A Source-Filter Model for Generative Metrics[1]

Daniel Currie Hall

University of Toronto

1. Verse in Linguistics: Questions and Previous Approaches

This paper has two goals: first, to account for some metrical patterns attested in Russian iambic tetrameter; and second, to show how a grammar of categorically ranked constraints can make predictions about non-categorical phenomena. The general framework adopted here is that of generative metrics; this paper proposes a new constraint-based approach that builds most directly on the work of Friedberg (1997, 2000).

One obvious question for generative metrics is, what is the relation between linguistics and poetry? A general answer is provided by Jakobson ([1960] 1981: 18):

> Poetics deals with problems of verbal structure, just as the analysis of painting is concerned with pictorial structure. Since linguistics is the global science of verbal structure, poetics may be regarded as an integral part of linguistics.

This paper in particular takes a poetic question as a point of departure for exploring how the interaction between two components of a grammar can give rise to patterns of variation not inherent in either component independently. The model proposed here, in which one component provides a source of variability that is filtered through the other, can in principle be extended to other problems of linguistic variation.

Metrical verse is defined by its use of regular alternations between strong (long or stressed) positions and weak (short or unstressed) ones. Verse forms can generally be characterized by templates such as the one in (1).

(1) Template for a line of iambic tetrameter: `WS WS WS WS`

Sometimes the template is followed exactly. In (2), for example, each strong position is filled by a stressed syllable, and each weak position by an unstressed one.

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(2) Ĭámbĭcs márch frŏm shórt tŏ lóng— (S.T. Coleridge, “Metrical Feet,” l. 5)

Frequently, though, the correspondence is inexact, and there are mismatches between what Žirmunskij (1966: 23) defines as **meter**—“the ideal law governing the alternation of strong and weak sounds in the verse”—and **rhythm**, “the actual alternations of strong and weak sounds, resulting from the interaction between the natural characteristics of the linguistic material and the metrical law.” An example of such a mismatch may be seen in the second line of (3), in which the word *folded* represents a temporary rhythmical reversal of the iambic pattern.

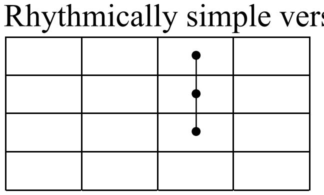
(3) Bŭt thóu wĭlt névĕr móre ăppéar
<u>Fóldĕd</u> wĭthín mỹ hémĭsphéar, (Henry King, “The Exequy,” ll. 31-2)

The task of the metricist, then, is not merely to identify the template, but also to explain why some deviations (such as (3)) are allowed, while others (such as (4)) are not.

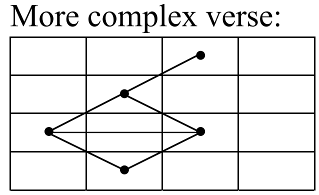
(4) *Bŭt thóu wĭlt névĕr <u>ăppéar</u> móre[2] (construct)

In English iambic verse, reversals like the one in (3) are common. In Russian, however, the most prevalent form of deviation is stress omission, i.e., the association of an unstressed syllable with a metrically strong position. The importance of stress omission in Russian verse was established by the work of Andrey Bely. Bely (1910) proposed a graphical method of gauging the complexity of verse, in which each metrically strong position is represented as a table cell, and stress omissions are marked with dots. Rhythmical complexity is revealed by connecting the dots, as in (5).

(5) a. Rhythmically simple verse:



b. More complex verse:



Bely’s approach has left its mark not only on the theory of Russian verse, but also on its practice. Vladimir Nabokov has the aspiring poet in his novel *The Gift* say:

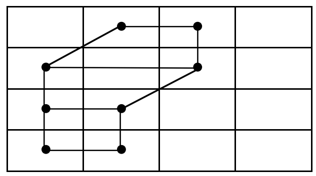
> A little later Andrey Bely’s monumental work on “half stresses” […] hypnotized me with its system of graphically marking off and calculating these scuds, so that I immediately reread all my old tetrameters from this new point of view and was terribly pained by the paucity of modulations. When plotted, their diagrams proved to be plain and gappy, showing none of those rectangles and trapeziums that Bely had found for the tetrameters of great poets; whereupon for the space of almost a whole year—an evil and sinful year—I tried to write with the aim of producing the most complicated and rich scud-scheme possible.
> Nabokov (1963: 163)

The fictitious poet produces the stanza in (6a). (6b) shows the verse in transliteration, (6c) its ‘scud-scheme,’ and (6d) an English translation (in which most of the stress omissions show up as secondary stresses).

[2] Lines like (4) are unmetrical for many poets, though licit for some. See Kiparsky (1977: 201-2).

(6) a. Задумчиво и безнадежно
распространяет аромат
и неосуществимо нежно
уж полуувядает сад, —
Nabokov (1952: 170)

b. Zadúmčivo i beznadéžno
rasprostranjáet aromát
i neosuščestvímo néžno
už poluuvjadáet sád, —

c. 

d. In míserable meditátions,
And aromátically dárk,
Full of interconvérted pátience,
Sighs the semidenúded párk.
Nabokov (1963: 163)

Bely's work revealed a number of generalizations about the rhythm of Russian tetrameter. In the verse tradition under consideration here, stress omission is not permitted (a) on the final foot of a line, (b) on three consecutive feet, or (c) on the first two feet of the line (although this last configuration is used by Nabokov's fictitious poet).

Taranovsky ([1971] 1980) describes the attested patterns of stress omission in terms of **regressive accentual dissimilation.** The final strong position of the line is the 'strongest' (in Taranovsky's terminology)—that is, the one most likely to be filled by a stressed syllable. Strong positions alternate in relative likelihood of being stressed: the penultimate strong position is stressed less often than the final one; the antepenultimate syllable is stressed more often than the penultimate one; and so on. The effect of accentual dissimilation diminishes towards the beginning of the line: in tetrameter, the difference between the last two strong positions is much greater than the difference between the first two.

The result is that the line, viewed as a statistical aggregate, has an iambic structure at three levels of organization. This is illustrated in (7). (7a) shows Taranovsky's figures for the frequency of stressed syllables in each strong position; (7b) shows how the recursively iambic structure might be represented in a bracketed grid of the sort used by Halle and Vergnaud (1987). (Note, however, that the grid structure incorrectly suggests that the 'weakest' strong position should be the first one, not the third. In fact, the second hemistich is 'stronger' than the first in the sense of being more emphatically iambic, not in the sense of having uniformly more frequently stressed strong positions.)

(7) a. Average likelihood of stressed σ:

(wS)	(wS)	(wS)	(wS)
86%	89%	45%	100%

b. Bracketed grid:

(. *)	line
(. *) (. *)	hemistichs
(. *) (. *) (. *) (. *)	feet

A complete theory of metrics, then, should not only be able to describe a template and explain what deviations from that template are possible; it should also provide some account of why some permissible deviations are more frequent than others.

2. Accounting for Preferences in Generative Metrics

This paper follows the approach of generative metrics (Halle and Keyser 1971; Kiparsky 1975, 1977; Hanson and Kiparsky 1996; Hayes and MacEachern 1996; Hayes 2000; Friedberg 1997, 2001 *inter alia*), which seeks to account for metrical patterns using the tools of generative phonology. More specifically, it builds on the work of Friedberg (1997, 2001), who derives patterns of stress omission in Russian iambic tetrameter using the ranked, violable constraints of Optimality Theory (Prince and Smolensky 1993; henceforth OT). Friedberg's approach differs from traditional OT in that her tableaux do not select single optimal output forms, but rather determine the relative well-formedness of several permissible line types.

In Friedberg's system, a line is metrical if and only if it does not violate any constraint ranked higher than *NULLPARSE, the constraint that penalizes the null candidate. Two such constraints are shown in (8). (These constraints are drawn from Friedberg 2001: 20 and Friedberg 1997: 39. The constraint HEAD is based on Dresher and van der Hulst's (1995) work on head-dependent asymmetries.)

(8) Constraints ranked above *NULLPARSE:
a. ENDING - The last strong position in a line must be stressed.
b. HEAD - A hemistich must have a head, which must be stressed.

These constraints rule out lines with stress omission on the last foot (`XXXW`) and lines in which there are two stress omissions in the same hemistich (`WWXX`, `XXWW`).[3]

Any constraint ranked below *NULLPARSE is violable. Some of the violable constraints proposed by Friedberg (1997: 39-45; 2001: 22) are shown in (9).

(9) Constraints ranked below *NULLPARSE:
a. *LAPSE - Stress omissions should not occur on adjacent feet.
b. MARKL(LN) - The leftmost strong position of the line should be stressed.
c. MARKR(HS) - The rightmost strong position of a hemistich should be stressed.
d. CONTRAST - A line should contain at least one stress omission.
e. SYMMETRY - The two hemistichs should have the same number of stresses.
f. BINARYCOLON - At least one hemistich must contain two stresses.
g. STRESSS - All strong positions should be stressed.

Ranked in the order in which they are listed in (9), these constraints predict the relative frequency of occurrence of the six different line types that occur in Pushkin's *Eugene Onegin*, as illustrated in the tableau in (10). The line type `SSWS`, which is judged most harmonic by the constraint ranking, is the most frequent, while `SWWS`, the least harmonic of the six permissible line types, occurs least often. In a standard OT calculation, the presence of a more harmonic alternative suffices to rule a candidate out; in Friedberg's theory, the less harmonic candidate is dispreferred, but it is not deemed unmetrical unless it is so ill-formed as to be worse than the null candidate.

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[3] Here and in the following discussion, four-letter abbreviations for line types indicate the realization of the four strong positions in the template. The letter `S` stands for a stressed syllable, `W` stands for an unstressed syllable, and `X` stands for any syllable.

(10) Tableau for line types in Pushkin's *Eugene Onegin* (based on Friedberg 1997: 46)

	*LAPSE	MARKL	MARKR	CONT	SYMM	BINCOL	STRS
1. SSWS					*		*
2. SSSS				*			
3. SWSS			*		*		*
4. WSWS		*				*	**
5. WSSS		*			*		*
6. SWWS	*		*			*	**

Various rankings of the constraints in (9) correctly generate the patterns of stress omission found in the work of a number of poets.

This approach does, however, have certain theoretical and empirical limitations. For example, the constraint hierarchy in (9) and (10) does not make explicit the notion that the line type SSSS, in which all strong positions are filled by stressed syllables, represents perfect conformity to an abstract metrical ideal. There is one constraint (STRESSS) that prefers SSSS over all other line types, but another constraint (CONTRAST) specifically penalizes SSSS. This conceptual objection can be at least partially answered by formulating STRESSS as a faithfulness constraint (as in Friedberg 2001), giving the metrical template privileged status as the input form. Even so, STRESSS is not always active; in the *Eugene Onegin* grammar in (10), for instance, it is ranked so low as to have no influence on the hierarchy of line types produced.

The model also has some difficulty capturing the principle of FIT. As originally formulated by Hanson and Kiparsky (1996: 294), FIT pertains to the choice of meter: "Languages select meters in which their entire vocabularies are usable in the greatest variety of ways." For example, iambic pentameter is a good meter for English verse, because most English words are easily accommodated by the iambic template (given a certain degree of licence for deviation). However, the same principle also applies to rhythm, as the natural prosodic tendencies of a language determine which kinds of deviation from the metrical template will be most useful. Russian, because it has many polysyllabic words with no secondary stress, must permit stress omissions, or else it would be forced to exclude much of its vocabulary from syllabo-tonic verse altogether. As Friedberg (1997: 47) notes, "Even Lomonosov, who aspired to write iambic poetry with no omissions of stress, still has more cases of SSWS than SSSS."

The constraints in (9) and (10) clearly derive line types with stress omission, but they do not present stress omission as a consequence of properties of the Russian language. Instead, the grammar combines meter and rhythm into a single set of constraints. While STRESSS unambiguously mandates adherence to the metrical template, and CONTRAST unambiguously mandates deviation, the meaning of the other constraints (which penalize particular forms of deviation) and their ranking is less obvious. If the grammar prefers WSWS to SWWS, is this because WSWS is a less severe departure from the template from a metrical point of view, or because SWWS is a less useful line type from the point of view of Russian vocabulary and syntax? The grammar in (10) predicts the results of the tension between meter and language, but does not model the tension itself.

Finally, the model is empirically limited in that while it can predict whether one line type will be preferred to another, it cannot predict how strong or weak the preference will be. For example, the grammar in (10) predicts that SSSS will be preferred to SWSS, and SWSS to WSWS; as the data in (11) reveal, both predictions are correct, but the difference in frequency between SSSS and SWSS is much greater than the difference between SWSS and WSWS.

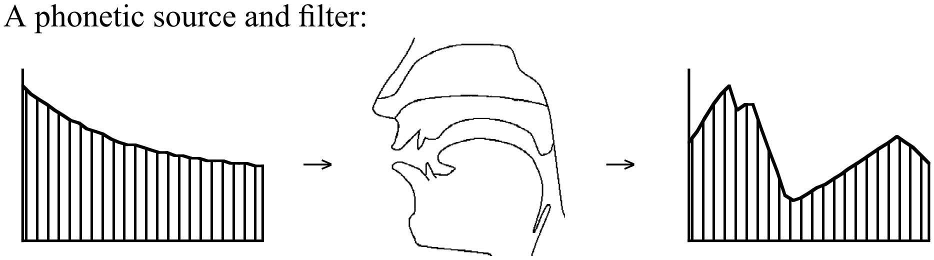
(11) Actual frequencies of line types in *Eugene Onegin*
(Friedberg 1997, citing Tomaševskij 1929):

1. SSWS 47.5%
2. SSSS 26.6%
3. SWSS 9.7%
4. WSWS 9.0%
5. WSSS 6.6%
6. SWWS 0.5%

3. An Alternative Account: The Source-Filter Model

This paper proposes an alternative theory that makes more fine-grained predictions about output frequencies by explicitly modelling the interaction between language and meter. The proposed theory is analogous to the phonetic source-filter model of phonation and articulation, illustrated in (12), in which the shape of the vocal tract filters the sound wave produced by the vocal folds, reinforcing some frequencies and dampening others to produce distinctive patterns of formants.

(12) A phonetic source and filter:



Source: glottal wave Filter: vocal tract Output: vowel sound

In the metrical source-filter model, the rhythmic patterns of a natural language serve as a source of variability that is filtered through a metrical grammar. The output is poetic rhythm, which results from the reinforcing and dampening of natural patterns by the metrical template.

Taranovsky ([1971] 1980) provides two sets of data that might serve as the natural-language source for Russian iambic tetrameter; these are listed in (13). The column labelled ‘theoretical’ shows Taranovsky’s predictions about how likely each line type is to occur naturally in (non-poetic) Russian; the column labelled ‘fortuitous’ indicates the results of his study of chance iambic sequences in an actual sample of Russian prose. The figures in (13) show the frequency of each line type as a proportion of all sequences of well-formed iambic tetrameter in prose; they have been adjusted to add up to 100% because Taranovsky’s original calculations include the unmetrical WWSS.

(13) Prose frequencies from Taranovsky ([1971] 1980):

Line Type	Theoretical	Fortuitous
SSSS	11.3%	10.9%
SSWS	29.5%	29.3%
SWSS	26.6%	20.2%
WSWS	14.2%	17.6%
WSSS	6.3%	9.3%
SWWS	11.4%	12.7%

The filter through which this source passes is a metrical grammar consisting of ranked, violable constraints similar to those used by Friedberg. For the data under consideration here—the range of eighteenth- to early twentieth-century poetry surveyed by Taranovsky—the constraints in (14) appear to be sufficient.

(14) Constraints in the metrical filter:
a. *LAPSE - Stress omissions should not occur on adjacent feet.
b. MARKL(LN) - The leftmost strong position of the line should be stressed.
c. SYMMETRY - The two hemistichs should have the same number of stresses.
d. MARKR(HS) - The rightmost strong position of a hemistich should be stressed.

The constraints in (14), all originally proposed by Friedberg, are repeated from (9). Ranked in the order in which they appear in (14), they form the grammar in (15), which generates an ordering of the six line types in which perfect adherence to the template (SSSS) is the most harmonic option.

(15) Deriving SSSS > SSWS > SWSS > WSWS > WSSS > SWWS:

	*LAPSE	MARKL(LN)	SYMMETRY	MARKR(HS)
1. SSSS				
2. SSWS			*	
3. SWSS			*	*
4. WSWS		*		
5. WSSS		*	*	
6. SWWS	*			*

The raw frequencies are filtered through the metrical grammar as follows: Three candidate line forms are selected at random based on the frequencies in (13), and the grammar in (15) selects the optimal candidate from the set. The predicted frequency of each line type is equal to the likelihood of its being generated by this procedure.[4]

[4] This probability can be calculated for a line type L by multiplying (a) the probability that, out of three randomly chosen lines, none is more harmonic than L by (b) the probability that, in three randomly chosen lines no more harmonic than L, L itself occurs at least once. For the line types at the extremes of the hierarchy, this calculation is simple. In the case of the most harmonic line type (here, SSSS), probability (a) is necessarily 100%, and so the predicted frequency is equal to (b), which is the probability of selecting SSSS at least once. For the least harmonic line type (SWWS), probability (b) is necessarily 100%, and the predicted frequency is equal to (a), which is the probability of selecting SWWS all three times. The predicted frequencies of the other line types require somewhat more calculation, but are ultimately straightforward.

The procedure is mathematically similar to rolling a six-sided die three times and selecting the lowest number rolled. In this case, however, the die is weighted by the prosody of Russian prose, and it is the grammar in (15) that determines which of the rolled numbers is chosen. Some examples of how the procedure works are shown in (16).

(16) Selecting the optimal candidate from a random set:

a. Roll:	2: SSWS	2: SSWS	5: WSSS	Selection: 2: SSWS
b. Roll	3: SWSS	4: WSWS	1: SSSS	Selection: 1: SSSS
c. Roll:	5: WSSS	4: WSWS	6: SWWS	Selection: 4: WSWS
d. Roll:	6: SWWS	6: SWWS	6: SWWS	Selection: 6: SWWS

In (16a), SSWS—the second-best candidate according to the metrical grammar and the most frequent one in the input frequencies—comes up twice; since the other randomly chosen candidate, WSSS, is less optimal, SSWS is chosen as the output. In (16b), the presence in the candidate set of SSSS, the most harmonic line type, guarantees that it will be selected by the grammar. None of the best three line types is present in the candidate set in (16c), and so the grammar chooses WSWS, the best one available. (16d) shows the only circumstance in which the procedure will select the least harmonic line type: SWWS must turn up all three times in order to be chosen.

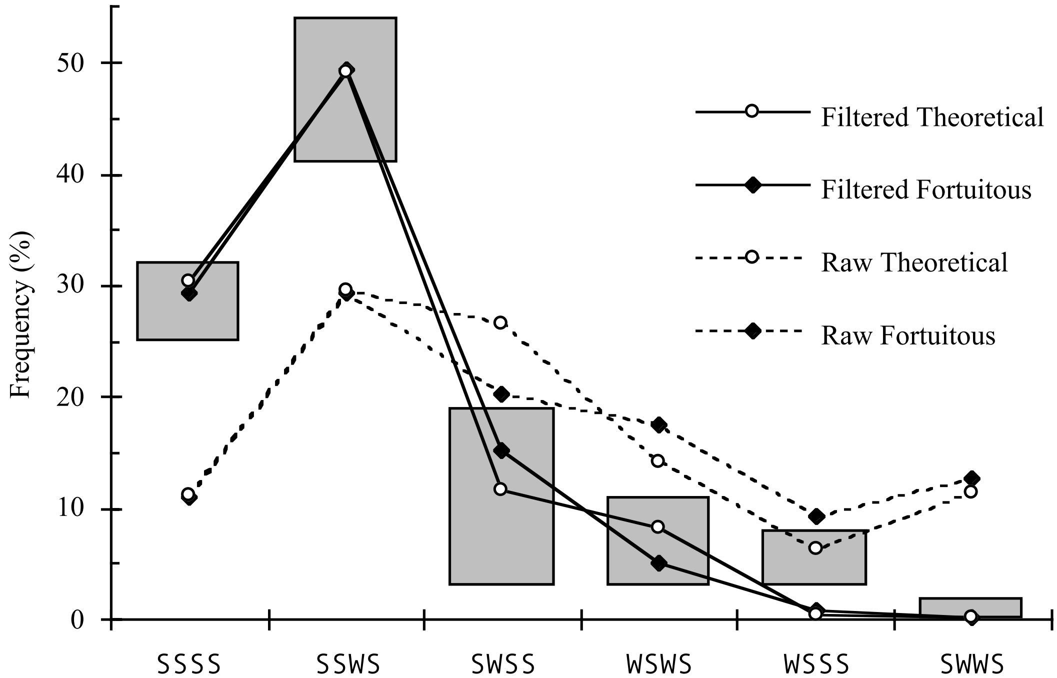
Calculating each line type's chance of being selected by this procedure yields a set of predicted frequencies in which the prose pattern of (13) is, in effect, filtered through the metrical preferences of the grammar in (15). The most harmonic line types are reinforced; the least harmonic ones are dampened. The table in (17) compares the predicted frequencies with the range of frequencies attested for each line type in the verse surveyed by Taranovsky.

(17) Raw, filtered, and attested frequencies:

	Fortuitous		Theoretical		
Type	Raw	Filtered	Raw	Filtered	Attested
1. SSSS	10.9	**29.3**	11.3	**30.4**	25 – 32
2. SSWS	29.3	**49.4**	29.5	**49.2**	41 – 54
3. SWSS	20.2	**15.2**	26.6	**11.6**	3 – 19
4. WSWS	17.6	**5.1**	14.2	**8.3**	3 – 11
5. WSSS	9.3	**0.9**	6.3	**0.4**	3 – 8
6. SWWS	12.7	**0.2**	11.4	**0.2**	0 – 2

For every line type except WSSS, the predictions of the source-filter model fall within the range of attested frequencies. As shown in (17), and graphically in the chart in (18), filtering either set of raw frequencies through the metrical grammar generates an overall pattern much closer in shape to that of actual Russian iambic tetrameter of the eighteenth to early twentieth centuries.

(18) The effects of the metrical filter:



In (18), dotted lines trace the pattern described by Taranovsky's data for theoretical and fortuitous sequences of iambic pentameter in Russian prose; solid lines indicate the results of filtering each of these sets of frequencies through the metrical grammar; and the shaded boxes show the ranges of frequencies attested for each line type in verse. The line types are listed in the order in which they are ranked by the metrical constraint grammar, from most harmonic to least. The two most harmonic line types, `SSSS` and `SSWS`, are reinforced by the grammar; the other four are dampened. The second-least harmonic line type, `WSSS`, is predicted by the model to be somewhat less common than it is in actual verse; for the other line types, the poets and the model appear to be in agreement.

4. Evaluation

The results in (17) and (18) provide some indication of the empirical viability of the source-filter model, at least in its application to the particular question of Russian iambic tetrameter. A number of theoretical questions, however, remain unanswered.

Of these questions, there is one that pertains specifically to the model itself: Why does the randomly chosen candidate set contain exactly three candidates? Empirically, the number three seems to provide just the right balance between the source and the filter. If the number of candidates is decreased, the filtered frequencies become more like the raw frequencies, and presumably, more like prose. (If there were only one candidate, it would necessarily be the optimal one, and so the likelihood of the model selecting a given line type would be equivalent to the likelihood of that line type occurring 'naturally.') If the number of candidates is increased, then the most harmonic line type predominates inordinately, since its chance of being included in the candidate set approaches 100% as the number of candidates approaches infinity. Too small a set produces the rhythm of prose; too large a set produces the monotony of perfectly regular iambic meter.

Clearly, some intermediate number of candidates must be chosen if the model is to portray at all realistically the poetic compromise between the rules of meter and the requirements of the language. Unfortunately, there is no immediately obvious reason for selecting three as the magic number *a priori*. Ideally, one or both of the following should turn out to be the case: (a) that the number of candidates in the set follows from some independent principle, and (b) that the number is universal, rather than specific to one language or one metrical tradition. Further testing of the source-filter model may shed more light on this problem.

Another, more general question is, what exactly should the model attempt to predict? In the case presented in this paper, the predictions of the model fared well when set beside aggregate data from various poets writing over a period of approximately two centuries. It remains to be seen whether similar results can be attained for narrower ranges of data. Friedberg (1997) provides grammars that generate rankings of line types for individual poets, and in some cases for different periods in the life of a single poet—and the grammar cited in (10) is a grammar of a single (long) poem. If the source-filter model could accurately predict frequencies of line types for individual poets, periods, or poems, that would be a remarkable result. However, it is not clear exactly how narrow the focus of the model's predictions ought to be.

This problem, however, is not specific to the source-filter model; it applies to any model of language variation, and especially to models that make predictions about patterns of frequencies rather than about more categorical phenomena. Should linguists attempt to write grammars for languages, for dialects, or for idiolects? There are potentially significant generalizations to be found at all these levels. This paper has taken a wide view of Russian iambic tetrameter and presented a grammar for a metrical tradition; it remains to be seen whether the variation within that tradition results from different metrical preferences, different poetic lexicons, random variability, or some other factor.

Finally, there is the question of how poets acquire their metrical grammars. In the case of the source-filter model (and other constraint-based theories of metrics), does the acquisition process involve only the ordering of a set of universal constraints (as in standard OT), or does the learner have to discover the constraints themselves as well as their ranking? And, in either case, what data does the learner rely on?

Some version of this question applies to any theory of generative metrics. It is made difficult to answer by the fact that standard linguistic arguments about learnability cannot necessarily be applied to poetry. All more or less normal children automatically learn to speak a language; not all children grow up to be poets. While generative metrics strives to capture 'natural' intuitions about what is metrical or unmetrical, the production of verse is generally considered to be an art. The procedures for the acquisition of poetic grammars are therefore much harder to limn than those that apply to ordinary language.

Despite these unanswered questions, though, the source-filter model has much to recommend it. In particular:

1. The model is able to predict that SSWS will be the most frequent line type, even though the metrical grammar prefers perfect adherence to the template (SSSS). This insight depends upon the ability to represent rhythm as the result of a negotiation between the language and the meter. In this respect, the source-filter model makes the principle of FIT explicit.

2. The model does not require an unreasonable number of constraints. The full ranking of the six line types can be achieved with four constraints, each of which can be formulated in terms of standard metrical constituents.

3. The model makes predictions about non-categorical phenomena without resorting to non-categorical constraint rankings.[5] Other OT models of variation, such as those proposed by Anttila (1995), Boersma and Hayes (1999), and Hayes (2000), require constraints that are variably ranked.

Anttila (1995) uses crucially unranked constraints to generate patterns of variation in Finnish genitives. This is a principled approach, but the number and granularity of the statistical patterns it can generate depend on the number of constraints involved.

Hayes (2000) applies the overlapping constraints of Boersma and Hayes (1999) to account for patterns in English folk verse. This model can generate more complex patterns of numbers, but the rankings are considerably less constrained.

It should be noted, however, that the source-filter model is viable only when there is an identifiable source of variation that can serve as the input to a filter composed of categorically ranked constraints.

4. The source-filter model, like Friedberg's (1997) theory, makes good use of OT's inherent power to generate a harmonic ordering of an entire candidate set. Most phonological applications of OT simply use constraints to select a single candidate as the optimal output; in such cases, the theory vastly overgenerates judgments, since it generally does not matter which form is deemed second-, third-, or fifth-most harmonic. In the source-filter model, all the judgments matter.

In summary, then, the proposed source-filter model appears to be a promising and principled approach to the problems of generative metrics, and perhaps to those of linguistic variation more generally. Applied to verse, it provides a picture of the interaction between natural language and metrical structure, and in doing so it distinguishes the source of variability from the orderly grammar of poetry.

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[5] In this respect, the source-filter model addresses an issue raised by Guy (1997); separating the source of variation from the grammar proper produces an OT model of variation somewhat closer to the variable rule model of Cedergren and Sankoff (1974).

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Department of Linguistics
University of Toronto
130 St. George Street
Toronto, Ont. M5S 3H1
Canada

danhall@chass.utoronto.ca