Towards a Quantitative Analysis of Fricative Voicing

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Abstract
Dutch shows evidence that the opposition of voiced vs. voiceless fricatives is really one of length, with voiceless fricatives being long; at the same time, voicing assimilation facts seem to argue in favour of an analysis where the two types are distinguished by a feature. It is argued in this paper that the relevant feature is [spread glottis], a feature which prefers to be linked to two positions cross-linguistically; this accounts for the cluster behaviour and for assimilation in a uniform fashion.

Outline
1. Voicing and fricatives in Dutch
2. Feature models of voicing in fricatives
3. OT Formalisation
4. Typological claims

1. Voicing and fricatives in Dutch

The 'voicing' opposition in West Germanic often behaves as a length distinction. There is phonological and phonetic evidence that this is the case also in Dutch.

Here is some phonological evidence. First, in intervocalic position, we find voiceless fricatives after 'short' vowels, and voiced fricatives after 'long' vowels.

(1)

\[ \text{knuffel} \quad [\text{kn}\tilde{\text{o}} \text{f}] \quad \text{'hug'} \quad *[\text{kn}\ddot{\text{o}} \text{f}] \\
\text{heuvel} \quad [\text{h}\ddot{\text{O}} \text{v}] \quad \text{'hill'} \quad *[\text{h}\varnothing \text{v}] \]

This can be understood if we assume that voiceless fricatives are 'long' and voiced fricatives are 'short' and every word-internal syllable contains at most two positions (represented here by way of mora structure):

(2)

\[
\begin{array}{cccc}
\ast & \ast & \ast & \\
\downarrow & \downarrow & \downarrow & \\
\ast & \ast & \ast & \\
\text{kn}\tilde{\text{o}} \text{f} & \text{h}\varnothing \text{v} & \text{h}\ddot{\text{O}} \text{v} & \text{kn}\ddot{\text{o}} \text{f} \\
\end{array}
\]

In some (Brabantish and Flemish) dialects of Dutch (De Schutter and
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Taeldeman 1986) deletion of t’s in clusters causes the fricative in those clusters to devoice.

(3)  
   a.  *ik doe [v]eel  ‘I do a lot’
   b.  *hij doe [f]eel  ‘he does a lot’

This can be seen as a form of compensatory lengthening under a quantitative analysis of the voicing contrast:

(4) (hij doe) x — x (eel)  (hij doe) x — x (eel)
     t       v          f

There is also phonetic evidence that length is more important in fricatives than voicing. Slis and Van Heugten (1989:131-132) wrote, based on their own measurements, that there are two cues indicating the voiced-voiceless distinction, viz. presence or absence of voice activity and duration. Remarkably, voicing is often lacking in [+voice] fricatives [...] The voiced-voiceless distinction in these cases is cued by duration.

Ten years later, Ernestus (1999:177) conducted different experiments and concluded:

Clusters of fricatives of the same place of articulation arise when a word-final fricative is followed by a word-initial one. These clusters are generally realized with a duration that is shorter than the duration of two segments (...). In what follows, clusters consisting of two segments with the same manner and place of articulation will be referred to as geminates. (...). The problem is that fricative geminates are always realized as voiceless, independently of their context, exact duration, etc.

From this we can thus at least conclude that longer fricatives are always voiceless. There is cross-linguistic evidence as well. In the 'standard' 'Zingarelli' (or dictionary) variety of Italian, we find contrasts such as the following (Krämer 2003):

(5)  
    ca[s]a  ‘house’
    ca[s]i[a]  ‘box, cashier’
    ca[z]o  ‘incident’

In other words, we find a voicing contrast in the short sibilants, but not in the long sibilants; the latter surface as voiceless only. In other dialects of Italian this two-way contrast may be further simplified: we find only a length contrast (and no fricative voicing) in Abruzzese, and only a voicing contrast (and no fricative length) in Veneto:
This leads to the following conclusion:

Yet, there is also at least one important reason to consider the relevant distinction in Dutch to be one of quality (a feature, such as [voice]) rather than quantity: this is voicing assimilation.

Assimilation is standardly analysed as feature spreading.

We thus face a paradoxical situation. On the one hand, the relevant opposition behaves as a quantitative one, on the other hand, it behaves as a qualitative one.

2. Feature models of voicing in fricatives

Vaux (1996) argues that voiced obstruents have a feature [+ATR]; furthermore, [+ATR] expresses tenseness and [-ATR] expresses laxness on vowels. For instance we find the following pattern in Babine (Cook 1989):

a. After: t, t̪, t̪l, t̪l̪, c̪, s, k, x̪, q, q̪l, o, q̪l̪, o̪l̪, o, h
Vowels surface as: ə, æ, o

b. After: b, d, dl, j̪, ð̪, ð̪l, m, n, l, z, j, ə, w
Vowels surface as: i, e, æ, o, u, ə

Vaux (1996) analyses this by postulating a rule spreading [+ATR] from the consonant to the vowel. It has been argued (in Van Oostendorp 2000, a.o.) that the vowel system of Dutch should be divided along the [+ATR]-[−ATR] dimension rather than along the dimension of vocalic length. If we take this to be true, the Babine facts in (2) would be mirrored in Dutch as follows:

a. After: a, e, i, o, u, y, ð̪, ø, u, ø
Fricatives surface as: z, v

b. After: ʊ, ð, ðl, ʊl
Fricatives surface as: s, f

This we could then see as spreading of [ATR] to the following fricative.
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This approach would have a surprising further minor consequence, viz. that it could potentially help to explain a gap in the Dutch consonant system: the voiced velar obstruents are absent. Vaux (1996) mentions a rule "causing [+ATR] vowels to become [-back]'', citing Archangeli and Pulleyblank (1994):

(11)  [+ATR]  [-back]

The problem with this approach is that it cannot really explain why fricatives behave differently from obstruents, and that happens to be the property we are most interested in.

The proposal by Vaux (1998) seems more promising from this perspective. In this view, voiceless fricatives are represented as [+spread glottis] (like aspirated voiceless stops). The proposal is dubbed Vaux's Law in Avery and Idsardi (2001):

(12)  Vaux's Law: Fricative [spread glottis].

For instance, in the New Julfa dialect of Armenian, there is a future tense prefix k- which assimilates in its laryngeal features to the first segment of the stem:

(14)  | Underlying form | Surface form | Gloss |
      |-----------------|-------------|-------|
      a.  k-ertʰ-a-m    kertʰam   I will go
      k-t-a-m          kʰtam      I will give
      b.  k-bzz-am      bʰbzzam    I will buzz
      k-l-a-m          bʰlam       I will cry
      k-zr-a-m         bʰzrám     I will bray
      c.  k-tʰos-n-ie-m  kʰtʰomniem I will allow
      k-savor-ie-m     kʰsavoriem I will grow accustomed to
      d.  k-bʰier-ie-m   bʰieriem  I will carry

According to Vaux (1998), this crucially shows that voiceless fricatives are like aspirated voiceless stops, not like plain voiceless stop. This is accounted for by assuming that /tʰ/ and /s/ in (27c) both have [+spread glottis], which spreads to to the preceding /k/.

Another interesting consequence of the proposed equality between voiceless fricatives and aspirated stops, is that it is well-known that aspirated stops are also known to be substantially longer than unaspirated stops. It has been proposed (by Ringen 1999) in the context of aspiration that there is a constraint MultiLink:

(15)  MultiLink
      a consonant is [+spread glottis] iff it is long

The relation expressed by MultiLink could be een as a kind of (mutual) enhancement of contrast. Ringen uses this constraint to explain why underlyingly aspirated stops in Icelandic are not allowed to surface as aspirated when they occur in a cluster (i.e. when they are followed by a sonorant). In this case, they occur as 'preaspirated' stops,
sharing their [spread glottis] with an [h]. The fact that in English onset clusters, aspiration spreads from the stop to the onset could be similarly explained by this constraint.

(16) \[ [p\]ead, [t\]ain \]

We could also use this constraint to explain why voiceless fricatives are (preferably) long or in a cluster. A short voiceless fricative prefers to share its [spread glottis] specification; it can do this either by being long (assuming the parts of the long fricative help each other satisfy MULTI\textsc{link}), or by occurring in a voiceless cluster.

In their discussion of laryngeal contrasts in Korean, Avery and Idsardi (2001) note that this language only has two fricatives, [s\textasciicircum{H}] and [s\textasciicircum{\textcircled{}}} . Both of them are bipositional, and receive the following representations:

\begin{align*}
\text{(17)} &
\begin{tikzpicture}
  \node (C) [circle,draw] at (0,0) {C};
  \node (V) [circle,draw] at (1,0) {V};
  \node (GW) [circle,draw] at (-0.5,-0.5) {GW};
  \node (spread) [circle,draw] at (-0.5,-1) {[spread]};
  \draw (C) -- (GW);
  \draw (C) -- (spread);
  \draw (V) -- (spread);
\end{tikzpicture} \\
&\begin{tikzpicture}
  \node (C) [circle,draw] at (0,0) {C};
  \node (C') [circle,draw] at (0.5,0) {C'};
  \node (V) [circle,draw] at (1,0) {V};
  \node (GW) [circle,draw] at (-0.5,-0.5) {GW};
  \node (spread) [circle,draw] at (-0.5,-1) {[spread]};
  \draw (C) -- (GW);
  \draw (C') -- (spread);
  \draw (V) -- (spread);
\end{tikzpicture}
\end{align*}

Avery and Idsardi (2001:58) state that their analysis "requires only a single statement that is specific to Korean: that GW must be bipositional". Given that MULTI\textsc{link} has been argued for independently from Korean, the statement may not be that language-specific after all.

In order to account for the fact that Dutch does not have aspirated (i.e. [spread glottis]) stops:

(18) *SOO: Stops in onsets are never [spread glottis].

Remark. Lost in this account, is the possible correlation with velarity. We consider this a minor loss, given the strong evidence in favour of the present proposal. (There is actually some evidence that velar consonants are also long.)

An important aspect of our current findings is that it allows us to understand the dual behaviour of voicing in fricatives: it behaves both as a length distinction and as a feature difference, because it involves both kinds of difference.

The core of the analysis are \textsc{vaux'slaw}, requiring fricatives to be [spread glottis] (’voiceless’), and \textsc{multi\textsc{link}}, requiring [spread glottis] to be spread over two positions.
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3. OT Formalisation

It is first necessary to show how these two constraints can account for the behaviour of fricatives in intervocalic context, in interaction with a constraint on syllable well-formedness to the effect that long consonants are not allowed after long vowels (called *mmm here):

<table>
<thead>
<tr>
<th></th>
<th>*mmm</th>
<th>MULTILINK</th>
<th>VAUX'S LAW</th>
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<tbody>
<tr>
<td>/a/sa/</td>
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<tr>
<td>a/sa/</td>
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<td>*</td>
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<td>a/sa/</td>
<td>*!</td>
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<tr>
<td>a/sa/</td>
<td></td>
<td>*!</td>
<td></td>
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In order to describe the behaviour of fricatives at the end of the word, we need to take a closer look at the actual structure of the word in that position. Dutch words syllables usually are at most bimoraic; trimoraic syllables are only found at the end of words. As a matter of fact, the end of word is even less restrictive. Here, we even find extra (coronal) consonants. We thus have words such as herfst (autumn) where herf is a trimoraic syllable and st is a cluster of ‘extrasyllabic’ segments, which are completely outside of the realm of syllabic structure. I assume that these extra positions are also available for free for the second half of geminates:

<table>
<thead>
<tr>
<th></th>
<th>*mmm</th>
<th>MULTILINK</th>
<th>VAUX'S LAW</th>
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</thead>
<tbody>
<tr>
<td>/a/sa/, /a/sa/</td>
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<tr>
<td>a/sa/</td>
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<tr>
<td>a/sa/</td>
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<td>*!</td>
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<tr>
<td>a/sa/</td>
<td></td>
<td>*!</td>
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</table>

Clusters of fricatives are always voiceless. Fricative clusters thus behave exactly as long fricatives, presumably because they can share their [spread glottis] specification, thus satisfying MULTILINK:
In this case, we start out with two underlingly voiced fricatives, but lengthening is not necessary for either of them to become lengthened: all that is needed is that the two share \(\text{[spread glottis]}\):

(22) \text{høysføyl} \\
[spread glottis]

How about clusters in which a stop participates? If the fricative is leftmost, the plosive determines the voicing of the whole cluster; but if the fricative is rightmost it determines that the whole cluster becomes voiceless. In order for these facts to come out right, we need to add two constraints to our inventory. Because there is obviously assimilation of the feature \(\text{[voice]}\) when this is present on the plosive, we need a constraint such as \text{AGREE} (Bakovic 2000), and in order to prevent this constraint from randomly introducing new features \(\text{[voice]}\) into the representation, we need a constraint against this feature. Also the constraint against \(\text{[spread glottis]}\) (aspirated) stops (*SOO) now becomes relevant, but notice that we still do not need a faithfulness constraint for \(\text{[spread glottis]}\), mirroring the fact that the 'voicing' of fricatives is still not distinctive in this position. The curious fact that if the first obstruent of a cluster is a fricative, the direction of assimilation is 'progressive' (i.e. the whole cluster ends up as voiceless), which has been a puzzle for phonologists, can now be reduced to the familiar \text{VAUX'S LAW}:

(23) \text{AGREE}: Obstruent clusters share their laryngeal nodes. \text{IDENT[voice]}: Respect the \text{[voice]} specification of (onset) stops.

<table>
<thead>
<tr>
<th>(24)</th>
<th>(\text{[ash]})</th>
<th>(\text{[tray]})</th>
<th>\text{AGREE}</th>
<th>\text{IDENT[voice]}</th>
<th>\text{*SOO}</th>
<th>\text{MULTILINK}</th>
<th>\text{VAUX'S LAW}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Øzbök</td>
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<td>Øspök</td>
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<td>Øshök</td>
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<td>Øzpök</td>
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</table>
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The last issue we have to worry about is the representation of fricatives in onset position. This is basically the only position where we have a contrast. Notice that faithfulness on fricative voicing (or length) does not play any role at all in the analysis given thus far. But voicing is contrastive in onsets:

(27)  

a.  zee [ze] 'sea'    C [se] '(the letter) C'
b.  vee [ve] 'cattle'    fee [fe] 'fairy'
c.  chloor [xlç˘r] 'chlore'    gloor [xlç˘r] 'gleam'

Let us concentrate on the labial case in (41b) as exemplary. We have two options: either we allow initial 'geminates' in the cases at hand, or we do not allow them. But in both cases the result is less than satisfying. If we do not allow for geminates, we get the result that all fricatives should be voiced:

(28)  

<table>
<thead>
<tr>
<th></th>
<th>MULTILINK</th>
<th>VAUX’S LAW</th>
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</thead>
<tbody>
<tr>
<td>ve</td>
<td></td>
<td>*</td>
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<tr>
<td>fe</td>
<td>*</td>
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</tbody>
</table>

But if we do allow for geminates, the result is that all fricatives should be voiceless:

(29)  

<table>
<thead>
<tr>
<th></th>
<th>MULTILINK</th>
<th>VAUX’S LAW</th>
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<tbody>
<tr>
<td>f˘e</td>
<td></td>
<td>*</td>
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<tr>
<td>ve</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>v˘e</td>
<td>*</td>
<td>*</td>
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<tr>
<td>fe</td>
<td>*</td>
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</tbody>
</table>

This result is not without interest since there are indeed dialects of Dutch which
lift the contrast in voicing also in initial position, either in the direction of only voiceless consonants (Standard’ Netherlands Dutch) or in the direction of only voiced consonants (Roermond Dutch, cf. Kats 1939, Van Oostendorp 2002). One possibility to deal with dialects which do have constrast would be to invoke positional faithfulness (Beckman 1998, for instance of the following type:

(30) IDENTWORDINIT([spread glottis])
The specification for [spread glottis] in the first syllable of a word, should be faithful.

<table>
<thead>
<tr>
<th></th>
<th>ve</th>
<th>IDWRDINIT</th>
<th>MULTILINK</th>
<th>VAUX’S LAW</th>
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<tr>
<td></td>
<td>ve</td>
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<td></td>
<td>*</td>
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<tr>
<td>f³</td>
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<td>* !</td>
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<tr>
<th></th>
<th>f³</th>
<th>IDWRDINIT</th>
<th>MULTILINK</th>
<th>VAUX’S LAW</th>
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<tr>
<td>f³</td>
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<td>(*)</td>
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<td>ve</td>
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<td>* !</td>
<td>(*)</td>
<td>*</td>
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</tbody>
</table>

4. Typological claims

In the previous sections we have discussed the voicing system of Dutch fricatives in some detail. The question may arise how these facts can be related to those of other languages.

There are basically three groups of Germanic dialects. The first group, of which Frisian counts as an example, only allows voiceless fricatives at the beginning of the word. Compare for instance the following words with their Dutch cognates (Tiersma 1985):

(33) sinke [sINk´] ‘to sink’ (Dutch: zinken)
    seuren [sOr´n] ‘to nag’ (Dutch: zeuren)
    fluch [fløx] ‘quickly’ (Dutch: vlug)
    fioele [fijul´] ‘violin’ (Dutch: viool)

The second group, of which Roermond Dutch can be given as an example, only allows voiced fricatives in this position (Kats 1939). Speakers of German famously display a same tendency to voice fricatives also in loanwords, proncouncing [z]ity, etc. But facts which look like the ones discussed here can be found in typologically unrelated languages as well. There exists a very interesting similarity between the Dutch facts discussed here and the facts of the Athapaskan language Ahtna (Rice 2003). Ahtna has long vowels and short vowels. Word-finally (most Ahtna words are monosyllabic), both syllables with long vowels and with short vowels can be closed with a consonant. But these consonants behave in different ways, which are explained by Rice with the assumption that consonants after a short vowel are in a coda, but consonants after a long vowel are in the onset of an empty-headed nucleus. Interestingly, one of the arguments is voicing of fricatives. Before
vowel-initial suffixes, fricatives voice after long vowels, but not after short vowels:

(34)  
<table>
<thead>
<tr>
<th>CVVC</th>
<th>CVVC+V</th>
</tr>
</thead>
<tbody>
<tr>
<td>affirmative</td>
<td>negative</td>
</tr>
</tbody>
</table>
| a. t’aa[s] | t’aa[z]e | 'cut several times for a period of times (durative imperfective)'
| b. kae[l] | kae[l]e | 'go by boat (imperfective progressive)'
| CVC    | CVC+V   |
| a. ne[s] | ne[s]e  | 'be alive (customary imperfective)'
| b. ghe[l] | ghe[l]e | 'be crazy (durative imperfective)'

Interestingly, Rice also adduces arguments that there is a difference between 'morphological empty vowels' and empty vowels which are there for purely phonological reasons. In the Metasta dialect of Ahtnan, certain vowel-initial suffixes which are overt in other dialects (such as the Western dialect) no longer have a clear phonetic identity; yet they still trigger voicing of the fricative.

(35)  
<table>
<thead>
<tr>
<th>Western</th>
<th>Mentasta</th>
</tr>
</thead>
</table>
| a. bi[i][l] | bi[i][l] | 'snare for large game (non-possessed)'
| b. -bi[i][l]e | -bi[i][l] | 'snare for large game (possessed)'

The parallel with the Dutch dialects is of course striking. In both cases, fricatives get exceptionally voiced at the end of a word in those cases where other dialects have a full vowel.

Another well-known case where fricative length seems to coincide with fricative voicelessness is Italian:

(664)  
<table>
<thead>
<tr>
<th>Zingarelli</th>
<th>Abruzzese</th>
<th>Veneto</th>
</tr>
</thead>
<tbody>
<tr>
<td>ca[s]a</td>
<td>ca[s]a</td>
<td>ca[z]a</td>
</tr>
</tbody>
</table>
| ca[s]a   | ca[z]a    | ca[s]a | 'box, cashier'
| ca[z]o   | ca[z]o    | ca[z]o | 'incident' |

The Abruzzese dialect does not have any voiced fricatives. In terms of the present analysis, this means that Vaux’s Law is dominant in this dialect, and faithfulness decides that MULTILINK cannot play a role:

(65)  
MAX, DEP, Vaux’s Law » MULTIINK, IDENT[s.g.]
For the Zingarelli dialect, we need to assume that there is faithfulness to [spread glottis] for short vowels, but

(67) \[ \text{Dep, Ident[s.g.]} \rightarrow \text{Vaux'sLaw, Multilink} \rightarrow \text{Max} \]

The Veneto dialect could be derived in the following way:

(69) \[ \text{NoGeminate, Ident[s.g.]} \rightarrow \text{Vaux'sLaw, Multilink, Max, Dep} \]
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<table>
<thead>
<tr>
<th>(70) /asa/, /asă/</th>
<th>NOGEMINATE</th>
<th>IDENT[s.g.]</th>
<th>VAUX'S LAW</th>
<th>MULTILINK</th>
<th>MAX DEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>asa</td>
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<td>(*)</td>
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<tr>
<td>~ ază</td>
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<td>*!</td>
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<tr>
<td>~ asă</td>
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</tbody>
</table>

| /aza/, /ază/     |           | 1           |           | (1)       |         |
| ~ asa             |           | *!          | L         | W         | (L)     |
| ~ ază             |           | *!          |           | W         | (L)     |
| ~ asă             |           | *!          |           | L         | (L)     |

This is obviously not a complete factorial typology of the constraints involved — the constraints given until now seem to conspire to make sure that contrasts appear preferably on short consonants before it appears on long consonants, but it is not clear why this is the case, since an ‘anti-Zingarelli’ ranking MAX, IDENT[s.g.] » VAUX’S LAW, MULTILINK » DEP — but at least it gives an impression of the constraint interactions involved.
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