system. To reduce overall running time, the program also discards generated candidates that are not four-beat lines. Still, the average number of candidates per line was over 2500.

Although the Hayes is corpus is marked with four possible levels of stress for each syllable as described above, since Hayes's stress-matching constraints only refer to two levels of stress, as a baseline experiment, I ran his system and my system against the corpus only considering two levels of stress (1 = unaccented and 3-4 = accented). In this first experiment, the new system is roughly equivalent to Hayes's system, achieving 70.9% accuracy versus 70.3% for the Hayes system, determined by unique correct outputs. There is a telling example, though, that illustrates how the approaches can differ. (54a) is the preferred setting, but Hayes's system chooses the setting in (54b) because the stressless syllable "her" is set on an L(0) position in (54a), but not in (54b). The tableau for the relative prominence system and the particular prominence violations are given below the tableau for the Hayes system.

(54) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	5	0	5	0	5	1	6	0	3	0	3	0	3	0	5	0
	Two		sweet		lit-	tle	babes		to		her		were		born	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0	0	5	0	5	0	5	0	1	0	6	3	3	3	5	0
			*Two		sweet		lit-		tle		babes	to	her	were	born	

(55)

		*Lapse	*Null in S	*S-less in S	*S-ed in W	*S-less in W	Strong Is Long	*S-ed in M	*Null in M
	a.	0	0	1	0	1	8	2	0
☞	b.	0	0	0	0	2	9	1	1

(56)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
☞	a.	0	0	2	0
	b.	0	0	4	1

(57) a. $\left\langle \begin{array}{c} \\ x \\ x \\ 5 \\ Two \end{array} , \begin{array}{c} x \\ x \\ x \\ 3 \\ her \end{array} \right\rangle \left\langle \begin{array}{c} \\ x \\ x \\ 5 \\ lit- \end{array} , \begin{array}{c} x \\ x \\ x \\ 3 \\ her \end{array} \right\rangle$

b. $\left\langle \begin{array}{cc} & x \\ x \;, & x \\ 3 & 0 \\ \textit{to} & \end{array} \right\rangle \left\langle \begin{array}{cc} & x \\ x \;, & x \\ 3 & 1 \\ \textit{to} & \textit{tle} \end{array} \right\rangle \left\langle \begin{array}{cc} & x \\ x \;, & x \\ 3 & 0 \\ \textit{were} & \end{array} \right\rangle \left\langle \begin{array}{cc} & x \\ x \;, & x \\ 3 & 1 \\ \textit{were} & \textit{tle} \end{array} \right\rangle$

Although such cases were rare in the corpus, they illustrate how the two approaches might differ.

As rare as these cases are when considering two levels of stress, as the number of stress levels distinguished increases, the new system improves in accuracy. Since the Hayes system only considers two levels of stress, it obviously does not improve in accuracy. At the four levels of stress represented in the corpus, the relative prominence system reaches 74.5% accuracy (271 right). An example of a case that the four-level stress system gets is below. Most cases were ties or ruled out by STRONG IS LONG before distinguishing the extra levels of stress. In this example, the crucial difference is the setting of the word "and," of stress level one:

(58) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	3	0	1	0	3	1	2	0	4	0	1	0	1	0
	Come		now		my		love	and	sit		down		by		me	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	3	0	1	0	3	0	1	0	2	0	4	1	1	0
	*Come		now		my		love		and		sit		down	by	me	

(59)

		*LAPSE	*NULL IN S	*S-LESS IN S	*S-ED IN W	*S-LESS IN W	STRONG IS LONG	*S-ED IN M	*NULL IN M
	a.	0	0	1	0	1	9	2	0
☞	b.	0	0	1	0	1	8	2	0

(60)

		*LAPSE	*UPBEAT MISMATCH	RELPROM	STRONG IS LONG
☞	a.	0	0	2	1
	b.	0	0	6	0

(61) a. $\left\langle \begin{array}{cc} & x \\ x & x \\ x \;, & x \\ 3 & 1 \\ \textit{Come} & \textit{me} \end{array} \right\rangle \left\langle \begin{array}{cc} & x \\ x & x \\ x \;, & x \\ 2 & 1 \\ \textit{sit} & \textit{me} \end{array} \right\rangle$

$$\text{b.}\ \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 2 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 1 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \end{array} \right\rangle$$

Come sit Come me down now down love

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 2 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 1 \end{array} \right\rangle$$

down sit down me

The system really improves, though, when distinctions are made among the syllables that Hayes and Kaun mark as stress level one. In fact, after splitting the original stressless syllables into three different levels, the accuracy reaches 89.3%. In the next section, I go through how this is done in detail.

4.3 Distinguishing Levels of Stress

The main factors that seem to distinguish which syllables are stronger and weaker are its position in a larger word, heaviness, and morpho-phonological status. The question of whether these differences directly affect the text-setting or simply affect the stress level, which in turn affects the text-setting is hard to test. For the purposes of this paper, I am assuming that these factors affect the stress level, and the only thing that the textsetting portion of the grammar considers is the stress itself.

One line that illustrates most of the levels of stress I discuss below is the following (with Hayes and Kaun's original stress levels indicated):

(62)

1	1	3	1	2	1	4	2	1	3	1	1	1	4
O	the	Che-	sa-	peake	so	bold	out	of	Bos-	ton	she	was	towed

It is important to note that as I made modifications to the stress-settings of the syllables in the corpus, in the majority of the cases, few sentences changed from being set correctly to being set incorrectly due to the modifications outlined below. Furthermore, even though some of the modifications only helped a few sentences in the corpus, the ones that they helped represent a larger set of similar sentences that would be set the same way had they appeared in the corpus.

4.3.1 Stressless Syllables in Poly-Syllabic Words

By far the most prevalent distinction in stressless syllables is whether they are a mono-syllabic word, or part of a poly-syllabic word. Stressless syllables inside poly-syllabic words seem to have lower linguistic prominence. The stressless syllables from mono-syllable and poly-syllablic words above are:

(63) Mono-: O, the, so, of, she, was

(64) Poly-: -sa-, -ton

An example where this makes a difference in the setting is the following line. Without the extra distinction in stress, these two candidates are tied:

(65) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	1	0	2	0	3	0	1	0	1	0	3	0	1	0	4	0
	He		goes		out		to		his		stab-		le		groom	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0	0	1	0	2	0	3	0	1	1	3	0	1	0	4	0
			*He		goes		out		to	his	stab-		le		groom	

(66)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
☞	a.	0	0	2	0
☞	b.	0	0	2	0

(67) a.
$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 2 \\ \textit{out} & & \textit{goes} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 1 \\ \textit{out} & & \textit{to} \end{array} \right\rangle$$

b.
$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 2 & & 1 \\ \textit{goes} & & \textit{He} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & \\ & & x \\ x & , & x \\ 1 & & 0 \\ \textit{his} & & \end{array} \right\rangle$$

However, the distinction between mono-syllabic unstressed words and unstressed syllables in poly-syllabic words distinguishes them. Therefore, as a first pass to divide the stressless syllables, I raised the stress level of every syllable except stressless syllables inside poly-syllabic words:

(68) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	2	0	3	0	4	0	2	0	2	0	4	0	1	0	5	0
	He		goes		out		to		his		stab-		le		groom	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0	0	2	0	3	0	4	0	2	2	4	0	1	0	5	0
			*He		goes		out		to	his	stab-		le		groom	

(69) ☞

	*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
☞ a.	0	0	2	0
b.	0	0	3	0

(70) a.

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 2 \end{array} \right\rangle$$

out *goes* *out* *to*

b.

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 2 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 0 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \end{array} \right\rangle$$

goes *He* *his* *his* *le*

This move improves the accuracy to 83% (302 right). Our example line now looks like:

(71)

2	2	4	1	3	2	5	3	2	4	1	2	2	5
O	the	Che-	sa-	peake	so	bold	out	of	Bos-	ton	she	was	towed

4.3.2 Word-Medial Stressless Syllables

Not all stressless syllables inside poly-syllabic words are the same, however. The stressless syllables entirely internal to words with more than two syllables are even weaker than others. For instance, "-sa-" above is weaker than "-ton." This makes a difference in examples like the following:

(72) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	1	5	1	1	0	5	0	3	0	3	0	3	0	6	0
	The	re-	mark-	ab-	le		day		that		I		was		wed	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	1	5	0	1	1	5	0	3	0	3	0	3	0	6	0
	*The	re-	mark-		ab-	le	day		that		I		was		wed	

(73)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
	a.	0	0	0	1
☞	b.	0	0	0	0

Here Strong Is Long rules out the preferred setting because there is no distinction between the highly unstressed "-ab-" and the unstressed "-le." To account for these cases, I raised the Hayes and Kaun stress levels by two, lowered word-medial stressless syllables by two, and lowered other stressless syllables that are part of a poly-syllabic word by one. Changing this yields the correct outcome:

(74) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	2	5	1	2	0	5	0	3	0	3	0	3	0	6	0
	The	re-	mark-	ab-	le		day		that		I		was		wed	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	2	5	0	1	2	5	0	3	0	3	0	3	0	6	0
	*The	re-	mark-		ab-	le	day		that		I		was		wed	

(75)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
☞	a.	0	0	0	1
	b.	0	0	2	0

(76) a. (no violations)

b. $\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \\ re- & & ab- \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 2 & & 1 \\ le & & ab- \end{array} \right\rangle$

With these changes, the accuracy improves to 308 (84.6%) and the example line is now:

(77)

3	3	5	1	4	3	6	4	3	5	2	3	3	6
O	the	Che-	sa-	peake	so	bold	out	of	Bos-	ton	she	was	towed

4.3.3 Super-Heavy Syllables

In addition, certain stressless syllables inside poly-syllabic words are not treated as less stressed. These are the ones that are super-heavy, containing more than one consonant in their coda, for instance:

(78) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	3	4	2	5	3	5	0	3	0	5	0	2	0	6	0
	For	I	would-	n't	give	a	kiss		from		gip-		sum's		lips	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	3	0	4	2	5	0	3	0	5	3	5	2	6	0
	*For		I		would-	n't	give		a		kiss	from	gip-	sum's	lips	

(79)

	*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
a.	0	0	3	1
☞ b.	0	0	2	1

(80) a. $\left\langle \begin{array}{ccc} & & \\ & & x \\ x & , & x \\ 3 & & 2 \\ I & & sum's \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 4 \\ give & & would- \end{array} \right\rangle \left\langle \begin{array}{ccc} & & \\ & & x \\ x & , & x \\ 3 & & 2 \\ a & & sum's \end{array} \right\rangle$

b. $\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \\ would- & & I \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 3 \\ gip- & & I \end{array} \right\rangle$

When I changed the program to leave the super-heavy syllables at the same level as mono-syllabic stressless words, the accuracy increased to 312 (85.7%). There are no super-heavy syllables in our example line, so it does not change with this modification, but (78) comes out as follows:

(81) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	3	4	2	5	3	5	0	3	0	5	0	3	0	6	0
	For	I	would-	n't	give	a	kiss		from		gip-		sum's		lips	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	3	0	4	2	5	0	3	0	5	3	5	3	6	0
	*For		I		would-	n't	give		a		kiss	from	gip-	sum's	lips	

(82)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
☞	a.	0	0	1	1
	b.	0	0	2	1

(83) a. $\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 4 \end{array} \right\rangle$
give *would−*

b. $\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 4 & & 3 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 3 \end{array} \right\rangle$
would− *I* *gip−* *I*

4.3.4 Articles and Affixes

Last, there are certain prefixes and clitics that fall between the poly-syllabic stressless syllables and the mono-syllabic ones:

(84) Clitics: “a”, “the”, “an”, “my”, “our”

(85) Prefixes: “re-”, “a-”, “un-”

For example:

(86) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	3	5	0	2	0	6	0	3	0	5	0	2	0	6	0
	With	our	sails		un-		furled,		our		an-		chor		weighed	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	3	0	3	0	5	2	6	0	3	0	5	0	2	0	6	0
	*With		our		sails	un-	furled,		our		an-		chor		weighed	

(87)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
	a.	0	0	2	0
☞	b.	0	0	1	0

(88) a. $\left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 3 & & 2 \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & , & x \\ 3 & & 2 \end{array} \right\rangle$
our un− *our chor*

b. $\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 3 \end{array} \right\rangle$
sails our

So, I added another level of stress, raising the original Hayes and Kaun levels by three, lowering the word-medial syllables by three, the other syllables from polysyllabic words by two, and articles and affixes by one. This solves the case above:

(89) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	4	3	6	0	3	0	7	0	3	0	6	0	2	0	7	0
	With	our	sails		un-		furled,		our		an-		chor		weighed	

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	4	0	3	0	6	3	7	0	3	0	6	0	2	0	7	0
	*With		our		sails	un-	furled,		our		an-		chor		weighed	

(90)

		*LAPSE	*UPBEAT MISMATCH	RELPROM	STRONG IS LONG
☞	a.	0	0	1	0
	b.	0	0	3	0

(91) a. $$\left\langle \begin{array}{c} \\ x \\ 3 \\ \textit{our} \end{array} , \begin{array}{c} x \\ x \\ 2 \\ \textit{chor} \end{array} \right\rangle$$

b. $$\left\langle \begin{array}{c} x \\ x \\ 4 \\ \textit{With} \end{array} , \begin{array}{c} x \\ x \\ x \\ 3 \\ \textit{our} \end{array} \right\rangle \left\langle \begin{array}{c} x \\ x \\ 6 \\ \textit{sails} \end{array} , \begin{array}{c} x \\ x \\ x \\ 3 \\ \textit{our} \end{array} \right\rangle \left\langle \begin{array}{c} x \\ 3 \\ \textit{un-} \end{array} , \begin{array}{c} x \\ x \\ 2 \\ \textit{chor} \end{array} \right\rangle$$

The example line now looks like:

(92)

4	3	6	1	5	4	7	5	4	6	2	4	4	7
O	the	Che-	sa-	peake	so	bold	out	of	Bos-	ton	she	was	towed

Finally, with all of these improvements, the accuracy of the system reaches 89.3%.

5 Extension

5.1 Cole Porter

Cole Porter songs are different from English folk verse in that they allow lapses (as defined above) in order to satisfy relative prominence rules. For instance, consider the following line from the song "Easy to Love" (Porter 1981). The attested setting includes a lapse, but is predicted to be incorrect by the ranking used for English folk verse (ignore the lapse at the end of the line which is required by higher-level constraints):

(93) a.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0	0	7	0	0	0	6	0	3	0	6	2	5	0	0	0
			So				worth		the		yearn-	ing	for			

b.

L(0)			x				x				x				x	
L(-1)	x		x		x		x		x		x		x		x	
L(-2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0	0	7	0	6	0	3	0	6	0	2	0	5	0	0	0
			*So		worth		the		yearn-		ing		for			

(94)

		*Lapse	*Upbeat Mismatch	RelProm	Strong Is Long
	a.	1	0	5	1
☞	b.	0	0	9	0

(95) a.

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 3 & & 0 \\ \textit{the} & & \end{array} \right\rangle \left\langle \begin{array}{ccc} & & \\ & & x \\ x & , & x \\ 2 & & 0 \\ \textit{ing} & & \end{array} \right\rangle \left\langle \begin{array}{ccc} & & \\ & & x \\ x & , & x \\ 2 & & 0 \\ \textit{ing} & & \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ & & x \\ x & , & x \\ 2 & & 0 \\ \textit{ing} & & \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 0 \\ \textit{for} & & \end{array} \right\rangle$$

b.

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 6 & & 3 \\ \textit{worth} & & \textit{the} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 6 & & 2 \\ \textit{worth} & & \textit{ing} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 6 & & 0 \\ \textit{worth} & & \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 6 & & 3 \\ \textit{yearn}- & & \textit{the} \end{array} \right\rangle$$

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 6 & & 2 \\ \textit{yearn}- & & \textit{ing} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 6 & & 0 \\ \textit{yearn}- & & \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 3 \\ \textit{for} & & \textit{the} \end{array} \right\rangle \left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 2 \\ \textit{for} & & \textit{ing} \end{array} \right\rangle$$

$$\left\langle \begin{array}{ccc} & & x \\ x & & x \\ x & , & x \\ 5 & & 0 \\ \textit{for} & & \end{array} \right\rangle$$

Reranking the *Lapse constraint below RelProm produces the correct answer for this case:

(96)

		RelProm	Lapse
☞	a.	5	1
	b.	9	0

One possible musical reason why such lapses might be allowed in Cole Porter songs, but not in folk verse, is that the Cole Porter songs were written for musical theatre performances, including a full orchestra, whereas the folk verse were probably often performed a cappella. The orchestra does, in fact, fill in the lapses to keep the song going during a held note as an unaccompanied singer cannot do. Another way of looking at this is that the apparently empty positions in the metrical grid are actually filled by "syllables" from the orchestra; and in fact, it would not be an acceptable song if these lapses were not filled in with notes in the accompaniment.

Further analysis of systems such as that employed by Cole Porter might be able to add more evidence for RelProm in the following way. Even if a meta-ranking for the individual constraints in a Hayes-type system for stress-matching could be found, such a system would predict that *Lapse might be ranked between any two stress-matching constraints in the meta-ranking. If, on the other hand, only systems where *Lapse is ranked on one side or the other of the stress-matching constraints are found, it would provide evidence that perhaps only one constraint is actually in play.

6 Conclusion

This paper has explored two Optimality Theoretic systems for textsetting, based on two different basic intuitions about stress-matching. The Hayes system implements stress-matching directly, with a constraint regulating each possible setting of stressed, stressless, and null syllables to strong, medium, and weak positions. The relative prominence system captures stress-matching with a single constraint requiring linguistic prominence relationships to be maintaining in settings to a metrical grid. The relative prominence system has empirical advantages once the full range of stress levels is considered and also presents conceptual advantages, such as simplicity and predicting the typology of textsetting systems. Examining how relative prominence works in different genres (such as Cole Porter) will help determine how the RelProm constraint interacts with the other constraints above, and possibly new constraints, as well.

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