Stress Patterns in Intra-word Code-switching

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1 Introduction

Code-switching, the use of two languages within a single discourse, has been studied primarily at the sentence level (Myers-Scotton, 2005; Poplack, 1980; MacSwan, 2012; Muysken, 2000). In contrast, the phonology of *intra-word* code-switching remains less well understood. A recent review of intra-word code-switching research synthesizing 57 examples of intra-word code-switching from more than 20 language pairs shows that existing accounts often disagree on whether morphologically mixed words follow a single phonological system or exhibit hybrid behavior, and that many claims rely on impressionistic evidence or lack discussion of phonological integration altogether (Stefanich et al., 2019). Moreover, much of the evidence supporting a single-phonology account for intra-word code-switching comes from experimental studies targeting segmental features (e.g., voiced obstruents, voicing assimilation) and is drawn primarily from Spanish–English code-switching data (Stefanich & Cabrelli, 2018; Stefanich et al., 2019; MacSwan & Colina, 2014). Extending prior work, we investigate intra-word code-switching in Kazakh–Russian, a robust and socially widespread phenomenon in Kazakhstan (Zharkynbekova & Chernyavskaya, 2022), and examine the phonology of intra-word code-switching at the suprasegmental level. This language pair provides a particularly informative testing ground because Kazakh and Russian differ sharply in prominence systems: Kazakh is typically described as having default word-final prominence largely realized through duration, as shown in (1) (Mukhamedova, 2015; Özçelik, 2015), while Russian has lexical stress that can occur on any syllable and is cued by duration, intensity, and vowel quality, as shown in (2) (Melvold, 1989; Halle, 1973; Crosswhite, 2000; Padgett & Tabain, 2005; Jouravlev & Lupker, 2014; Chrabaszcz et al., 2014).

1. **Kazakh**
   (a) *ɑlˈmɑ* ‘apple’
   (b) *ɑlmɑ-ˈlɑr* ‘apple-PL’
   (c) *ɑlmɑ-lɑr-ˈəm* ‘apple-PL-POSS.1SG’
   (d) *ɑlmɑ-lɑr-əm-ˈdə* ‘apple-PL-POSS.1SG-ACC’

2. **Russian**
   (a) *raˈbotə* ‘work.SG’ vs *raˈbotɨ* ‘work.PL’
   (b) *ˈzamək* ‘castle’ vs *zaˈmok* ‘lock’
   (c) *ˈgorət* ‘city.SG’ vs *gəraˈda* ‘city.PL’
   (d) *kəlɛˈso* ‘tire.SG’ vs *kaˈlʲesə* ‘tire.PL’

The agglutinative morphology of Kazakh makes intra-word switches especially frequent: Russian noun roots can be integrated into a Kazakh morphosyntactic frame via case suffixation (e.g., [ˈ***polzə***-*men*] ‘benefit-INST’, [***stɛ***ˈ***na***-*dɑ*] ‘wall-LOC’, [ˈ***opət***-*qɑ*] ‘experience-DAT’, [***sɛ***ˈ***lo***-*nə*] ‘village-ACC’). In such mixed words, Russian roots may bear different stress patterns – a trochaic pattern as in [ˈ***opət***-*qɑ*] and an iambic pattern as in [***stɛ***ˈ***na***-*dɑ*], while Kazakh suffixation introduces a potential locus for final prominence. Our goal is to determine how prominence is realized when a Russian noun root combines with a Kazakh case suffix: *does stress shift to the suffix, remain on the Russian root, or is there evidence of a hybrid pattern?*

Table 1 summarizes the three working hypotheses and their predictions for Russian-root + Kazakh-suffix inputs (e.g., /ˈopɨt-KA/ and /steˈna-DA/).[1] Under **H1: Kazakh-dominant**, prominence is predicted to fall on

[1] Kazakh case suffixes undergo both backness harmony and voicing assimilation with the stem. We assume their underlying representations are underspecified for these features.

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Table 1: Hypotheses for stress in Russian root + Kazakh suffix combinations.

Underlying Form	Hypotheses	Predictions
/ˈopɨt-QA/ /steˈna-DA/	**H1: Kazakh-dominant** Final lengthening on the suffix.	[opɨtqɑː] [stenadɑː]
	H2: Russian-dominant Root stress preserved.	[ˈopətqɑ] [stɛˈnadɑ]
	H3: Hybrid Root stress preserved + final lengthening	[ˈopətqɑː] [stɛˈnadɑː]

the final syllable. This hypothesis seems plausible, given the Kazakh morphosyntactic frame in which single Russian switches occur. Under **H2: Russian-dominant**, root stress is preserved after suffixation, yielding outputs that retain the original Russian prominence pattern (trochaic or iambic) and exhibit typical Russian vowel reduction in unstressed syllables. Under **H3: Hybrid**, root stress is preserved while Kazakh-style final lengthening may also surface, resulting in both root-aligned prominence and enhanced final duration. We test these predictions experimentally and provide evidence in support of H3 that intra-word code-switching can yield systematic hybrid prominence patterns in bilingual speech.

2 Method

2.1 *Participants* Four Kazakh-Russian bilinguals (2 female, 2 male) participated in the study. At the time of data collection, all participants resided in Irvine, California, having recently moved from Kazakhstan to the United States for educational purposes. The mean age was 29.5 years. All participants identified Kazakh as their native language and Russian as their second language. According to the LEAP-Q survey (Marian et al., 2007), all participants indicated native proficiency for Kazakh, with average self-ratings of 10/10 for understanding, 10/10 for speaking, and 10/10 for reading. They also reported high levels of Russian proficiency, with average self-ratings of 10/10 for understanding, 9.5/10 for speaking, and 9.5/10 for reading. In addition, three participants reported that they started to study Russian as early as 2-3 years old, while only one participant started at the age of 5. In general, all participants are highly proficient in both languages.

2.2 *Stimuli* Disyllabic Kazakh and Russian nouns were elicited in a carrier phrase under three conditions: (a) Kazakh tokens in a Kazakh context (non-CS), with and without Kazakh affixes; (b) Russian tokens in a Kazakh context (CS), with and without Kazakh affixes; and (c) inflected Russian tokens in a Russian context. The Russian and CS stimuli consisted of 40 disyllabic Russian nouns drawn from the Russian National Corpus (Savchuk et al., 2024). The position of lexical stress for each item was confirmed using the Accentological subcorpus (Grishina et al., 2010). The final list was balanced for both stress pattern (50% trochaic, 50% iambic) and stress mobility (50% fixed, 50% mobile). Stress mobility in Russian nominals refers to the variable behavior of lexical stress: stress may be fixed on the root, as in (2a); form stress minimal pairs that distinguish lexical meaning, as in (2b); or shift position under inflection, either moving forward, as in (2c), or backward, as in (2d). For more details on Russian nominal stress patterns, see Melvold (1989).

We selected Kazakh words (40 disyllabic tokens) with roughly similar syllable structure to the Russian words (e.g., CV–CVC, VC–CVC, CV–CV, CVC–CV, and CVC–CVCC). Russian syllable structures involving complex onsets (e.g., CCV, CCVC, CCCV) were approximated, as Kazakh phonotactics prohibit consonant clusters in onset position (McCollum & Chen, 2021:pp. 15–16). Target items were elicited in the following carrier phrase:

3. Būl mätınnıñ ıshınde *X* sözi bar
   'This text contains the word X.'

For CS tokens, the same Kazakh carrier phrase was used. For monolingual Russian tokens (inflected Russian words in Russian sentences), the following Russian carrier phrase was used:

4. Slovo *X* est' v etom tekste
   'This text contains the word X.'

The Kazakh suffixes used in the stimuli had CV and CVC syllable structures and included the accusative, dative, genitive, and plural suffixes. These suffixes follow regular Kazakh allophonic processes of backness harmony and consonant voicing assimilation at the stem-suffix boundary. For example, after stems containing back vowels and ending with voiced sounds, these suffixes surface as: [*pɑjda-nə*] 'benefit-ACC', [*sɑbən-də*] 'soap-ACC'; [*sərʁɑ-ʁɑ*] 'earring-DAT'; [*olʒɑ-nəŋ*] 'trophy-GEN'; and [tʊlʁɑ-lɑr] 'figure/individual-PL'. For Russian tokens, Kazakh suffix forms were selected based on the backness of the final vowel in the Russian root and the voicing of its final sound. Illustrative examples include: [*ˈgorət-tə*] 'city-ACC', [*zaˈkon-də*] 'law-ACC'; [*ˈopət-qɑ*] 'experience-DAT'; [*gaˈra-nəŋ*] 'mountain-ACC'; and [*zvezˈda-lɑr*] 'star-PL'. Participants did not report that the Russian root-Kazakh suffix mappings were perceived as unnatural or incorrect. The complete list of target items is provided on GitHub.[2]

2.3 *Procedure* All recordings were made in the Speech Science Lab at the University of California, Irvine. The participants completed two separate recording sessions in a quiet room. Recordings were made using the software Audacity (Audacity Team, 2024) with a Shure WH20 headset mic and a Focusrite Scarlet 2i2 USB audio interface. The audio recordings were sampled at a frequency of 44,100 Hz with a 16-bit resolution per sample. In the first session, only inflected tokens were recorded, while the second session focused on bare root forms. Before each recording, participants completed two to three practice trials to familiarize themselves with the task. During the task, participants went through randomized PowerPoint slides and read each stimulus embedded in the carrier phrase. All examples were presented in Cyrillic script. Each session lasted approximately 20–30 minutes, including the administration of a background survey in the first session. Overall, we elicited 800 tokens from 40 stimuli produced by 4 speakers across the five conditions (non-CS root vs. inflected; CS root vs. inflected; Russian inflected). The recordings were hand-segmented in Praat (Boersma & Weenink, 2026) at the syllable and vowel levels, and Praat scripts were used to extract measures of syllable duration, mean intensity, and mean f0, as well as vowel formants (F_1, F_2). The resulting datasets each contained over 1,900 observations. One dataset captured syllable-level prosodic measures (duration, intensity, f0), while the other captured vowel-level acoustic measures (formants), with one vowel observation per syllable.

2.4 *Analysis* We conducted two sets of analyses at the *syllable* and *vowel* levels, fitting linear mixed-effects models using `lme4` with `lmerTest` (Bates et al., 2015). Section 3 compares syllable duration, intensity, and pitch between CS and non-CS tokens; Section 4 compares vowel formants between CS and non-CS tokens; and Section 5 presents a phonological analysis. All data and code is available on GitHub.[2]

3 Syllable-Level Modeling

In this section, we first establish baselines for monolingual tokens by predicting syllable duration, intensity, and pitch from syllable position for Kazakh, and from stress placement and syllable position for Russian. We then proceed to the analysis of mixed tokens by predicting acoustic measurements from stress placement, word form (root vs. inflected), and language context (non-CS vs. CS), including relevant interactions, with random intercepts for speaker and word in all models.

3.1 *Stress Position and Acoustic Correlates in Kazakh* We first analyzed Kazakh-only tokens to test existing claims about word-level prominence. The literature presents two conflicting accounts of prominence in Kazakh. The dominant view holds that word-level prominence is final (Balakayev, 1962; Mukhamedova, 2015; Kirchner, 1998; Musaev, 2008), whereas an alternative view argues that Kazakh lacks word-level prominence altogether (Vajda, 1994; Dzhunisbekov, 1987). However, to our knowledge, Kazakh stress has not been investigated extensively using experimental methods that could shed light on these competing claims. Moreover, the limited existing experimental work continues to yield divergent interpretations. For instance, Özçelik (2015) identifies duration as the most reliable correlate of prominence in Kazakh and suggests that prominence is typically associated with word-final position. However, subsequent experimental

[2] `https://github.com/moldir23/ICS_Acoustic_Analysis`

evidence remains inconclusive: McCollum (nd) shows that while lengthening of word-final syllables is robust, its source – word-level stress or phrase-level prosodic effects – cannot be clearly identified, with evidence supporting stress-related durational contrasts emerging only in non-final positions in verbs. Overall, McCollum argues that Kazakh does exhibit stress, but its acoustic correlates are weak (McCollum, nd:p. 1). In light of this evidence, the present study contributes to clarifying the realization of stress in Kazakh, particularly in nominal forms, through quantitative analysis.

First, to test whether final syllables are prominent in both root (uninflected) and inflected tokens, we fit models predicting acoustic measures (duration, mean intensity, or mean pitch) from syllable position (s1, s2, s3), word form (inflected vs. uninflected), and their interaction. Our results are consistent with the prevailing view that the expected pattern involves final-syllable lengthening, as shown in Figure 1, panel A. In disyllabic root (uninflected) forms, the second syllable (s2) was significantly longer than the first (s1) ($\beta = +52.62$ ms, $p < .001$); and in inflected forms, post-hoc Tukey comparisons revealed no reliable durational difference between the first and second syllables (s1-s2: estimated difference = 0.50 ms, $p = .996$), indicating that these positions are durationally comparable. In contrast, the third syllable (s3) was significantly longer than both s1 and s2 (s3-s1: estimated difference = 47.64 ms, $p < .0001$; s3-s2: estimated difference = 48.13 ms, $p < .0001$), consistent with robust final-syllable lengthening. Intensity (Figure 1, panel B) did not consistently vary by syllable position across word types ($p = 0.53$); however, there was an effect of word form such that syllables in inflected forms were louder than in uninflected forms ($\beta = +6.48$, $p < .001$). Fundamental frequency (f0) was reduced in root forms in the final syllable ($\beta = -15$, $p < .001$), while inflected forms showed elevated f0 in the final syllable ($\beta = +11.26$, $p < .001$; see Figure 1, panel C). We note that the pitch differences observed between root and inflected forms may arise from differences in prosodic phrasing, and the intensity differences from microphone placement, as the two forms were recorded in different sessions. In addition, as noted by McCollum (n.d.), f0 variation in Kazakh may reflect phrase-level intonational effects rather than word-level stress, particularly in final position.

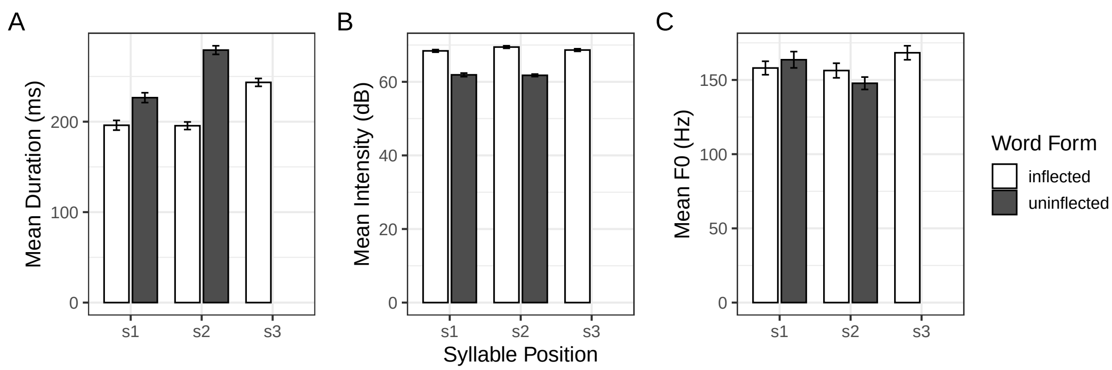

Figure 1: Mean acoustic measurements across syllable positions (s1, s2, s3) in Kazakh tokens by word form (inflected vs. uninflected). **Panel A:** Mean duration (ms). **Panel B:** Mean intensity (dB). **Panel C:** Mean f0 (Hz). Error bars represent standard error.

In sum, the acoustic evidence presented here supports claims that Kazakh nouns display final prominence cued by increased duration, but does not allow us to determine whether this is the result of word-level stress or phrasal prosody.

3.2 *Acoustic Correlates of Russian Stress* In contrast, based on the productions of Kazakh-Russian bilingual speakers, lexical stress in Russian significantly influences all three acoustic correlates, with duration emerging as the most distinctive, aligning with previous experimental accounts of Russian stress (Chrabaszcz et al., 2014; Padgett & Tabain, 2005; Yanushevskaya & Bunčić, 2015). For the Russian tokens, we fit models that predict a syllable's acoustic measurements (duration, mean intensity, or mean pitch) from stress (stressed vs. unstressed). The duration model revealed that unstressed syllables are shorter than stressed ones ($\beta = -34.18$, $p < .001$; Figure 2, panel A), highlighting duration as a robust cue to prominence across across both Kazakh and Russian. Unstressed syllables also have lower intensity ($\beta = -1.97$, $p < .001$; Figure

2, panel B); however, this difference falls near reported perceptual thresholds (McShefferty et al., 2015). Finally, unstressed syllables exhibit lower pitch than stressed syllables ($\beta = -8.39$, $p < .001$; Figure 2, panel C); however, native Russian speakers have been reported to be less sensitive to pitch changes under stress (Chrabaszcz et al., 2014: p. 11).

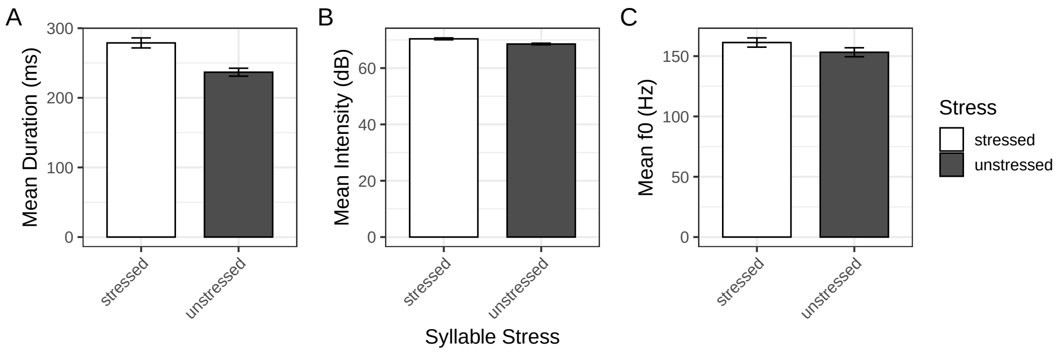

Figure 2: Mean acoustic measurements for stressed vs unstressed syllables in Russian tokens derived in a Russian carrier phrase. **Panel A:** Mean duration (ms). **Panel B:** Mean intensity (dB). **Panel C:** Mean f0 (Hz). Error bars represent standard error.

To test whether there are effects of syllable position on acoustic correlates beyond those attributable to stress, we fit separate linear mixed-effects models predicting duration, mean intensity, and mean f0 from stress (stressed vs. unstressed) and syllable position (s1, s2, and s3), as well as their interaction.

Across syllable positions, our models revealed position-dependent realization of stress on acoustic correlates. For duration, with stressed s1 as the reference level, unstressed syllables were shorter than stressed syllables ($\beta = -41.36$ ms, $p = .006$), and stressed syllables in s2 and s3 were longer than those in s1 ($\beta = +47.70$ ms, $p = .004$; $\beta = +69.56$ ms, $p = .012$). The duration of stressed syllables in s2 and s3 did not differ significantly ($p > .30$).

Next, we look at intensity, again with stressed s1 as the reference level. The effect of stress is not significant ($p = .45$), but there is a significant stress and syllable position interaction at s3 ($\beta = -3.50$ dB, $p = .028$), indicating that unstressed syllables in the final position were reliably less intense than stressed s1.

For f0, unstressed syllables had lower pitch than stressed syllables at s1 ($\beta = -15.65$ Hz, $p < .001$), but this contrast was effectively absent at s2 (interaction: $\beta = +15.19$ Hz, $p = .008$) and showed no further modulation at s3 ($p = .82$).

Since duration appears to be the most distinctive correlate of stress in Kazakh-Russian bilingual productions, further post-hoc Tukey comparisons were conducted only on the duration model and showed that stressed syllables were significantly longer than unstressed syllables in all syllable positions, with robust and reliable effects in s1 (estimated difference = 41.4 ms, $p = .007$), in s2 (estimated difference = 66.6 ms, $p < .0001$) and in s3 (estimated difference = 57.0 ms, $p = .048$).

In sum, Russian lexical stress is realized through multiple acoustic dimensions, with duration serving as the most robust and consistent correlate. While intensity and f0 also differentiate stressed from unstressed syllables, their contributions are more context-dependent. Together, these findings indicate that Russian stress is primarily encoded through durational prominence, consistent with prior work on Russian stress realization, and suggest that, in the present study, bilingual speakers show largely stable realizations of Russian stress, despite Russian functioning as their second language.

3.3 *Acoustic Correlates of Stress in Code-switching* So far, we have found that in both Kazakh and Russian, duration is the most reliable acoustic correlate of prominence. However, the two languages differ in how this durational prominence manifests at the word level: in Kazakh, prominence is positionally defined, with final syllables being longer, whereas in Russian, duration is tied to stress position. This leads to the central question: *in code-switched words, is prominence realized according to Kazakh positional patterns or Russian stress-based patterns?*

First, to examine whether Russian prominence is preserved in both inter-word (uninflected) and intra-word (Kazakh-inflected) code-switched tokens, we check to see that stressed syllables are longer than unstressed syllables. We fit a model predicting syllable duration by word form (inflected vs. uninflected), root stress (1 = stress on s1; 2 = stress on s2), and their interaction, together with random intercepts for root and participant. As Figure 3 shows, unstressed syllables were shorter than stressed syllables ($\beta = -45.78$ ms, $p < .001$) and syllables in inflected forms were shorter than uninflected forms ($\beta = -53.59$ ms, $p < .001$). However, the interaction was not significant ($\beta = +16.40$ ms, $p = .149$), providing no reliable evidence that inflection modulates the durational stress contrast. Given that stressed syllables in Russian roots have similarly longer durations in both inter-word and intra-word contexts, we conclude that Russian prominence (i.e., the lengthening associated with stress) is preserved in intra-word code-switching.

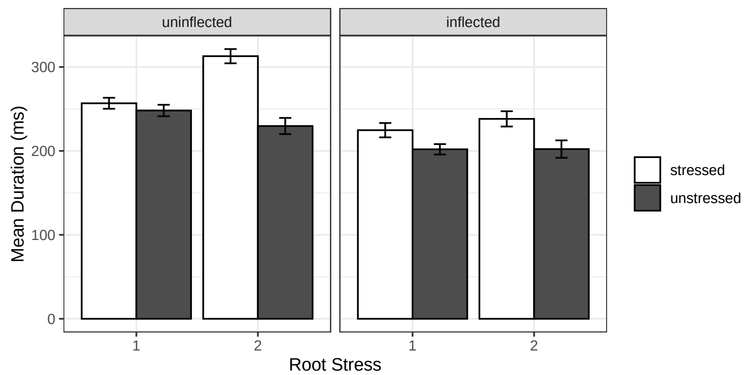

Figure 3: Mean duration (ms) in uninflected and inflected code-switched tokens, plotted by root stress position (1 = stress on s1; 2 = stress on s2) and stress placement (stressed vs. unstressed). Error bars represent standard error.

Next, we investigated whether Kazakh prominence (i.e., final lengthening) is preserved in intra-word code switches. To evaluate the presence of Kazakh prominence in intra-word switches, we first compared the duration of s3 (the Kazakh suffix) with the duration of stressed syllables in the Russian root. We fit a model predicting syllable duration by syllable position. One model compared stressed s1 with s3, and the other compared stressed s2 with s3. As Figure 4 shows, we do not have evidence that stressed s1 or stressed s2 are reliably longer than s3 (s1 vs. s3: $p = .49$; s2 vs. s3: $p = .67$). The duration of s3 is comparable to that of the stressed syllable in the Russian root, suggesting that the Kazakh suffix is similarly prominent.

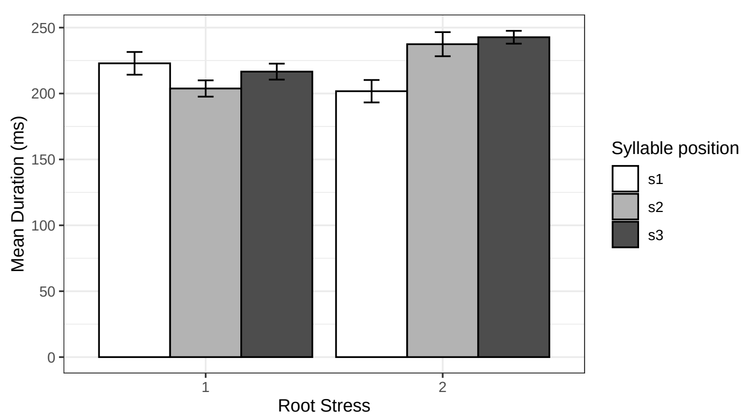

Figure 4: Mean duration (ms) across syllable positions (s1, s2, s3) in inflected code-switched tokens, grouped by root stress position (1 = stress on s1; 2 = stress on s2). Error bars represent standard error.

We then checked whether the prominence observed for s3 in intra-word code-switches compares to the Kazakh baseline for final lengthening in Kazakh (i.e., non-code-switched) words. Figure 5 plots s3 duration for code-switched and Kazakh words; a model predicting syllable duration by context (code-switched vs. Kazakh) did not find that s3 in code-switched tokens was reliably shorter than s3 in Kazakh tokens ($\beta = -8.92$, $p = 0.27$). In other words, final lengthening is comparable across both contexts.

Together with our finding from above that s3 in intra-word code-switches is comparable in duration to the stressed Russian root syllable, this result suggests that Kazakh-style final lengthening is preserved in intra-word code-switches.

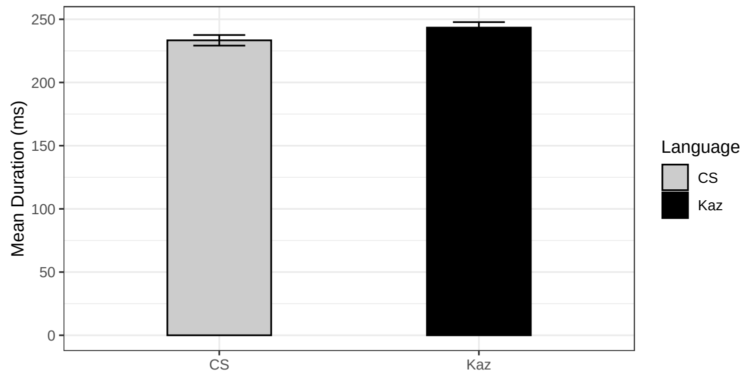

Figure 5: Mean duration (ms) for the final syllable (s3) in Kazakh and CS. Error bars represent standard error.

In sum, these results suggest that Russian prominence is preserved in intra-word code-switches, as stressed syllables are longer than unstressed syllables in inflected forms. They also suggest that Kazakh prominence is also preserved in intra-word code-switches, as we observed that stressed Russian syllables, both s1 and s2, are comparable to the Kazakh suffix s3, which itself is comparable to the Kazakh non-code-switched baseline for s3 duration. Taken together, these results support hypothesis **H3: Hybrid**: Russian root stress is preserved, while Kazakh final lengthening also surfaces in intra-word code-switching.

4 Vowel-Level Modeling

4.1 *Effects of Stress on Vowel Quality in Russian and Code-Switched Tokens* In addition to syllable duration, Russian stress is closely tied to vowel quality: stressed vowels retain their full quality, whereas unstressed vowels undergo systematic reduction (Crosswhite, 2000; Padgett & Tabain, 2005). To examine whether this stress-related pattern is preserved in a code-switched context, we analyzed vowel quality in both monolingual Russian and mixed productions using first and second formant values (F1 and F2). Following Wright et al. (2004), vowel quality was quantified as the degree of dispersion in the vowel space, operationalized as the Euclidean distance of each token from the center of the speaker's F1–F2 space. Under standard accounts of Russian stress, stressed vowels are expected to show greater dispersion than unstressed vowels; the central question is whether the magnitude of this stress-based contrast differs between Russian and code-switched contexts. *In other words, we ask whether Russian vowel reduction occurs in intra-word code-switches.*

Raw F1 and F2 values for Russian root vowels were converted to the Bark scale using the auditory transformation proposed by Traunmüller (1997). Dispersion values computed in Bark-transformed space and were analyzed using a linear mixed-effects model predicting vowel-space dispersion from stress (stressed vs. unstressed), vowel identity, and context (Russian vs. intra-word code-switched), with random intercepts for word and speaker.

The model revealed a robust effect of stress (Figure 6): unstressed vowels in the Russian context exhibited significantly smaller vowel-space dispersion than stressed vowels ($\beta = -0.435$, $p < .001$), indicating greater centralization under reduced prosodic prominence. In contrast, context-related effects were comparatively weak. Relative to the Russian reference level, code-switched inflected tokens did not differ reliably in vowel-space dispersion ($\beta = -0.019$, $p = .85$). In other words, the effect of stress on vowel quality was consistent across contexts, with no additional effect of code-switching once stress was taken into account. Figure 7 further illustrates vowel reduction patterns by individual vowel identity in Russian and code-switching contexts. Several of the stimuli includes the palatalized vowel allophone [æ], which we treat as a separate category due to its acoustic distinctness.

Overall, analyses based on Bark-transformed formants indicate that stress is the primary predictor

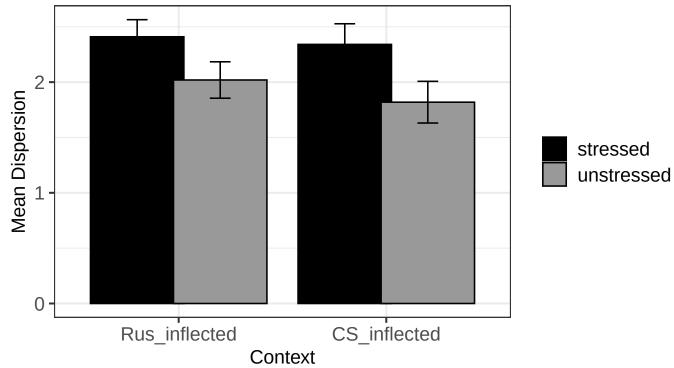

Figure 6: Mean dispersion for stressed and unstressed vowels by context. Error bars indicate 95% confidence intervals.

of vowel-space dispersion in the present data, with unstressed vowels showing systematic centralization. Crucially, this stress-conditioned pattern appears to be preserved in code-switched speech, as contextual differences between monolingual Russian and code-switched productions do not yield robust effects beyond those attributable to stress and vowel identity. We therefore find additional evidence that Russian prominence is preserved in intra-word code-switches.

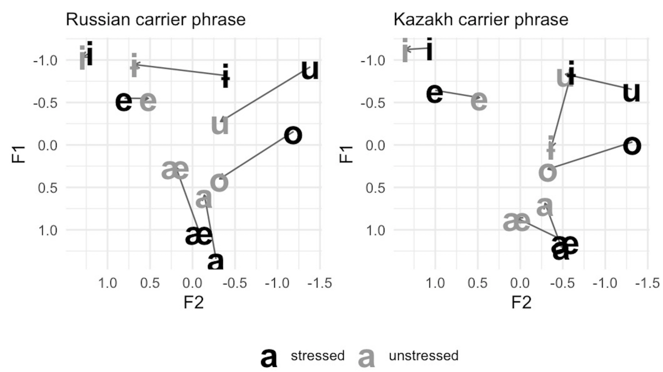

Figure 7: Vowel spaces showing Z-score normalized mean F1 and F2 values by vowel category, separated by stress condition (stressed vs. unstressed). **Left panel:** Russian tokens elicited within a Russian carrier phrase in an inflected context. **Right panel:** CS tokens elicited within a Kazakh carrier phrase with Kazakh suffixes.

5 Phonological Analysis

The experimental results support a *hybrid stress pattern* in Kazakh-Russian intra-word code-switching, whereby Russian-derived roots retain core stress properties while participating in Kazakh morphophonological processes at the level of the word and phrase. We find evidence for this conclusion from the analyses of syllable duration, where we saw that both Russian and Kazakh prominence is preserved in code-switched tokens, and of vowel quality, where we saw that Russian vowel reduction applies similarly in both Russian and code-switched tokens. This suggests that in code-switched tokens, Russian phonology applies at the level of the root (duration and vowel quality) and Kazakh phonology at the level of the word (backness harmony and voicing assimilation) and phrase (final lengthening), but without modifying the root. This pattern, where phonological processes apply first to smaller units and then to larger ones without necessarily overwriting the processes applied to the smaller units, is similar to other phenomena that have motivated the use of *levels* or *strata* in phonological models (e.g. Kiparsky, 1982, 2015). Building on the proposal in Stefanich

(2019:p. 135) that this mechanism might be used to model hybrid phonology in intra-word codeswitching, we present an analysis using Stratal Optimality Theory (Kiparsky, 2015; Bermúdez-Otero, 2017).

In Stratal OT, the grammar is divided into strata associated with hierarchically-related domains such as the root, the word, and the phrase. Each stratum has an associated OT grammar (Prince & Smolensky, 2004), with constraint rankings allowed to differ across strata. The output of strata that are lower in the hierarchy serve as the input to higher strata. In the analysis we present here, rather than associating strata with morphosyntactic domains, we associate them with *languages*. Intuitively, our analysis proceeds as follows: in code-switched tokens, the embedded Russian root first undergoes Russian phonological processes that determine stress position and vowel reduction. This derived root subsequently serves as the input to Kazakh word-level morphophonology, which attaches a case suffix and applies vowel harmony (and voicing assimilation, which we will not illustrate here), but without further modifying the Russian root. Finally, a Kazakh post-lexical process of final lengthening applies to the derived word form.[3] We illustrate each component of this analysis below.

5.1 *Stratum 1: Russian* In the first stratum, Russian phonology is applied to the embedded Russian root. We assume the following simplified constraints for our analysis (for more comprehensive analyses, see, e.g. Alderete, 1995; Crosswhite, 2000).

> **MAX-PROM**: Every prominence in the input must have a corresponding prominence in the output (i.e., underlying stress must be preserved in the output; Alderete, 1999).
>
> ***STRUC(FT)**: Assign one violation per foot in the output (i.e., prefer fewer feet/stressed syllables; Prince & Smolensky, 2004).
>
> **HEAD(σ)-IDENT(F)**: Segments in stressed syllables in the output must agree for all features with their input correspondent (i.e., do not reduce stressed vowels; Alderete, 1995).
>
> ***FULLVOWEL**: Vowels should be reduced. We use this schematic constraint as a stand-in for more detailed analyses of Russian vowel reduction (Alderete, 1995; Crosswhite, 2000).
>
> **IDENT(F)**: Features of output segments must match features of corresponding input segments.

The tableau below shows the first stage of the derivation of the intra-word code-switched token /opɨt-KA/ → [opətqɑː] 'experience-DAT', where /K/ refers to a velar stop that is unspecified for backness, and /A/ refers to a low vowel that is unspecified for backness (see, e.g., Mayer et al., 2022). At this stage, the grammar associated with the Russian stratum is applied to the Russian root /opɨt/, producing vowel reduction and preserving the underlying stress location.

/ˈopɨt/	MAX-PROM	HEAD(σ)-IDENT(F)	*FULLVOWEL	IDENT(F)	*STRUC(FT)
☞ a. ˈopət			*	*	*
b. ˈopɨt			**!		*
c. ˈapət		*!		**	*
d. apət	*!			**	

The key rankings are MAX-PROM ≫ *STRUC(FT), preventing deletion of underlying stress (Candidate D); HEAD(σ)-IDENT(F) ≫ *FULLVOWEL, preventing vowel reduction in stressed syllables (Candidate C); and *FULLVOWEL ≫ IDENT(F); preventing full vowels in unstressed syllables (Candidate B).

5.2 *Stratum 2: Kazakh* The derived Russian root next serves as the input to the Kazakh stratum, where Kazakh morphophonology is applied. At this stratum, case suffixes are attached to the Russian root and Kazakh vowel harmony is applied. We introduce the following constraint to capture backness harmony:

> **AGREE**: Vowels and velar consonants must agree for the feature [back] with the preceding vowel (Lombardi, 1999; Hayes & Londe, 2006). In Kazakh, both velar consonants and vowels participate in backness harmony: this constraint is a shorthand for separate VAGREE and CAGREE constraints (e.g., Mayer, 2021: Ch. 4).

[3] We assume for the purposes of this analysis that Kazakh final prominence results from phrasal prosody, but the important details of the analysis remain the same if we assume it is driven by stress.

The constraints MAX-PROM and *STRUC(FT) from the previous subsection will also be used in the analysis.

Finally, we formalize a type of faithfulness constraint that we take to apply to code-switching more generally. We assume that the output of strata corresponding to different languages have a feature reflecting their source language: thus the input received from the Russian stratum described above might be notated as /ˈopət/$_{\text{RUS}}$. We define an indexed faithfulness constraint that applies only to constituents with the RUS tag.

> **FAITH/RUS**: Assess one violation for each modification of a constituent with a RUS tag. This is based on the treatment of Japanese lexical strata in Itô & Mester (2017), and we follow them in consolidating the full family of faithfulness constraints into this abbreviated constraint.

The tableau below shows the second stage of the derivation of [opətqɑː] at the Kazakh stratum.

/ˈopət/$_{\text{RUS}}$+/-KA/	FAITH/RUS	AGREE	*STRUC(FT)	MAX-PROM
☞ a. ˈopətqɑ			*	
b. opətqɑ	*!			*
c. ˈopətke		*!*	*	

The key rankings are FAITH/RUS ≫ *STRUC(FT) ≫ MAX-PROM. Although *STRUC(FT) prefers Candidate B, where stress has been removed from the Russian root, the higher ranked FAITH/RUS constraint prevents this. A hypothetical Kazakh root with underlying stress would not violate FAITH/RUS, and would thus have stress removed. The AGREE constraint requires that the suffix form match the backness of the final vowel in the Russian root. This reflects an interesting property of the intra-word CS tokens in this study: although the Russian root is impermeable to Kazakh phonological processes, it is not phonologically inert, with vowels in the root determining suffix backness following the same pattern as vowels in Kazakh words.

Finally, we assume that final lengthening occurs as a post-lexical process (not illustrated here), producing [opətqɑː] as the surface form.

Taken together, this stratal analysis accounts for the experimentally observed coexistence of Russian stress realization and Kazakh morphophonological processes. The success of this analysis supports a hybrid model of intra-word code-switching in which phonological computation is distributed across strata corresponding to the source language of constituents.

6 Discussion

This study investigated the acoustic correlates of stress in Kazakh-Russian intra-word code-switching, with a focus on how duration, intensity, pitch, and vowel quality vary as a function of stress position and morphological inflection. Across analyses, our findings reveal a complex yet systematic pattern of prosodic integration in bilingual speech. First, non-CS productions were broadly consistent with past descriptions of prominence in Kazakh and Russian, and we provide some new empirical data on Kazakh nominal forms.

Turning to code-switching, the analysis of intra-word code-switched tokens at the syllable level provides support for the hybrid hypothesis (H3). The results show that root stress has a robust effect on syllable duration in both code-switched and non-code-switched tokens, indicating that Russian stress is preserved despite Kazakh suffixation. Further analysis refines this picture by comparing individual syllables within inflected code-switched words. Russian stressed syllables (s1 or s2) are comparable in duration with the Kazakh suffix (s3). The comparison of final syllables in monolingual Kazakh vs. code-switched tokens shows that, relative to Kazakh tokens, final syllables in code-switched words do not differ reliably in duration. We therefore conclude that Russian root stress persists, while Kazakh-style final lengthening also applies.

The vowel-level analyses further support this interpretation. Stress reliably predicts vowel-space dispersion across both monolingual Russian and code-switched contexts, with unstressed vowels exhibiting greater centralization. Crucially, no independent effect of language context emerges once stress is accounted for, indicating that core phonetic properties of Russian stress, including vowel reduction, are preserved in intra-word code-switching.

Our phonological analysis suggests that the derivation of intra-word code-switched forms is organized stratally, with Russian phonology first applying to the root and Kazakh phonology subsequently applying to the word and phrase. The preservation of the properties of Russian roots across higher strata is driven by faithfulness constraints indexed to particular language strata. Beyond capturing the dynamics of intra-word code-switching observed in this study, this approach also holds promise for analyzing other reported cases of intra-word code-switching where the phonology of the matrix language exerts more of an influence on the embedded code-switched structure (Stefanich et al., 2019). Analogous to the case presented in Itô & Mester (2017) for different Japanese loanword strata, varying the ranking of the stratally-indexed faithfulness constraints with respect to the hierarchy of markedness constraints in the matrix language can produce different degrees of nativization of the embedded code-switched form. We leave this as an exciting area for future research, particularly as it pertains to bilinguals with different degrees of language dominance.

Taken together, these findings demonstrate that bilingual speakers coordinate multiple phonological systems within a single word. Intra-word code-switching does not reduce to a single dominant phonological template; instead, it reflects a layered interaction in which Russian lexical stress is preserved at the root level while Kazakh morphophonological effects emerge at the word and phrase level. These results provide empirical support for hybrid and stratal models of bilingual phonology and underscore the importance of experimental acoustic evidence in the study of intra-word code-switching.

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