Latent consonant harmony in Russian: Experimental evidence for Agreement by Correspondence

Alexei Kochetov, University of Toronto
Milica Radisic, University of Toronto
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Experimental Evidence for Agreement by Correspondence

Alexei Kochetov and Milica Radišić
University of Toronto

It has been recently proposed that phonological constraints enforcing consonant harmony (long-distance consonant assimilation) are grounded in functional exigencies of speech production. Specifically, the Agreement by Correspondence approach (Walker 2000; Hansson 2001, 2007; Rose & Walker 2004) hypothesizes that patterns of consonant harmony originate in difficulties at the level of phonological planning and phonetic implementation of featurally similar consonants.

One interesting prediction of this approach is that harmony-like patterns may arise spontaneously, under certain conditions, even in languages that do not exhibit consonant harmony as a phonological process. In this study we test this prediction experimentally, by examining patterns of errors involving sibilant fricatives in Russian, a language that does not exhibit consonant harmony as a phonological process.

1. Consonant Harmony and Agreement by Correspondence

Consonant harmony, or long-distance assimilation of consonants, is characterized by a number of salient properties. Consonants participating in harmony are featurally similar to each other, and intervening segments are apparently unaffected, skipped over. Harmony may involve various consonantal features: laryngeal, place, nasality, etc., and can be manifested as alternations or morpheme structure constraints (Hansson 2001; Rose & Walker 2004; but see Gafos 1999 for a different approach).

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The most common sub-type of consonant harmony is coronal sibilant harmony (Hansson 2001).

A prototypical example of sibilant consonant harmony, from Sarcee (Athapaskan), is given in (1). Only sibilant obstruents (/s ts’ʃʧʧ’/) interact in the process, showing agreement in the feature [+anterior]; intervening vowels and consonants are not apparently affected. The harmony is asymmetric in several respects: it is regressive (right-to-left) rather than progressive (left-to-right); [+anterior] sibilants (/s ts’/) rather than [-anterior] sibilants are the targets (undergoers) of the process; [-anterior] sibilants (/ʃʧ/) are the triggers of the process. These directionality and target/trigger asymmetries are representative of most sibilant harmony systems (Hansson 2001).

(1) Sibilant harmony in Sarcee (Cook 1984, cited in Hansson 2001)

/si-tʃogo/ → [fi-tʃogo] ‘my flank’
/si-tʃiz-aʔ/ → [fi-tʃiʣ-aʔ] ‘my duck’
/na-s-yatʃ/ → [na-f-yatʃ] ‘I killed them again’
/sa-ts’i-gu-si-ni-s-jaj/ → [sa-ts’i-gu-si-ni-faj]
   → [ʃa-tʃ’i-gu-fi-ni-faj] ‘you forgot me’

The Agreement by Correspondence approach (ABC: Walker 2000; Hansson 2001, 2007; Rose & Walker 2004) captures properties of consonant harmony systems using a set of Correspondence C↔C constraints, Identity[F] CC constraints, and the traditional Identity[F] Input/Output constraints. Correspondence C↔C constraints impose a correspondence relation on two segments cooccurring in an output string. For example, the constraint Corr S↔S requires that sibilant fricatives are in correspondence relation, regardless of their position in the string (e.g. [s…ʃ]). Fixed rankings of such correspondence encode similarity.

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1 Hansson (2001) identifies 46 languages exhibiting sibilant harmony, as alternations and/or morpheme structure constraints.
2 All cases of progressive (left-to-right) application of sibilant harmony appear to involve root/stem control; in some systems both [+anterior] and [-anterior] sibilants are targets; there is only one case where [-anterior] sibilants are targets to the exclusion of [+anterior] sibilants (see Hansson 2001 for details).
relations, for example, Corr $S \leftrightarrow \tilde{S}$ (sibilant fricatives, $[s…\tilde{s}]$) » Corr $S \leftrightarrow F$ (all fricatives, $[s…f], [\tilde{s}…\tilde{x}]$, etc.). Identity[F] CC constraints require featural identity of segments in correspondence relations. For example, Ident-CC (Place) requires that a pair of segments $[s,…\tilde{s}]$ correspond to each other. Such constraints can also encode directionality, for example, the ranking Ident-$C_RC_I(Pl)$ » Ident-$C_I$-$C_R$ (Pl) ensures regressive (right-to-left) direction of harmony in $[s,…\tilde{s}]$ ($\rightarrow [\tilde{s}…\tilde{s}]$) and no change in $[\tilde{s}…s]$. Finally, the traditional Identity[F] Input/Output constraints can encode relative faithfulness to feature values. For example, the ranking of the faithfulness Input-Output constraint to [-anterior] above the faithfulness Input-Output constraint to [+anterior] (Ident IO[-anterior] » Ident IO[+anterior]) ensures that [-anterior] is always a trigger and not a target in the process ($[s,…\tilde{s}] \rightarrow [\tilde{s}…\tilde{s}]$, but not $\rightarrow [s,…s]$). The tableau in (2) illustrates a partial agreement by correspondence analysis of Sarcee sibilant harmony.

(2)

<table>
<thead>
<tr>
<th>/si-tʃo/</th>
<th>Id-$C_RC_I$ (Place)</th>
<th>Id-IO [-ant]</th>
<th>Corr $S \leftrightarrow \tilde{C}$</th>
<th>Id-IO [+ant]</th>
<th>Id-$C_I$-$C_R$ (Place)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>$s,t\tilde{t}s_o$</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>$s,t\tilde{t}s_o$</td>
<td>*!</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>c.</td>
<td>$\tilde{s},t\tilde{t}s_o$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>$s,t\tilde{t}s_o$</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Agreement by Correspondence approach hypothesizes that the phonological constraints enforcing consonant harmony are grounded in functional exigencies of speech production – difficulties at the level of phonological planning and phonetic implementation of featurally similar consonants (Hansson 2001; Rose & Walker 2004). Some evidence for functional grounding of agreement constraints comes from psycholinguistic and phonetic research on speech errors. In particular, studies of speech errors have identified asymmetries similar to consonant harmony patterns: palatal bias ([+anterior] $\rightarrow$ [-anterior]) and
anticipatory (regressive) directionality (Fromkin 1971; Shattuck-Hufnagel & Klatt 1979; Stemberger 1991; Frisch 1996, on English). Such errors were found to be either categorical or gradient (partial gestural intrusions: Pouplier & Goldstein 2005; cf. Mowrey & MacKay 1990; Frisch & Wright 2002; Goldrick & Blumstein 2006; Goldstein et al. 2007; Pouplier 2008; but see Stemberger 2007 for a different interpretation of gradience).

One prediction based on the phonetic grounding hypothesis is that harmony-like patterns may arise spontaneously, under certain conditions, even in languages that do not exhibit consonant harmony as a phonological process. The goal of this study is to test this prediction experimentally, by examining patterns of errors involving Russian sibilant fricatives.

2. Russian Sibilant Fricatives

2.1 Phonology

Russian exhibits a complex set of sibilant obstruents with a four-way contrast in voiceless fricatives /s s̱ s̱ j/ (Avanesov 1984; Timberlake 1993), that can be described as phonologically differentiated by the features [±anterior] (anteriority/posteriority /s s̱ vs. /j s̱/) and secondary articulation [±back] (velarization/palatalization: /s̱ vs. /s̱ j/) (3).

(3) a. /s/ sol’ соль ‘salt’
   /s̱/ s̱el сёл ‘villages, gen.’
   /ʃ/ [ʂ] šelk шёлк ‘silk’
   /ʃ̱/ [ʂ̱ː] ščelk шёлк ‘click’

b. /s/ sbros сброс ‘dump’
   /s̱/ bros’ брось ‘throw, imp.’
   /ʃ/ [ʂ] broš’ брошь ‘broach’
   /ʃ̱/ [ʂ̱ː] boršč борщ ‘borsht’

Importantly for the current study, the language shows no apparent restrictions on combinations of sibilant consonants within a word or a
root, as shown in (4). (It should be also noted that the four segments differ in terms of their relative frequency (/s/ > /s\j/, /ʃ/ > /ʃ\j/; Kučera & Monroe 1968: 31) and in patterns of alternations (mainly /s/ - /s\j/ and /s/ - /ʃ/; Timberlake 1993)).

\[
\begin{array}{cccc}
\text{ʃ}s & \overset{\text{quick}}{\text{šustryj}} & \overset{\text{’quick’}}{\text{шустрый}} \\
\text{s\j} & \overset{\text{’being’}}{\text{suščnost’}} & \overset{\text{сущность}}{\text{суščnost’}} \\
\text{s\j} & \overset{\text{’land’}}{\text{suša}} & \overset{\text{суша}}{\text{suša}} \\
\text{ʃ\j}s & \overset{\text{’happiness’}}{\text{ščast’je}} & \overset{\text{счастье}}{\text{ščast’je}}
\end{array}
\]

In terms of the ABC analysis, Russian exhibits a ranking where constraints triggering sibilant harmony are dominated by Input/Output faithfulness constraints: Ident[±ant] » Id-CC(Place), Corr $\tilde{S}$$\leftrightarrow\tilde{S}$, etc. Yet, rankings of subsets of relevant constraints are presumably the same as in languages with sibilant harmony, since these rankings are assumed to be phonetically/cognitively motivated. Specifically, this refers to the rankings encoding the target/trigger asymmetries (Ident-IO[-anterior] » Ident-IO[+anterior]) and directionality (Ident-C$_R$C$_L$(Place) » Ident-C$_L$C$_R$(Place)). One may also expect fixed rankings of correspondence constraints referring to segment pairs that differ in similarity, for example, Corr S$^F$$\leftrightarrow\tilde{S}^F$ » Corr S$$\leftrightarrow\tilde{S}$ (where C$^F$$\leftrightarrow$C$^F$ stands for segments that share secondary articulation features). The tableau in (5) illustrates a relevant subset of the Russian grammar.

(5) Partial ABC analysis of Russian (no sibilant harmony)

<table>
<thead>
<tr>
<th>/s\j/</th>
<th>Id-IO [-ant]</th>
<th>Id-IO [+ant]</th>
<th>Id-CC(Place$^L$)</th>
<th>Corr S$^F$$\leftrightarrow\tilde{S}^F$</th>
<th>Corr S$\leftrightarrow\tilde{S}$</th>
<th>Id-CC(Place$^R$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. $s\j$s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. $s\j$s</td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. $\text{ʃ}s\j$s</td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. $s\j$s</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.2 Phonetics

Based on previous descriptions of articulation of Russian fricatives (using x-ray tracings and static palatography: Avanesov 1984; Bolla 1981) and our current work on the dynamic aspects of these sounds using ultrasound (with Tim Bressman, in prep.), we assume the gestural representations for the Russian fricatives (supra-laryngeal gestures) shown in (6). These representations specify articulatory targets of articulatory gestures – linguistically-significant movements of articulators, following Browman & Goldstein (1989).

(6) Articulatory gestures involved in the production of Russian fricative sibilants. TT = Tongue Tip; TB = Tongue Body; [critical], [narrow], and [wide] refer to constriction degrees.

<table>
<thead>
<tr>
<th>Consonant</th>
<th>Primary constriction gesture</th>
<th>Secondary constriction gesture</th>
</tr>
</thead>
<tbody>
<tr>
<td>/s/</td>
<td>TT [critical, alveolar]</td>
<td>--</td>
</tr>
<tr>
<td>/s/</td>
<td>TT [critical, alveolar, down]</td>
<td>TB [narrow, palatal]</td>
</tr>
<tr>
<td>/ʃ/ [ʃ]</td>
<td>TT [critical, palatal, up]</td>
<td>TB [narrow, palatal]</td>
</tr>
<tr>
<td>/ʃ/ [ʃː]</td>
<td>TB [critical, palatal]</td>
<td>(TT [down])</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(TB [narrow, palatal])</td>
</tr>
</tbody>
</table>

Several points in this table deserve special attention. First, the anterior nonpalatalized fricative /s/ is gesturally relatively simple, lacking the tongue body constriction. Second, the anterior palatalized fricative /s/ has a dual articulatory nature; it is similar to /s/ by having an alveolar primary constriction, while being similar to the other fricatives by having a more posterior tongue body constriction. These gestural properties may render /s/ and /ʃ/ relatively dynamically unstable, when featurally similar (and possibly more gesturally complex) consonants are planned and produced in the same utterance (cf. Pouplier & Goldstein 2005 on the English contrast /s/ vs. /ʃ/).

3. Experiment

The goal of this experiment was to investigate patterns of speech errors with Russian fricatives and to test parallels between errors and consonant harmony patterns.
3.1 Method
Four native speakers of Russian participated in the study: two females (S1 and S2) and two males (S3 and S4) from Perm’. The first three speakers were monolinguals recorded in Russia; the last speaker was a late English bilingual (the first author), recorded in Toronto, Canada.

The stimuli were two-word (nonsense) utterances with alternating onset consonants of the type $C_1{ap} C_2{ap}$, where $C_1/C_2$ differed in primary (anterior/posterior) and secondary places (velarized/palatalized). The list of stimuli is given in (7). Each item was presented one at a time in Cyrillic; all instructions were given in Russian. The task employed was the repetition task (cf. Pouplier & Goldstein 2005; Goldstein et al. 2007), where a speaker was asked to repeat each utterance as fast as possible. To determine the ‘default’ acoustic properties of the four fricatives, the speakers were also asked to produce them in the following nonsense words: a’sa, a’sja, a’ʃa, a’ʃja (presented in Cyrillic: асá, ася́, ащá, ащя́). These will be referred to as ‘control items’.

(7) Target stimuli used in the experiment

<table>
<thead>
<tr>
<th>$C_1$</th>
<th>$C_2$</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>s [+ant, +bk]</td>
<td>s’ [+ant, -bk]</td>
<td>sap s’ap сап сяп</td>
</tr>
<tr>
<td>s’ [-ant, +bk]</td>
<td>s [+ant, +bk]</td>
<td>sap s’ap сап сяп</td>
</tr>
<tr>
<td>s’' [-ant, -bk]</td>
<td>s’ [-ant, -bk]</td>
<td>s’ap s’ap сяп сяп</td>
</tr>
<tr>
<td>s’' [-ant, +bk]</td>
<td>s’ [-ant, +bk]</td>
<td>s’ap s’ap сяп сяп</td>
</tr>
<tr>
<td>s' [-ant, +bk]</td>
<td>s' [+ant, -bk]</td>
<td>s’ap s’ap сяп сяп</td>
</tr>
<tr>
<td>s' [-ant, +bk]</td>
<td>s' [+ant, -bk]</td>
<td>s’ap s’ap сяп сяп</td>
</tr>
</tbody>
</table>

The recordings of S1-S3 were made directly to a laptop computer using a head-mounted dynamic microphone Shure SM-10A in a quiet room; recordings of S4 were made to a portable digital recorder Fostex FR-2 using a cardioid condenser microphone AT3035 in a sound-attenuated booth at the University of Toronto phonetics lab. The
sampling rate was 44 kHz with 16-bit resolution. On average, 178 tokens were collected per speaker, or 22 tokens per each target utterance.

Acoustic analysis of control items included a range of measurements previously used in studies of fricatives (Gordon et al. 2002, Kochetov & Lobanova 2007, Padgett & Zygis 2007, among others): fricative duration (ms), relative intensity of fricative noise (compared to the following vowel, dB), formant transitions to the following vowel - F1, F2, F3 (Hz), and the centre of gravity – mean frequency of fricative noise (COG, Hz). The results showed that COG and F2 distinguished the contrasts most consistently. COG values for males were about 5500-5600 Hz for /s/ and /ʃ/, and about 3800 Hz for /ʃ/ and /ʃ/; for females, they were about 5600-6100 Hz for /s/ and /ʃ/, and about 3700-3900 Hz for /ʃ/ and /ʃ/. F2 values for males were about 1400 Hz for /s/ and /ʃ/, and about 1850 Hz for /ʃ/ and /ʃ/; for females, they were about 1600-1700 Hz for /s/ and /ʃ/, and about 2050-2100 Hz for /ʃ/ and /ʃ/. Figure 1 illustrates the acoustic contrasts among the four fricatives, as produced by Speaker 2 (largely representative of all the participants). The anterior/posterior contrasts correspond to higher or lower COG (high or mid frequency noise, correlated with the length of the front oral cavity); the palatalized/non-palatalized contrasts correspond to higher or lower F2 (correlating with the front/back position of the tongue body).

Given these findings for control items, the acoustic analysis of target utterances was limited to the measurements of COG of fricative noise and F2 at the onset of the following vowel. The details of the token classification into errors and non-errors will be discussed below.

3 All the speakers produced the ‘ш’ sound as a palatalized fricative, consistently with the standard Russian pronunciation (Avanesov 1984: 112–114). For most speakers, this fricative was significantly longer than /ʃ/ and /s/, but not necessarily longer than /ʃ/ (S1, S2, and S4; no any differences for S3). The posterior fricatives tended to have higher intensity than their anterior counterparts: /ʃ/ > /s/ (S1, S2, S4) and /ʃ/ > /ʃ/ (S1, S2, S3).
Figure 1. Tokens of the fricatives /s s ʃ ʃ j/ in control (V_V) utterances produced by speaker 2, plotted by centre of gravity of fricative noise (COG, in Hz) and second formant (F2, in Hz) values at the onset of the following vowel. Vertical and horizontal lines correspond to the means for each parameter.

3.2 Predictions
It was expected that most productions of sibilants would be error-free, given the assumed ranking of relevant constraints for Russian (Ident-IO[±ant] » Ident-CC(Pl), Corr S→Ś; see section 2). Most errors were expected to be assimilatory, rather than dissimilatory or exchange (metathesis-like) errors, since phonological long-distance interactions of sibilants are predominantly assimilatory. With respect to targets and triggers of assimilatory errors in primary place, it was expected that [+anterior] fricatives (/s/ and /s ʃ/) would be the primary targets and [-anterior] fricatives (/ʃ/ and /ʃ j/) would be the primary triggers (given the functionally-motivated ranking Id-IO[-anterior] » Id-IO[+anterior]). This
prediction was also based on previous speech error studies with English fricatives /s/ and /ʃ/ (Stemberger 1991, among others).

With respect to directionality, errors were expected to be predominantly regressive (anticipatory) (given the assumed ranking Id-CrC1(Place) > Id-C1R (Place)). With respect to similarity, consonants that agreed in secondary articulation (/s/ and /ʃ/, /s/ and /ʃ/) were expected to participate in errors to a greater extent than consonants that did not agree in it (/s/ and /ʃ/, /s/ and /ʃ/) (given the assumed ranking S↔ŠF » Corr S↔Š).

It was difficult to make specific predictions about errors in secondary place, given the paucity of long-distance assimilation involving secondary articulations (Hansson 2007). Consonants with secondary articulation, especially palatalization, have a strong effect on adjacent vowels; it was therefore hypothesized that errors with palatalized consonants may show some properties of palatal vowel harmony (with [-back] as a trigger and progressive directionality).

Finally, phonetic realization of primary and secondary articulation errors was expected to be both gradient/partial and categorical/complete. It was also expected that phonetic gestural properties (e.g. the relative dynamic instability of /s/ and /ʃ/ in the context of featural similarity) of segments could play a role.

3.3 Results
A preliminary analysis of data identified disfluent productions, i.e., errors that a speaker attempted to correct errors (e.g. sapʃap → ʃ-sapʃap) or non-errorful hesitations and false starts (e.g. sapʃap → s-sapʃap). These accounted on average for 11% of all collected tokens. The focus of this paper, however, will be on fluent productions, that is, utterances without attempted corrections or hesitations (cf. Frisch & Wright 2002).

For each utterance, the last 10-11 tokens of fluent productions were selected for acoustic analysis (more tokens were collected and analyzed for S4). The results of the analysis show that the four categories /s sʃʃʃ/ were largely kept distinct (based on statistically significant differences between in /s sʃʃʃ/ vs. /ʃʃʃ/ in COG and /sʃʃʃ/ vs. /ʃʃʃ/ in F2, consistent with the findings for control items). However, both categorical and gradient deviations from the expected patterns were often observed, overall and in
terms of individual tokens. This is illustrated in Figure 2, which plots all fluent productions of the four consonants by Speaker 2. Note the overall greater within-category variability, compared to the production of the same consonants in control items, whose range is indicated by the circles and vertical/horizontal lines (see Figure 1).

![Figure 2](image)

**Figure 2.** Tokens of the fricatives /s sʲʃʃ/ in target (C1ap C2ap) utterances produced by speaker 2, plotted by centre of gravity of fricative noise (COG, in Hz) and second formant (F2, in Hz) values at the onset of the following vowel. Ovals and vertical/horizontal lines correspond to the distribution of the four categories and means for each parameter in control items.

To further analyze the data, it was necessary to consistently classify all productions as errors or non-errors. To do that, we adopted the following error metric: An error was defined based on a midpoint between innerquartile means (IQM) for 2 categories (cf. Pouplier 2008) for either COG or F2. This procedure excludes from consideration 25% of tokens at both ends of the lowest-to-highest continuum, effectively...
eliminating all outliers. As shown in Figure 3, the threshold for the /s/ vs. /ʃ/ contrast for Speaker 2 was determined as a midpoint between the innerquartile means for both consonants. All tokens of the intended /s/ that had F2 below this threshold (1957 Hz) were classified as non-errors ([+back]) and those above it were classified as errors ([-back]). Similarly, the threshold for the /s/ vs. /ʃ/ contrast was a midpoint between the IQM values for the two consonants. All tokens above the threshold (4458 Hz) were classified as non-errors ([+anterior]), and all tokens below it as errors ([-anterior]).

Figure 3. An illustration of the classification procedure where all tokens of the intended /s/ are classified as errors and non-errors based on midpoints between pairs of innerquartile means (IQM) for F2 and COG of the categories /s/, /ʃ/, and /ʃ/. See the text for details.

Errors determined by this procedure were further labeled as either ‘assimilatory’ (e.g. sap ʃap → ʃap ʃap, s'ap sap → s'ap s'ap), ‘dissimilatory’ (sap s'ap → sap ʃap), or ‘exchange errors’ (metathesis-
like; e.g. ñap sap → sap ñap). Such errors could be either categorical or
gradient (in the sense of Goldstein et al. 2007); however, no attempt was
made to distinguish the two types. Further, tokens that belonged to an
intended category but had more extreme COG or F2 values (determined
as the distance from IQM to the relevant threshold, taken in the opposite
direction) were also considered as dissimilatory errors (gradient; e.g. a
more extreme COG value of /s/ in sap ñap). Depending on the direction
of the change, assimilatory and dissimilatory errors were labeled as
‘regressive’ (anticipatory, e.g. sap ñap → ñap ñap) or ‘progressive’
(perseveratory, e.g. ñap sap → ñap ñap).

Based on the adopted error metric, on average 18% of speakers’
fluent productions were classified as errors (28% for S1, 27% for S2,
11% for S3, and 9% for S4). Figure 4 plots total numbers of errors for
each speaker, broken down by assimilatory, dissimilatory, and exchange
errors. It is seen that for all four speakers, assimilatory errors were
predominant, followed by dissimilatory errors; exchange errors were
rather infrequent or absent altogether.

![Figure 4. Numbers of errors per speaker (fluent productions), classified by type: assimilatory, dissimilatory, and exchange errors](image-url)
Figure 5 plots all assimilatory errors (pooled from four speakers), broken down by the acoustic dimension and featural changes. In terms of COG, most errors involved a change from anterior ([+anterior]) to posterior ([-anterior]). In terms of F2, there were more errors involving palatalization ([+back] $\rightarrow$ [-back]) rather than depalatalization.

Further exploring the most common changes, [+anterior] $\rightarrow$ [-anterior] and [+back] $\rightarrow$ [-back], Figure 6 presents total numbers of errors for each segmental change, broken down by directionality. The first two errors in (a) involve a change of /s/ to [ʃʃ] before /ʃ/ or /ʃʃ/; the other four errors involve a change of /ʃ/ to [ʃʃ] or (less commonly) to [ʃʃ] before or after /ʃ/ or /ʃʃ/. The first error in (b) involves a change of /s/ to [ʃʃ] after or before /ʃʃ/; the other two errors involve a change of /ʃʃ/ to [ʃʃ] after or before /ʃʃ/ or /ʃʃ/. It should be noted that /sʃ/ was the most likely target and /ʃʃ/ was the most likely trigger of primary place errors. In secondary articulation errors, /s/ was the most likely target and /sʃ/ was the most likely trigger. Whether targets and triggers agree or disagree in secondary articulation does not seem to have had an effect, since errors involving both types seemed to be equally frequent. Finally, most
primary place errors were regressive (anticipatory), while most secondary articulation errors were progressive (perseveratory).

Figure 6. Anterior \( \rightarrow \) posterior (a) and nonpalatalized \( \rightarrow \) palatalized (b) errors (all speakers), classified by the segmental change and directionality
Like assimilatory errors, category-changing dissimilatory errors in COG involved changes of anterior /s/ and /s/ to posterior /ʃ/ or /ʃ/ (e.g. sap s'ap → ŋap s'ap). (Note, however, that the former error may be interpreted as assimilatory, as both output fricatives have some kind of a posterior constriction.) Unlike assimilatory errors, category-changing dissimilatory errors in F2 were mostly depalatalizing (s'ap f'ap → sap f'ap). Gradient dissimilatory errors tended to increase F2 of palatalized fricatives, thus enhancing the contrast in secondary articulation. Three quarters of dissimilatory errors were regressive.

Most exchange (metathesis-like) errors involved consonants that disagreed in secondary articulation (either agreeing or disagreeing in primary place, e.g. s'ap sap → sap s'ap, ŋap s'ap → s'ap ŋap).

3.4 Discussion
The results of the experiment support the general predictions that most productions would be error-free and most errors would be assimilatory (harmonic).4 The prediction about targets and triggers of assimilatory errors in primary place have also been supported. Indeed, [+anterior] fricatives were the primary targets and [-anterior] fricatives were the primary triggers. As expected, errors in primary place were predominantly regressive (anticipatory). However, the prediction that more similar consonants (agreeing in secondary articulation) would be more likely to participate in errors did not receive consistent support. It appears that featural similarity can be influenced, or even overridden by phonetic, gestural properties of segments, such as the relative dynamic instability of /s/ and /s/.

As expected, assimilatory errors in secondary articulation patterned differently from primary place errors. Both features were affected in such errors, with [-back] being a more likely trigger (palatalization). Interestingly, these errors were predominantly progressive, unlike the predominantly regressive errors in primary place. This points to some possible parallels between palatalization errors and palatal vowel harmony and suggests that palatalization errors may have an inherently different mechanism, perhaps involving feature spreading rather than

4 It should be noted that dissimilatory errors were not uncommon, at least for three of the four speakers. This result did not fully follow from the predictions.
feature correspondence (cf. Gafos 1999; Ni Chiosáin & Padgett 2001).\(^5\)
Caution, however, should be taken when discussing directionality under
current experimental conditions, since contextual effects within a given
repetition of an utterance could have been confounded by contextual
effects of preceding or following repetitions. This question, therefore,
merits further research.

Finally, the prediction about the phonetic realization of errors –
gradient/partial or categorical/completer was also supported, for both
primary place and secondary articulation errors.

It should be noted that other factors may have influenced the
speakers’ performance, among which are relative phoneme frequency,
lexical neighbourhood, patterning of the segments in alternations, and
influence of stress.\(^6\) Possible effects of these factors are currently under
investigation.

4. General Discussion

The findings of our speech error experiment are consistent with results of
studies of speech errors in English. Recall that these studies also showed
some asymmetries in participating features and directionality
(Stemberger 1991; Frisch 1996). The findings are also in line with the
growing body of work reporting frequent gradient-realizations of speech
errors (Mowrey & MacKay 1990; Frisch & Wright 2002; Pouplier &
Goldstein 2005; Goldrick & Blumstein 2006; Goldstein et al. 2007).

Most important, the patterns of errors are similar to those observed in
languages with phonological consonant harmony (e.g. Sarcee). This
supports the hypothesized link between consonant harmony and speech
production (cf. Walker 2007 on experimental evidence for nasal
consonant harmony). These findings suggest that while consonant
harmony in languages like Russian is not manifested phonologically, it
may become active under certain conditions, triggered by difficulties in
planning and implementing similar consonants.

\(^5\) Our preliminary examination of formant values of vowels in tokens with palatalization
errors, however, did not provide consistent evidence for the spreading alternative.
\(^6\) An examination of vowel duration showed that, although the speakers produced
utterances with both syllables stressed, the primary stress tended to fall on the second
syllable (as manifested by longer vowel duration). There were, however, instances of
errors in utterances whose syllables did not show stress differences.
Interestingly, further evidence for the ‘latent status’ of consonant harmony in Russian comes from sporadic harmonization found in Russian sound changes, loanword adaptation, and dialect formations, as shown in (8) (based on Vasmer 1986-87). These changes involve long-distance assimilation of sibilants in place, mainly regressive assimilation of anterior sibilants to posterior ones.

(8) a. $s\ldots s \rightarrow s\ldots s$  
\begin{itemize}
  \item $\text{čeršen} \ ‘\text{hornet}'$
  \item ($<\text{Old Russian } s\text{ršens};\ cf.\ Slovak\ s\text{ršen})$
  \item $\text{šubaš} \ ‘\text{head of police}'$
  \item ($<\text{Turkish } s\text{ubaş};\ cf.\ Romanian\ s\text{ubasǎ}$
  \item $\text{šaška} \ ‘\text{sword}'$
  \item ($<\text{Circassian/Kabardian } s\text{ešgo}$
\end{itemize}

b. $s\ldots s \rightarrow s\ldots s$  
\begin{itemize}
  \item $\text{šaša} \ ‘\text{highway}'$
  \item ($<\text{French } chaussée;\ cf.\ Standard\ Russian\ šosse}$
\end{itemize}

c. $s\ldots tʃ \rightarrow s\ldots tʃ$  
\begin{itemize}
  \item $\text{šmorček} \ ‘\text{shorty}'$
  \item ($<\text{šmorček};\ cf.\ Standard\ Russian\ smorček}$
  \item $\text{šljaca} \ ‘\text{slush}'$
  \item ($<\text{sljaca};\ cf.\ Standard\ Russian\ sljakot}$
\end{itemize}

5. Conclusion

In this paper we investigated the hypothetical relation between the phonological mechanism of consonant harmony as Agreement by Correspondence and errors in speech production and planning (Hansson 2001; Rose & Walker 2004). The results of the experiment where four Russian speakers produced utterances with various combinations of sibilant fricatives showed that speech errors with fricatives were indeed characterized by some segmental and directionality asymmetries typical of patterns of sibilant harmony. The findings of the study, therefore, provide support for the functional grounding of the mechanism of consonant harmony in difficulties of speech production and planning, while raising some new questions for further research.
References


