Metrical Tension and Prose Cadence

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1 Overview

Across poetic traditions, lines of metrical verse exhibit METRICAL CLOSURE: beginnings are lax, endings are strict (Smith 1968; Hayes 1983; Fabb 1997; Ryan 2017; Kiparsky 2020). We provide evidence that metrical closure is not just a property of metered verse but a general property of language. The gradient metrical patterns we document here parallel the gradient phonological patterns (e.g., hiatus avoidance) that have recently been observed in sentence formation (Breiss and Hayes 2020).

2 Scansion in verse and prose

SCANSION is a correspondence relation between a metrical template and a line of text (Halle and Keyser 1971; Kiparsky 1977; Prince 1989; Hayes et al. 2012; Blumenfeld 2015, a.o.). Consider the following line of iambic pentameter (*s* = strong position, *w* = weak position):

(1) A well-behaved scansion (Shakespeare, Sonnet 2, 1):

w	s	w	s	w	s	w	s	w	s	(template)
|	|	|	|	|	|	|	|	|	|	
When	fór-	ty	wín-	ters	shâll	be-	síege	thy	brów	(syllables)

In this scansion, every stressed syllable (*fór*, *wín*, *shâll*, *síege*, *brów*) corresponds to a strong metrical position and every unstressed syllable (*when*, *ty*, *ters*, *be*, *thy*) corresponds to a weak metrical position. This scansion perfectly satisfies the following two METRICAL CONSTRAINTS:

(2) (a) *W/STRESSED No stressed syllable in a weak position
(b) *S/UNSTRESSED No unstressed syllable in a strong position

Not all lines of metered verse are this well behaved. Violations of metrical constraints are not uncommon. Consider the following example:

(3) A less well-behaved scansion (Shakespeare, Sonnet 1, 7):

w	s	w	s	w	s	w	s	w	s
|	|	|	|	|	|	|	|	|	|
Má-	king	a	fá	mine	whére	a-	bún	dance	liés

The line in (3) illustrates "trochaic substitution" or "inversion" in the first foot of an iambic line. The word *Máking* violates both *W/STRESSED by having a stressed syllable in a weak position and

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*S/UNSTRESSED by having an unstressed syllable in a strong position. This type of metrical violation occurs in upwards of 10 percent of all iambic lines in English (Steele, 1999:61). Line-initial inversion is so common that it can be viewed as a conventionalized special case of metrical closure.

We set out to investigate whether prose also exhibits metrical closure, i.e., whether the ends of prose sentences are more likely to be metrically regular (have fewer metrical violations) while the beginnings are more lax (have more metrical violations). However, traditional methods of studying meter are insufficient to evaluate metrical violations in prose. Consider the following line:

(4) Soap is ordinarily thought of as the common cleansing agent well known to everyone.
(E. G. Thomssen, *Soap-Making Manual*)

Identifying metrical violations in this line would seem to presuppose a conventional metrical template paired with the text, but there is none because prose is unmetered. In order to evaluate the metricality of prose, we need new tools.

3 The Prosodic method

The automatic scansion tool we employ in our analysis is the open-source library Prosodic (Heuser et al. 2010). Prosodic is a powerful resource for metrics research because it makes manual annotation unnecessary: one can automatically annotate large amounts of text for metrical violations at no cost. Crucially, Prosodic can annotate both verse and prose using the same metrical constraints without presupposing a single correct scansion, making verse and prose commensurable. For an early application, see Anttila and Heuser 2016.

Prosodic borrows from Optimality Theory (Prince and Smolensky, 1993/2004) the idea of a CANDIDATE SCANSION evaluated against metrical constraints. For the purposes of this study, we selected five constraints from Hanson and Kiparsky 1996 and Kiparsky 2020, making no assumptions about their mutual ranking or weighting.

(5)
1. *S/UNSTRESSED (“THE HOPKINS CONSTRAINT”)
   A strong position must not contain an unstressed syllable.
2. *W/STRESSED
   A weak position must not contain a stressed syllable.
3. *W/PEAK (“THE SHAKESPEARE CONSTRAINT”)
   A weak position must not contain a stressed syllable of a polysyllabic word (e.g., *póison*).
4. W-RESOLUTION
   For disyllabic positions within a word, the first position must be light and stressed (e.g., *mány/*althóugh*).
5. F-RESOLUTION
   A disyllabic position across a word boundary must be weak with two function words (e.g., *as the/*líght’s fláme*).

Prosodic starts by analyzing the input phonologically, assigning word stress and syllable structure to raw text. Since each syllable can be either strong (*s*) or weak (*w*), the number of logically possible candidate scansions is 2^n where n = the number of syllables in the line. This number can be large: a 10-syllable line has 1,024 candidate scansions. Prosodic focuses on those candidate scansions that are not HARMONICALLY BOUNDED by any other candidate scansion and that have at most two syllables per metrical position. These are the VIABLE SCANSIONS. For a textbook explanation of harmonic bounding, see McCarthy 2008:80–83.

The notion of viable scansion is well-defined for any text, verse or prose, and there may be more than one viable scansion per line. By summing up metrical constraint violations across the viable scansions, we arrive at a measure of the line’s metricality. For example, consider the three candidate scansions below:

(6) Iambic pentameter:

w	s	w	s	w	s	w	s	w	s
|	|	|	|	|	|	|	|	|	|
When	fór-	ty	wín-	ters	shåll	be-	síege	thy	brów

(7) Trochaic pentameter:

s	w	s	w	s	w	s	w	s	w
When	fór-	ty	wín-	ters	shāll	be-	síege	thy	brów

(8) Trochaic tetrameter with resolution (= two syllables in a single metrical position):

s	w		s		w		s	w	s
When	fór-	ty	wín-	ters	shāll	be-	síege	thy	brów

Considering only our five constraints we get the distribution of violations in Table 1. There is only one viable scansion: the one shown in (6) repeated as candidate (a) in Table 1. That is also the correct scansion (iambic pentameter). Table 1 uses the following notation: *s* = strong position; *w* = weak position; *s s* = split strong position; *w w* split weak position; _ = within word; ´ = stress; ☞= viable scansion.

	*W/PEAK	*S/UNSTR	*W/STRE	W-RESOL	F-RESOL
☞ a. w ś_w ś_w ś w_ś w ś					
b. s ẃ_s ẃ_s ẃ s_ẃ s ẃ	3	5	5		
c. s ẃ_w ś_s ẃ w_ś w ś	1	2	2	2	1

Table 1: Constraint violations for three candidate scansions of *When forty winters shall besiege thy brow*

Candidate scansion (a) harmonically bounds (b) and (c). This means that Prosodic would only output candidate (a). Lines with just one viable scansion are common in metrical verse, but many text inputs, particularly prose, can output a large number of viable scansions for a single line, making Prosodic an indispensable tool for finding viable scansions and evaluating their metricality.

4 Measures of metrical well-formedness

To assess metrical well-formedness we use two primary indicators: METRICAL UNCERTAINTY (de la Fuente et al. 2023) and METRICAL TENSION SUM (Anttila et al. 2022). Metrical Uncertainty is the total number of viable scansions generated by Prosodic divided by the number of syllables in the line. Metrical Tension Sum is the count of all violations across all viable scansions, divided by the number of syllables in the line. To demonstrate that these measures effectively indicate metrical well-formedness, below is an example of how the line *Making a famine where abundance lies* scores on our two metrics when we separately analyze the beginning and end of the line in Prosodic.

Sample line fragment	Metrical Uncertainty	Metrical Tension Sum
Making a famine where abundance	4	10
famine where abundance lies	1	0

Both Metrical Uncertainty and Metrical Tension Sum decrease in the second half of the line, showing that the line exhibits metrical closure. In what follows, we will use Prosodic to study metrical closure in both verse and prose. For simplicity, we will use the expression "metrical tension" for "Metrical Tension Sum" whenever there is no danger of confusion.

5 Data

We collected 28,403 lines from 51 texts sourced from *Project Gutenberg* (Project Gutenberg, n.d.) and *The American Presidency Project* (Woolley and Peters, 1999–). The text was grouped into four genres: political speeches, theatrical scripts, procedural texts, and verse. The text was lineated at full stops, excluding verse for which the original lineation was respected. All lines with less than 8 syllables or non-English characters were excluded. Syllable information was extracted using the *Syllables* library developed by Day (2023). The specific texts we studied are listed in the Appendices.

The text was then divided into two parallel datasets. One dataset contained the first ten syllables of each line; the other dataset contained the last ten syllables of each line. The text was divided in this way to allow for the exploration of metrical closure in prose based on our measures of metrical well-formedness. Each dataset was then run through Prosodic, from which we calculated Metrical Uncertainty (MU) and Metrical Tension Sum (MTS) for each line, text, and author. Below is a small sample of Prosodic's output for a selection of line fragments.

	LINE FRAGMENT	MU	MTS	SOURCE
(a)	infusorial earth of various kinds, silex, etc.	65	502	Soap Making Manual
(b)	And this may go on indefinitely.	6	26	Criminal Psychology
(c)	The capillary rise or spread of water	1	0	Rocks and Their Origins

Table 2: Example of Prosodic's output for a random selection of lines.

These examples also illustrate the fact that syllabification is not always obvious. In line fragment (a), the abbreviation *etc.* was parsed into four syllables. Genuinely ambiguous syllabifications like *wires* (1 or 2 syllables) and *generally* (3 or 4 syllables) receive separate scansions in Prosodic.

6 Studying the metricality of entire texts

Metrical Tension Sum is a property of an individual line. We generalized it to entire texts by taking the mean and standard deviation of Metrical Tension Sum across all lines of a text. Intuitively, the mean quantifies the text's overall metricality whereas the standard deviation quantifies its metrical heterogeneity. One would expect both measures to be very low in metrical verse where lines match a fixed metrical template (low mean) and where all lines are more or less equally metrical (low standard deviation). One might further expect both measures to be reasonably low in theatrical scripts and speeches, which are texts intended to be spoken and heard and thus perhaps scripted with special attention to phonology in mind, but relatively high in procedural texts primarily intended for silent reading.

Figure 1 shows a sampling of our 51 sources with the mean metrical tension shown on the x-axis and the standard deviation of metrical tension shown on the y-axis.

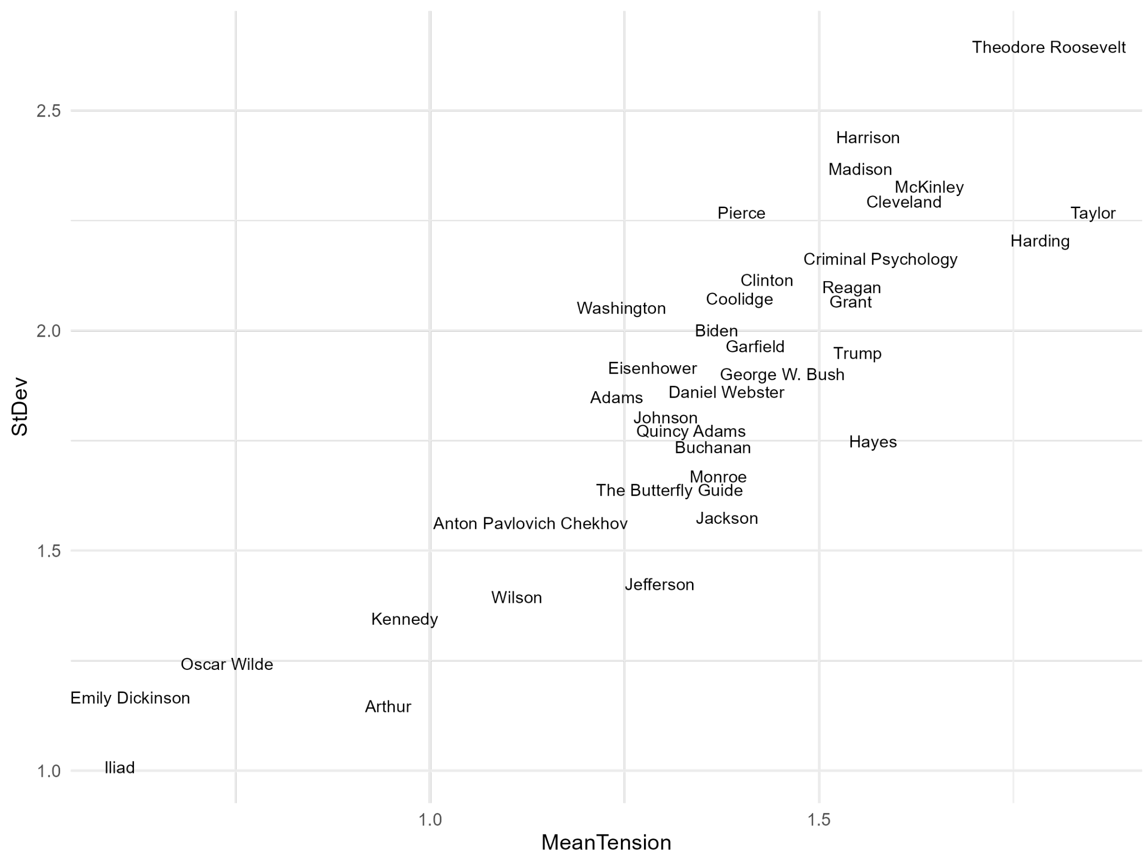

Figure 1: The mean and standard deviation of metrical tension

We know from earlier work that in metered verse beginnings of lines are lax and endings are strict. Our hypothesis is that the same holds true for language in general. Perhaps the simplest way to test this hypothesis would be to use linear regression to predict metrical tension from line-initiality. The structure of the model would be `lm(tension ~ initial)`. The response variable `tension` is numeric and ranges from 0 to 35.79 in our data; the predictor variable `initial` is either true or false. If line-initial strings indeed have higher tension than line-final strings, then the predictor `initial` should have a positive coefficient.

However, this model turns out too simple. It ignores an important variable that also matters to metrical tension: WORD LENGTH. Long words tend to increase metrical tension for the simple reason that some constraints can only be violated in polysyllabic words. We have two such constraints in our constraint set: *W/PEAK and W-RESOLUTION. Moreover, it is known that prose favors longer words than verse (see, e.g., Anttila and Heuser 2016), perhaps because verse and prose often deal with different topics, something that can be reflected in word length. Finally, genres differ in how constituent length is distributed in the line/sentence (Saintsbury 1912/1965; Croll 1919; Blumenfeld 2016). In utility prose, the tendency is "long last" (also known as "end weight"), whereas in verse and art prose the opposite tendency "short last" has been observed. These are some of the reasons that motivate including mean word length as a control in the model.

For these reasons, we revise the simple model by including mean word length as an additional predictor: `lm(tension ~ initial + mean_word_length)`. In our data, `mean_word_length` ranges from 1 to 5. Before fitting the model it is good to visually inspect the data. In Figure 2, the two tall bars on the left (LONG) are lines with "long words", i.e., lines where the mean word length is above the median, whereas the two short bars on the right (SHORT) are lines with "short words", i.e., all other lines. Two observations emerge immediately. First, metrical tension is higher in lines with long words. Second, in both groups, metrical tension is higher in initial strings than in final strings.

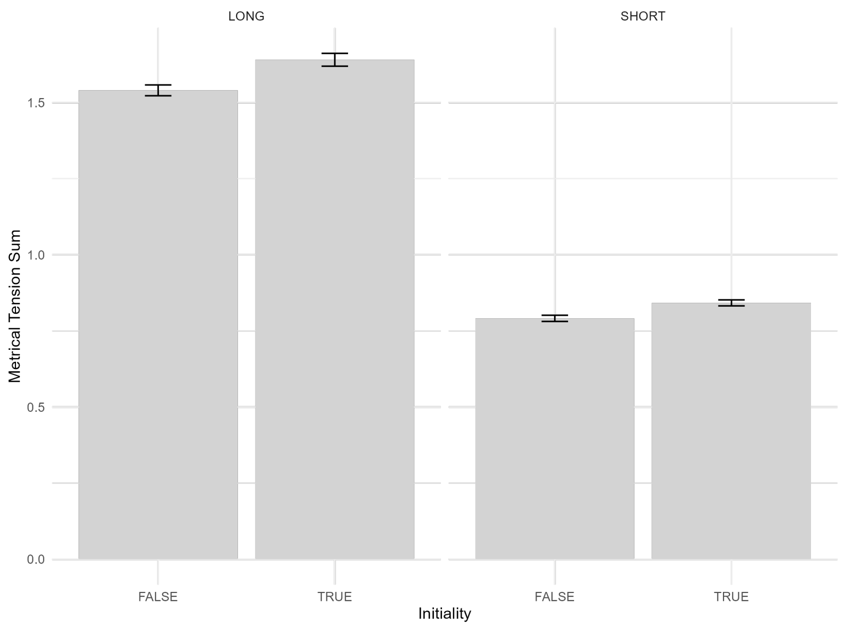

Figure 2: Metrical tension by mean word length and line-initiality

The regression model shows that our hypothesis is supported: metrical tension is higher in line-initial strings and increases with mean word length, just as expected. Put differently, metrical tension is positively associated with both line-initiality ($b = 0.11$, $SE = 0.01$, $p < 0.001$) and mean word length ($b = 0.98$, $SE = 0.02, p < 0.001$). It is interesting to note that the line-initiality effect only emerges as significant if we control for mean word length. That may be the reason why it has not been observed before.

Finally, we wanted to check whether our results hold up under various controls. Adding a fixed effect of `genre` (4 levels, Helmert-coded) did not make a difference: the initiality and word length effects persisted ($p < 0.001$). A mixed model with `source` (51 groups from *Project Gutenberg* and *The American Presidency Project*) as a random intercept was similar: both effects persisted ($p < 0.001$). Poisson regression and negative binomial regression (Winter 2020:218-231) showed similar results. A likelihood ratio test of a negative binomial model against a Poisson model revealed a significant difference ($\chi^2(1) = 23884.90, p < 0.0001$), suggesting that the negative binomial model achieves a better fit. We emphasize that these models are preliminary and we have made the data available at `https://web.stanford.edu/∼anttila/research/amp-2024/` for further exploration.

7 Conclusion

We have demonstrated a way to study metricality in prose and verse from a unified perspective. A key step involves establishing viable scansions that are well-defined for any text and make prose and verse commensurable. More specifically, we have provided evidence that metrical closure is robustly present in English and seems to be a general property of the language.

An interesting question still remains: why should metrical closure exist at all? What is its linguistic source? While we do not know the answer, the following speculation suggests itself. English sentences are prosodically asymmetric: phrasal stress typically piles up towards the end of the sentence because stress is cyclic (Chomsky and Halle 1968). For a recent study that confirms this prediction based on data from the inaugurals of several U.S. presidents, see Anttila et al. 2020. This opens up a possible explanation for metrical closure. While our metrical constraints only refer to word stress, they are no doubt also sensitive to phrasal stress (see, e.g., Blumenfeld 2015), and it is possible that they apply more strictly under increased phrasal stress. This in turn would result in the appearance of metrical closure. A similar generalization stated in terms of prosodic domains can be found in Hayes 1983. If this speculation is on the right track, then metrical closure would be a reflex of English phrasal stress and ultimately a consequence of the right-branching syntax of English.

8 Appendices

Author	**Lines**	**Author**	**Lines**
Joe Biden	139	Donald Trump	80
Barack Obama	210	George W. George Bush	198
Bill Clinton	197	George Bush	140
Ronald Reagan	255	Jimmy Carter	59
Richard Nixon	180	Lyndon B. Johnson	82
John F. Kennedy	49	Dwight D. Eisenhower	206
Harry S. Truman	115	Franklin D. Roosevelt	290
Calvin Coolidge	193	Warren G. Harding	157
Woodrow Wilson	64	William Howard Taft	165
Theodore Roosevelt	37	William McKinley	231
Grover Cleveland	60	Chester A. Arthur	16
James A. Garfield	117	Rutherford B. Hayes	67
Ulysses S. Grant	92	Abraham Lincoln	170
James Buchanan	88	Franklin Pierce	110
Zachary Taylor	28	James K. Polk	161
William Henry Harrison	220	Martin Van Buren	133
Andrew Jackson	65	John Quincy Adams	112
James Monroe	276	James Madison	37
Thomas Jefferson	131	John Adams	55
George Washington	36		

Table 3: Data from inaugural addresses in The American Presidency Project

Author	**Source**	**Genre**	**Lines**
Daniel Webster	Select Speeches of Daniel Webster	Political Speech	4232
Edgar George Thomssen	Soap Making Manual	Procedural Text	669
W. J. Holland	The Butterfly Guide	Procedural Text	193
Napoleon I	Napoleon's Maxims of War	Procedural Text	1015
Hans Gross	Criminal Psychology	Procedural Text	3570
Grenville A. J. Cole	Rocks and Their Origins	Procedural Text	1183
Homer	Iliad	Verse	5199
William Shakespeare	The Complete Works of William Shakespeare	Verse	2051
Emily Dickinson	Poems by Emily Dickinson, Three Series	Verse	1135
Oscar Wilde	Poems, with The Ballad of Reading Gaol	Verse	1207
Henrik Ibsen	A Doll's House	Theatrical Script	1629
Anton Pavlovich Chekhov	Ivanoff	Theatrical Script	1299

Table 4: Data from Project Gutenberg

References

Anttila, Arto, Timothy Dozat, Daniel Galbraith, and Naomi Shapiro. 2020. Sentence stress in presidential speeches. In *Prosody in Syntactic Encoding*, ed. Gerrit Kentner and Joost Kremers, 17–50. Berlin/Boston: Walter De Gruyter. Pre-print available on lingbuzz/004303.

Anttila, Arto, and Ryan Heuser. 2016. Phonological and metrical variation across genres. *Proceedings of 2015 Annual Meeting on Phonology* .

Anttila, Arto, Ryan Heuser, and Paul Kiparsky. 2022. Prose rhythm and antimetricality. LSA Symposium on Literary Linguistic Forms, January 8, 2022. Slides available at `https://web.stanford.edu/~anttila/`.

Blumenfeld, Lev. 2015. Meter as faithfulness. *Natural Language & Linguistic Theory* 33:79–125.

Blumenfeld, Lev. 2016. End-weight effects in verse and language. *Studia Metrica et Poetica* 3:7–32.

Breiss, Canaan, and Bruce Hayes. 2020. Phonological markedness effects in sentence formation. *Language* 96:338–370.

Chomsky, Noam, and Morris Halle. 1968. *The Sound Pattern of English*. Cambridge, Mass.: MIT Press.

Croll, Morris W. 1919. The cadence of English oratorical prose. *Studies in Philology* 16:1–55.

Day, David. 2023. Syllables: A fast syllable estimator for Python. Available at `https://github.com/prosegrinder/python-syllables/`.

Fabb, Nigel. 1997. *Linguistics and Literature*. Oxford, UK, and Malden, MA: Blackwell Publishers.

de la Fuente, Antón, Brennan Nick, and Arto Anttila. 2023. Metrical uncertainty. Poster presented at *MorrisHalle@100*, September 10, 2023, MIT, Cambridge, MA. Slides available at `https://web.stanford.edu/~anttila/`.

Halle, Morris, and Samuel Jay Keyser. 1971. *English Stress: Its Form, Its Growth, and Its Role in Verse*. New York–Evanston–London: Harper & Row, Publishers.

Hanson, Kristin, and Paul Kiparsky. 1996. A parametric theory of poetic meter. *Language* 72:287–335.

Hayes, Bruce. 1983. A grid-based theory of English meter. *Linguistic Inquiry* 14:357–393.

Hayes, Bruce, Colin Wilson, and Anne Shisko. 2012. Maxent grammars for the metrics of Shakespeare and Milton. *Language* 691–731.

Heuser, Ryan, Joshua Falk, and Arto Anttila. 2010. Prosodic. Software, Stanford University, available at `https://github.com/quadrismegistus/prosodic` and `http://prosodic.stanford.edu/`.

Kiparsky, Paul. 1977. The rhythmic structure of English verse. *Linguistic Inquiry* 8:189–247.

Kiparsky, Paul. 2020. Metered verse. *Annual Review of Linguistics* 6:25–44.

McCarthy, John J. 2008. *Doing Optimality Theory: Applying theory to data*. Malden, MA: Blackwell Publishing.

Prince, Alan. 1989. Metrical forms. In *Rhythm and meter*, Phonetics and phonology, Vol. 1, 45–80. Academic Press, Inc.

Prince, Alan, and Paul Smolensky. 1993/2004. *Optimality Theory: Constraint Interaction in Generative Grammar*. Malden, Massachusetts: Blackwell Publishing.

Project Gutenberg. n.d. Project Gutenberg. `https://gutenberg.org/`.

R Core Team. 2024. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL `https://www.R-project.org/`.

Ryan, Kevin M. 2017. The stress–weight interface in metre. *Phonology* 34:581–613.

Saintsbury, George. 1912/1965. *A History of English Prose Rhythm*. Bloomington: Indiana University Press. First edition 1912.

Smith, Barbara Herrnstein. 1968. *Poetic Closure*. Chicago and London: The University of Chicago Press.

Steele, Timothy. 1999. *All the Fun's in How You Say a Thing: An Explanation of Meter and Versification*. Athens: Ohio University Press.

Wickham, Hadley. 2016. *ggplot2: Elegant graphics for data analysis*. Springer-Verlag New York. URL `https://ggplot2.tidyverse.org`.

Winter, Bodo. 2020. *Statistics for linguists: An introduction using R*. Routledge.

Woolley, John T., and Gerhard Peters. 1999–. The American Presidency Project. Santa Barbara, California: UC Santa Barbara.