Vowel Reduction in Israeli Heritage Russian

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ABSTRACT
This study examines vowel reduction patterns of Israeli Heritage Russian speakers (IHRs). Contemporary Standard Russian is well documented as having a complex system of vowel reduction (e.g., Barnes, 2002; Crosswhite, 1999; Jakobson, 1929; Padgett, 2004): specifically, underlying /o/ surfaces as [o] in stressed syllables, as [ɐ] in the first pretonic syllable, and as [ə] in other unstressed syllables. In Modern Hebrew, on the other hand, stressed and unstressed vowels differ in duration, but not in quality (Cohen, Silber-Varod, & Amir, in preparation; Maymon, 2001). We conducted a production experiment to determine the patterns of vowel reduction in the Russian of IHRs. Sixteen IHRs were exposed to audio-based forms of real and nonce words with stressed /o/ and were required to produce the forms with and without stressed suffixes. Thus, underlying /o/ was produced in three distinct prosodic positions: stressed (e.g., /nos/ 'nose sg.'), pretonic (e.g., /nos-ˈɨ/ 'nose pl.'), and antepretonic (e.g., /nos-oˈvoj/ 'nasal.'). The quantity (duration) and quality (F1, F2) of /o/ were acoustically analyzed and compared to a control group of five Russian-speaking adult immigrants to Israel. The results showed that IHRs reduced unstressed /o/ in both real and nonce words, but in producing nonce words they did not display the height contrast that is expected between pretonic and antepretonic vowels. We argue that IHRs' productions of real words may be rote-learnt, whereas their treatment of nonce words better reflects their productive grammar. We propose that IHRs' productive system of vowel reduction is a mixed system, combining aspects of their heritage language (i.e., Russian) and dominant language (i.e., Hebrew).

Keywords: *heritage, phonology, Russian vowel reduction, nonce words*

INTRODUCTION
Heritage language studies have shed new light on fundamental questions in linguistics, particularly regarding the nature of native speakers and the acquisition of linguistic proficiency. Much important work has been done to define and identify heritage speakers (Benmamoun, Montrul, & Polinsky, 2010; Cummins, 2005; Montrul, 2010; Polinsky & Kagan, 2007; Valdés, 2000) and characterize their speech (Au & Romo, 1997; Godson, 2003, 2004; Peyton, Ranard, & McGinnis, 2001; and many others). The present study adds to this body of research by enriching the diversity of both the linguistic domain and the dominant language, focusing on the phonological component in Hebrew-dominant heritage speakers.

We study stress-related vowel reduction in the speech of Israeli Heritage Russian speakers (IHRs). Vowel reduction in Contemporary Standard Russian, as spoken in urban centers in the western (i.e., European) part of Russia, is well documented in native speakers (Alderete, 1995; Barnes, 2002, 2006, 2007; Crosswhite, 1999; Jakobson, 1929; Nesset, 2000; Padgett, 2004; Padgett & Tabain, 2005). The contrast between underlying /o/ and /a/ is neutralized in unstressed positions, so that for each of these phonemes speakers produce three surface forms distinguished in both quantity and quality. Underlying /o/ and /a/ surface respectively as [o] and [a] in stressed syllables, as shorter [ɐ] in the first pretonic syllable, and as the shortest [ə] in other unstressed syllables. In Modern Hebrew, on the other hand, vowel reduction is primarily quantitative (Cohen, Silber-Varod, & Amir, in preparation; Maymon, 2001), as stressed and unstressed vowels differ significantly in duration, but not in quality.

Our data are drawn from an experiment we designed and conducted that examines the production of real and nonce words in order to determine the vowel reduction patterns of Russian speakers, and compares the results of IHRs to those of a control group. This is the first study characterizing Russian vowel reduction in heritage speakers, Hebrew-speaking or otherwise. It is also the first study of Russian vowel reduction done without assuming orthographically-based underlying representations. Moreover, the study is unique in testing Russian reduction patterns in nonce words, which have been argued to better reflect productive patterns (Shademan, 2007; Vitevitch & Luce, 1998, 1999), and have been shown to behave differently from real words in experiments (e.g., Kawahara, 2011). The results show a pattern of reduction produced by IHRs that differs from that in both the heritage (i.e., Russian) and dominant (i.e., Hebrew) languages.

Previous Research

Heritage Speakers

There is disagreement among researchers as to the exact definition of heritage speakers. In this paper, we adopt Valdés' (2000) narrow definition of heritage speakers as sequential bilinguals who are exposed from birth to their heritage language (HL) and subsequently, and crucially, before the critical age, are exposed to the dominant language (DL) in their surroundings.

Heritage speakers display a wide range of diversity in all aspects of their linguistic knowledge. Their proficiency correlates mostly, but not exclusively, with the degree of exposure to the HL and the age of exposure to the DL (Au & Oh, 2005). Polinsky and Kagan (2007) suggest that heritage speakers' proficiency in their HL falls within a continuum, representing the distance from a monolingual baseline. In other words, variation among heritage speakers is systematic rather than random. This system is hierarchically organized, with certain aspects of linguistic proficiency (e.g., aural comprehension and lexical knowledge) taking precedence over others (e.g., spontaneous production and morphosyntactic knowledge).

Specifically regarding the sound system of the HL, there is a general impression that heritage speakers sound native-like (e.g., Au & Romo, 1997; Peyton, Ranard, & McGinnis, 2001), at least when compared to late learners of the same language. This impression is probably one of the reasons for the paucity of phonetic and phonological research of heritage speakers. Godson (2003, 2004) holds that contrary to this impression, there is evidence that heritage speakers differ both in production and in representations from monolinguals, as well as from other bilinguals.

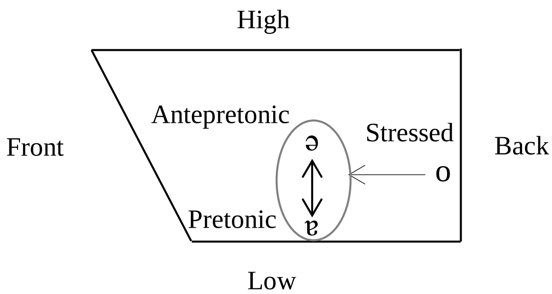
The heritage speakers we studied (ages 17-28, mean age 22.6) speak Russian as their HL and Hebrew as their DL. Typically, these speakers are exposed to Russian from birth, at home and in familial environments, but not in other contexts. Their exposure to Hebrew occurs in preschool and continues throughout their education and in most day-to-day contexts. This population has recently been the subject of several linguistic studies (Gopul, 2009; Laufer, 2003; Yeverechyahu, 2013). However, none of these has examined the speakers' sound system.

Russian Vowel Reduction

As stated in our introduction, vowel reduction in Contemporary Standard Russian has been studied extensively (Alderete, 1995; Barnes, 2002, 2006, 2007; Crosswhite, 1999; Jakobson, 1929; Nesset, 2000; Padgett, 2004; Padgett & Tabain, 2005). There is generally agreement in the literature in describing the phenomenon: the five-vowel contrast (/i, e, a, o, u/) in stressed syllables is reduced to a three-way contrast in unstressed syllables or to two vowels after a palatalized consonant (an environment which will not be discussed in this paper).

In unstressed syllables, /e/ is raised to [i], while /a/ and /o/ are neutralized to either [ɐ] or [ə]. The mid-low vowel [ɐ] surfaces in the pretonic syllable (i.e., immediately preceding the stressed syllable), in onsetless syllables, and in a hiatus before another non-high vowel. The [ə] variant surfaces in all other environments. This study focuses on the production of underlying /o/ in different positions in relation to stress: stressed (e.g., /nos/ 'nose sg.'), pretonic (e.g., /nos-ˈɨ/ 'nose pl.'), and other unstressed positions, specifically the antepretonic (e.g., /nos-oˈvoj/ 'nasal.'). Figure (1) portrays the relative backness and height of the surface forms of /o/ in these three positions.

Figure 1. Surface Forms of Underlying /o/ in Contemporary Standard Russian



Previous studies differ in explaining the observed distinction between pretonic and other unstressed positions. Nesset (2000) follows Alderete (1995) in accounting for the difference in terms of foot structure, assuming that a pretonic syllable is part of an iambic foot. He posits that this is a case of positional faithfulness (Beckman, 1997), where positional prominence blocks reduction to [ə], which occurs freely in unfooted syllables. This results in reduction to a surface form that retains some of the underlying vowel's features (e.g., [ɐ]). Crosswhite's (1999) analysis similarly relies on foot structure, but she further posits that footed syllables are moraic. In her account, non-moraic vowels undergo reduction to [ə] due to a constraint on their sonority. Meanwhile, moraic unstressed vowels (i.e., in pretonic syllables) undergo reduction due to a licensing constraint (Itô, Mester, & Padgett, 1995), which limits non-peripheral vowels (e.g., [o]) to stressed syllables.

The approaches outlined above posit a qualitative phonological distinction between pretonic and other unstressed syllables. Some have argued that such a distinction is unnecessary (Barnes, 2002, 2006, 2007; Padgett, 2004; Padgett & Tabain, 2005), and that phonologically, all unstressed vowels undergo a single process of reduction regardless of their position (e.g., unstressed /o/ always reduces to [ɐ]). They explain the observed difference in pronunciation on a phonetic rather than a phonological level, as a result of target undershoot. In support of this claim, Barnes (2006, 2007) presents two experiments in which speech rate is manipulated, showing that reduction of /o/ to [ɐ] is categorical, while reduction to [ə] is gradient and crucially depends on vowel duration. In light of these findings, vowel reduction can be characterized in terms of a backness contrast between stressed and unstressed vowels (henceforth *vowel fronting*), and a height contrast within unstressed vowels (i.e., between pretonic and other unstressed positions, henceforth *vowel raising*).

Hebrew Vowel Reduction

Contrary to Russian, stress-related vowel reduction in Modern Hebrew has received limited attention (e.g., Cohen, Silber-Varod, & Amir, in preparation; Maymon, 2001). Hebrew vowel reduction appears to be primarily quantitative, as stressed and unstressed vowels differ significantly in duration, but not in quality. In addition, no substantial differences with respect to quantity or quality have been found between different unstressed positions, unlike the case in Russian.

Nonce Words

It is generally accepted within generative phonology that nonce words are treated like real words in speakers' grammars (e.g., Halle, 1978). Nonce words are expected to follow phonological patterns attested in real words. Indeed, this is the reasoning underlying the use of wug-tests (Berko, 1958), a form of investigating the productivity of phonological patterns while avoiding lexicalized forms. Nonce words have been argued to reflect phonological knowledge more so than real words, as they are generally unaffected by lexical factors (Shademan, 2007; Vitevitch & Luce, 1998, 1999). Hence, cases in which nonce words fail to undergo a certain phonological process have been claimed as evidence that this process is not productive, but rather lexicalized (Griner, 2001; Ohala, 1974; Sanders, 2003).

Experimental studies on speech processing (e.g., Vitevitch & Luce, 1998, 1999) and on phonological judgments (e.g., Kawahara, 2011) have challenged the above rationale by showing that nonce words and real words are not always treated alike. Vitevitch and Luce (1998, 1999) demonstrate that phonotactic probabilities and lexical neighborhood densities affect the processing of nonce words and real words differently. Kawahara (2011) shows that variation in acceptability is reduced for nonce words compared to real words.

METHODOLOGY

We conducted a production experiment to determine the patterns of vowel reduction in the Russian of IHRs, and compared them to a control group's baseline. Subjects were exposed to auditory stimuli and were required to produce the target forms with and without stress-attracting suffixes. Hence, stem vowels were produced in three distinct prosodic positions: stressed, pretonic, and non-pretonic unstressed syllables (i.e., two syllables before a stressed syllable, henceforth *antepretonic*). As noted in the previous section of this paper, these three positions are all relevant to patterns of vowel reduction in Russian.

Participants

Sixteen IHRs (thirteen females and three males) between the ages of 17 and 28 (mean age = 22.6) participated in the study. All speakers had acquired Russian as their HL, and then subsequently acquired Hebrew as their DL. Seven of the speakers were born in Israel, and nine were born in Russia, having immigrated to Israel before beginning school (i.e., ages 0 to 7, mean age = 3). All participants' parents came from large urban areas in the western (i.e., European) part of Russia.

All participants had received their formal education in Hebrew-speaking schools in Israel. In preschool, thirteen of the speakers attended Hebrew-speaking kindergartens, two attended kindergarten in Russia, and one attended a Russian-speaking kindergarten in Israel. All participants self-assessed their knowledge of Hebrew as greater than (in 13 cases) or equal to (in 3 cases) their knowledge of Russian. Regarding day-to-day use, all participants reported using Russian with at least one family member, and using Hebrew in the majority of other contexts.

The IHRs' results were compared to the results of a control group of adult immigrants, which consisted of five native Russian speakers (four females and one male) between the ages of 24 and 28 (mean age = 25.2).[1] The speakers in the control group had immigrated to Israel within the last four years from large cities in the western part of Russia. All of them spoke very little or no Hebrew, and primarily used Russian in their day-to-day social interactions.

Information about the participants was collected in personal interviews conducted at the end of the production experiment. Every participant answered questions about their place of birth, age of arrival, family's origin, attitude towards the Russian language and culture, and language use in various contexts. Key information on all participants is summarized in Table 1. Interviews with IHRs included a written form, which is available in Appendix A.

Table 1.

Information about Participants

Speaker group	Sex	Age	Age of arrival	Years in Israel	City of family's origin
Heritage	F	23	Israeli Born	23	Saint Petersburg
Heritage	M	17	Israeli Born	17	Pyatigorsk
Heritage	F	21	Israeli Born	21	Saint Petersburg
Heritage	F	21	Israeli Born	21	Saint Petersburg
Heritage	F	23	Israeli Born	23	Saint Petersburg
Heritage	F	21	Israeli Born	21	Moscow
Heritage	F	21	Israeli Born	21	Saint Petersburg
Heritage	F	18	0	18	Yaroslavl
Heritage	F	25	1	24	Saratov
Heritage	M	25	1	24	Saint Petersburg
Heritage	F	22	2	20	Voronezh
Heritage	F	28	3	25	Nizhny Novgorod
Heritage	M	27	3	24	Moscow
Heritage	F	23	4	19	Saint Petersburg
Heritage	F	24	6	18	Yaroslavl
Heritage	F	22	7	15	Saky
Control	M	24	24	0	Kursk
Control	F	24	24	0	Moscow
Control	F	28	25	3	Moscow
Control	F	25	25	0	Moscow
Control	F	25	25	0	Kursk

Materials

The participants heard auditory stimuli and produced affixed and un-affixed words based on the stimuli. Each stimulus consisted of a target word, along with a paradigm: a set of two words, the first of which was a noun stem and the second of which was its suffixed form. The participants were instructed to first repeat the target word, and then produce a suffixed form of the target word based on the paradigm. An example of a stimulus and the expected native speaker response is given in (1). All data throughout the paper are presented in phonetic forms, ignoring consonant allophony (e.g., final devoicing). Where underlying forms are relevant, they are presented between slashes.

(1)	***Stimulus***	Paradigm:	*krug* ‘circle sg.’ - *krugɐˈvoj* ‘circular’
		Target word:	*n**o**s* ‘nose sg.’
	Response	Target word:	*n**o**s* (repeated three times)
		Suffixed form:	*n**ə**sɐˈvoj* ‘nasal’ (repeated three times)

The use of paradigms allowed us to trigger the desired morphological processes without presenting orthographic representations, and without presenting isolated affixes, which never naturally occur in speech (i.e., bound morphemes).

The target words were eight monosyllabic words with a stressed /o/ (four real and four nonce). The real nouns were all high frequency and were selected from the list of the 5,000 most frequent Russian words in Sharoff’s (2002) 40-million-word corpus of written modern Russian. In addition to preventing frequency-related inter-item variation, this ensured that heritage speakers would recognize the nouns presented to them. The frequency of the real nouns used in this study is given in Table 2 in instances per million (IPM), based on Sharoff’s data.

Table 2.

Real Noun Stems

Noun		**Frequency (IPM)**
most	'bridge'	80.68
dom	'house'	1022.96
god	'year'	2042.67
nos	'nose'	252.49

In order for the participants to produce the same underlying vowel in varying proximity to stress, we selected nouns with a stressed /o/ that have an unstressed /o/ elsewhere in their morphological paradigm (Halle, 1970, 1975; Redkin, 1971; Zaliznjak, 1977; among others).

The nonce nouns, given in Table 3, are based on the real noun stimuli. Each of the nonce nouns was created by replacing the onset of the stressed syllable in one of the Russian nouns in Table 2. The onset was replaced with a consonant that differs in both manner and place of articulation. In words with consonant sequences, regardless of their position, we replaced the entire consonant sequence with one consonant that differs from each of the original consonants in manner, place or both.

Table 3.

Nonce Noun Stems

Nonce word	Original real noun
tog	most
vom	dom
fod	god
xos	nos

In addition to the target words, the stimuli included paradigms, as explained above. There were four different paradigms, each consisting of a Russian noun stem and its suffixed form. Each of the paradigms was used to present a different Russian suffix, as shown in Table 4.[2] In three of the four paradigms, the noun stem's stressed vowel was /u/ (e.g., *krug* - *kruˈgi*) because it is the only vowel that does not participate in the reduction processes outlined in the previous section. The one exception is the paradigm *glaz* - *glɐˈza*, which served to fill the absence of Russian nouns with a stressed /u/ that take the stress-attracting suffix -*a*.

Table 4.

Paradigms

Paradigm		**Suffix**	
sup - supˈɨ	'soup sg.' – 'soup pl.'	-ˈ*ɨ*	plural
krug - kruˈgi	'circle sg.' – 'circle pl.'	-ˈ*i*	plural
krug - krugɐˈvoj	'circle sg.' – 'circular'	-*ɐˈvoj*	adjective
glaz - glɐˈza	'eye sg.' – 'eye pl.'	-ˈ*a*	plural

The participants were also presented with 32 fillers in the form of words with stressed /i/, /e/ or /a/ in their un-affixed form (see Appendix B). Half of the fillers were monosyllabic and half were disyllabic, and in each group, half were real nouns and half were nonce nouns.

The stimuli were recorded by a native Russian speaker (30 years old, female) who had immigrated to Israel from Moscow four years prior to the recording session.

Procedure

The instructions and four training questions were pre-recorded by the same native Russian speaker who recorded the stimuli and were presented in auditory form at the beginning of the experiment. All instructions were given in Russian to both the control group and the IHRs in order to ensure that Russian was the active language throughout the experiment (i.e., establishment of the language set, as in Elman, Diehl, & Buchwald, 1977, among others). An English translation of the instructions is available in Appendix C, along with the Russian source.

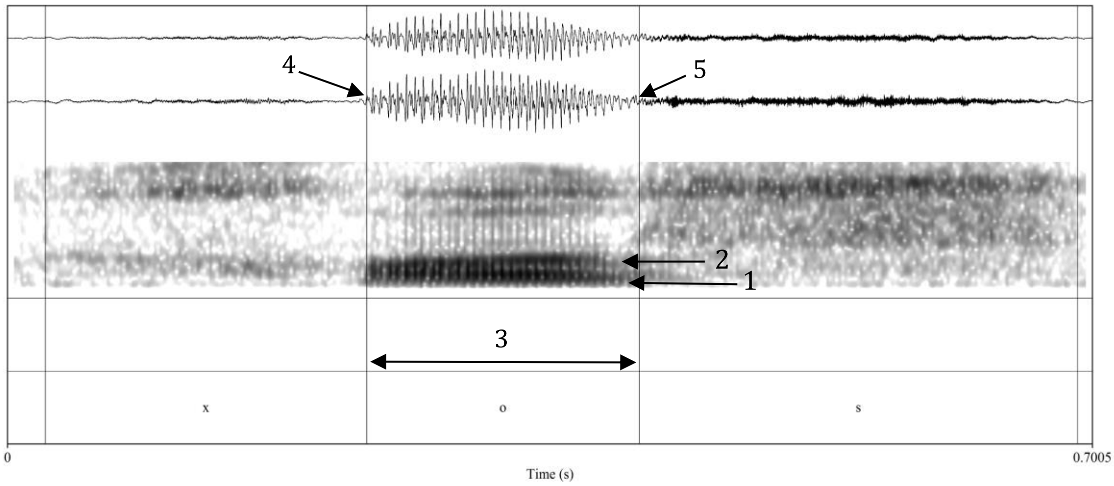
The experiment was conducted in a quiet room. The stimuli, including the fillers, were uploaded to an online surveying platform and presented to the subjects in random order. On each question page, a WAV file played a recording that was structured as follows: 500 milliseconds of silence, followed by a paradigm, then one more second of silence, and finally, an un-affixed target word.

The participants were asked to produce each target word three times without the given suffix, and three times with the given suffix. No further instructions regarding the nature of the production were given. All of the included suffixes attract stress in some morphological classes in Russian. If the participants' natural production of the suffixed forms did not include stress shift, those production data were excluded from the analysis.

After participants had finished listening to the instructions for the first time, they heard two training questions, one with a real word as a target, and one with a nonce word as a target, along with the correct answers. This was done in order to verify that they had indeed understood the nature of the task. They were then given the option to listen to the instructions again and answer two additional training questions. In all training questions, the target word's stressed vowel was /u/, which does not undergo vowel reduction in Russian. Participants were allowed to replay the instructions an unlimited number of times.

The participants' productions were recorded at a sampling rate of 48 kHz and analyzed in PRAAT (Boersma & Weenink, 2015). As shown in Figure 2, the underlying /o/ vowels from all environments were measured for values of the first and the second formants, as well as for duration (arrows 1, 2 and 3, respectively). The onset and offset of the vowels (arrows 4 and 5, respectively) were determined based on F2. If F2's onset/offset was undetectable, the vowel onset/offset was set at the point where the spectrogram and amplitude were less similar to the vowel body than they were to the adjacent segment.

Figure 2. Example of Measurement of Acoustic Properties in the Nonce Word *xos*



Note. 1- F1. 2-F2. 3-duration. 4-vowel onset. 5-vowel offset.

To minimize the influence of physiological differences among speakers on acoustic variation, measurements of each phonetic cue were normalized using Lobanov's *z*-score transformation (see Adank, Smits, & Van Hout, 2004; Lobanov, 1971). Values were normalized separately for real and nonce words in order to obtain faithful within-condition contrasts among prosodic positions. We excluded productions that were over 2.5 standard deviations from the mean of any phonetic cue (n=13) in order to account for performance aberrations. We also excluded cases in which vowels were masked by background noise or deleted (n=16). Eventually, 957 productions were included in the statistical analyses.

In order to detect systematic contrasts in the production of vowels, we conducted repeated measures analyses of variance (ANOVA). We compared the normalized means of vowel height (F1), backness (F2) and duration across prosodic positions (stressed, pretonic or antepretonic) and across word types (real or nonce) for both IHRs and the control group. For both groups, we report contrasts among different prosodic positions in each of the word types. For each group and word type, a significant difference would suggest that the speakers produce vowels differently in these positions systematically.

RESULTS

The mean values of the acoustic measurements for each speaker group are presented in Table 5. We separate the prosodic positions from each other, IHRs from the control group, and real words from nonce words. Following this, we conduct repeated measures analyses of variance (ANOVA) and report the conditions in which there was a systematic contrast between prosodic positions.

Table 5.

Mean Acoustic Values

			Stressed		**Pretonic**		**Antepretonic**		
			M	SD	M	SD	M	SD	
F1 (Hz)	Control	Real	557	84	675	69	487	79	*
		Nonce	531	55	605	61	557	45	*
	IHRs	Real	575	83	627	113	571	109	*
		Nonce	571.60	74	543	105	567	84	
F2 (Hz)	Control	Real	1036	127	1393	225	1496	183	*
		Nonce	966	111	1287	373	1344	191	*
	IHRs	Real	1100	154	1455	189	1588	202	*
		Nonce	1049	126	1285	256	1352	192	*
Duration (ms)	Control	Real	0.18	0.05	0.07	0.02	0.05	0.02	*
		Nonce	0.16	0.05	0.10	0.02	0.05	0.01	*
	IHRs	Real	0.19	0.07	0.06	0.02	0.06	0.03	
		Nonce	0.17	0.06	0.07	0.03	0.05	0.03	*

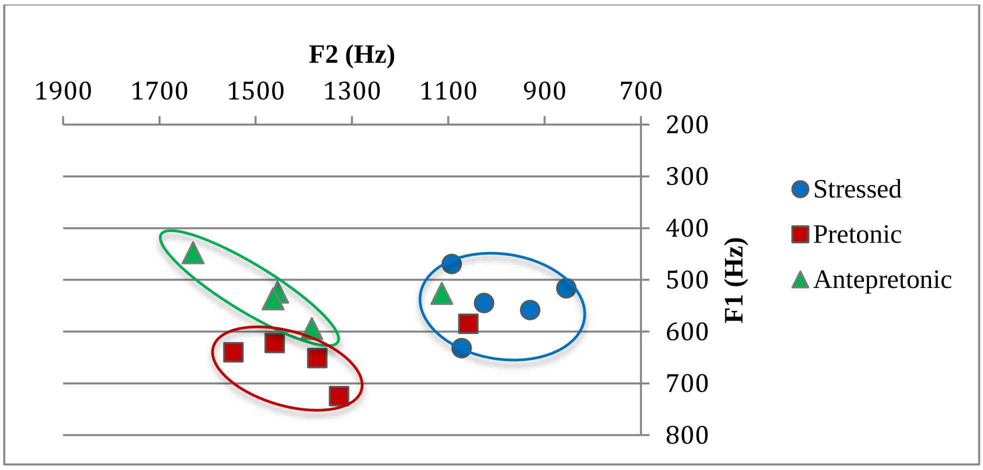
Note. * marks a significant difference between pretonic and antepretonic productions

Vowel Quality

The control group and the IHRs differed in their treatment of real and nonce words across prosodic positions. This difference is observed in vowel height, $F(2, 38) = 3.6$, $p = .04$, $\eta_p^2 = .16$, but not in vowel backness, $F(1.29, 24.4) = .36$, $p = .6$.

Height: As seen in Figure 3, the control group performed as expected, replicating the reduction pattern found in previous studies. Speakers in the control group distinguished among prosodic positions in height, $F(2, 8) = 6.27$, $p = .02$, $\eta_p^2 = .61$. A post hoc Šidák test (Šidák, 1967) showed that pretonic vowels were significantly lower than antepretonic, $p < .001$. Stressed vowels were higher than pretonic ones, $p = .03$, but did not differ from those that were antepretonic, $p = .97$.[3]

Figure 3. Control Group's Vowel Quality (ellipses include ≥ 80% of speakers)



IHRs treated real and nonce words differently, $F(2, 30) = 1.23$, $p < .001$, $\eta_p^2 = .52$, as shown in Figures 4 and 5, respectively. Although there was no overall effect of position, $F(2, 30) = 16.39$, $p = .3$, IHRs replicated the native height distinction in real words, $F(1.44, 21.62) = 9.04$, $p = .001$, $\eta_p^2 = .38$. A post hoc Šidák test showed that in real words, IHRs produced pretonic vowels lower than those that were antepretonic, $p < .001$. As in the control group, the height of stressed vowels was intermediate, between that of pretonic and antepretonic ones; this difference was not significant, $p = .09$ and $p = .47$, respectively.

Crucially, in nonce words, the height distinction was lost, $F(2,30) = 1.92$, $p = .16$. That is, IHRs preserved the height distinction among unstressed categories in real words, but failed to do so in nonce words.

Figure 4. IHRs' Vowel Quality in Real Words

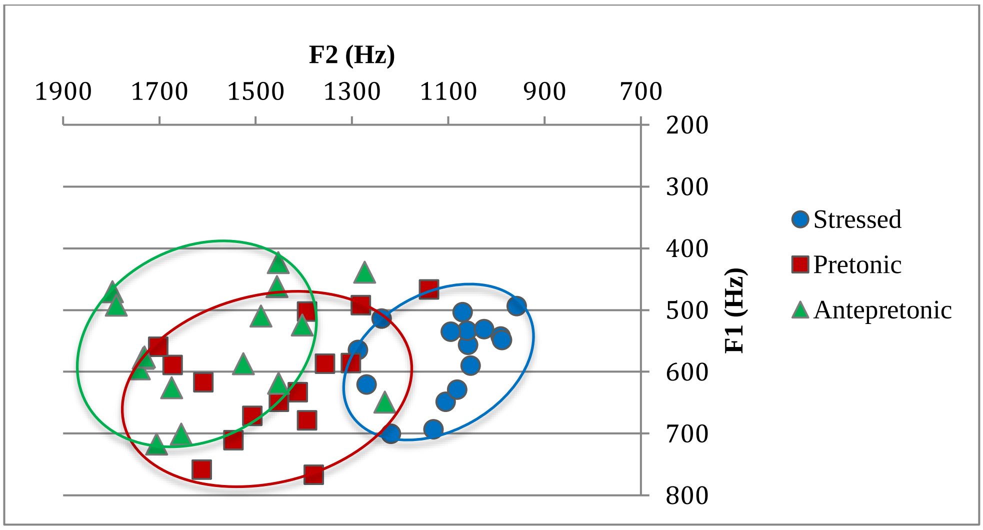
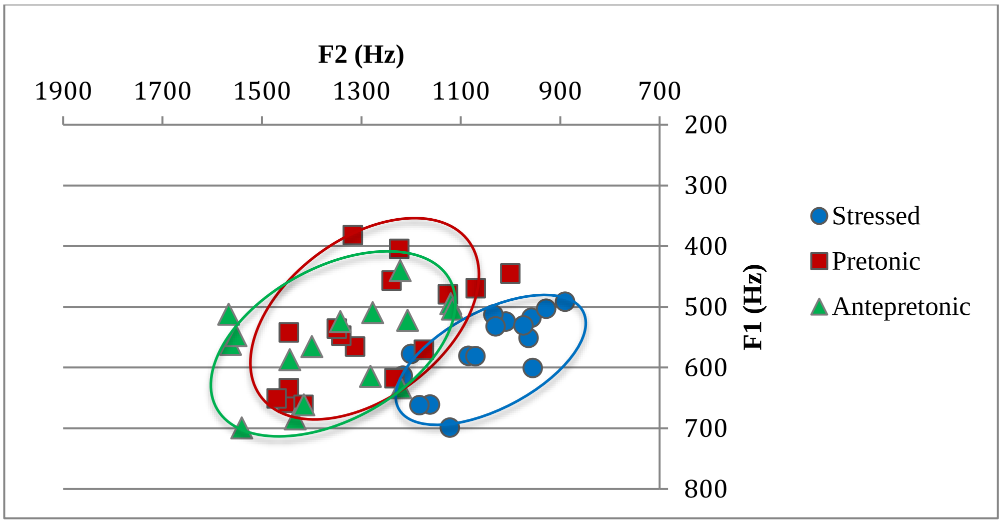


Figure 5. IHRs' Vowel Quality in Nonce Words



Backness: We found an overall prosodic effect on vowel backness, $F(1.39, 26.4) = 141.25$, $p < .001$, $\eta_p^2 = .88$, with no interaction with speaker group, $F(1.39, 26.4) = 1.1$, $p = .32$. A post hoc Šidák test revealed that both pretonic, $p < .001$, and antepretonic vowels, $p < .001$, were fronted compared to stressed vowels. Antepretonic vowels were also further fronted compared to those that were pretonic, $p = .02$.[4]

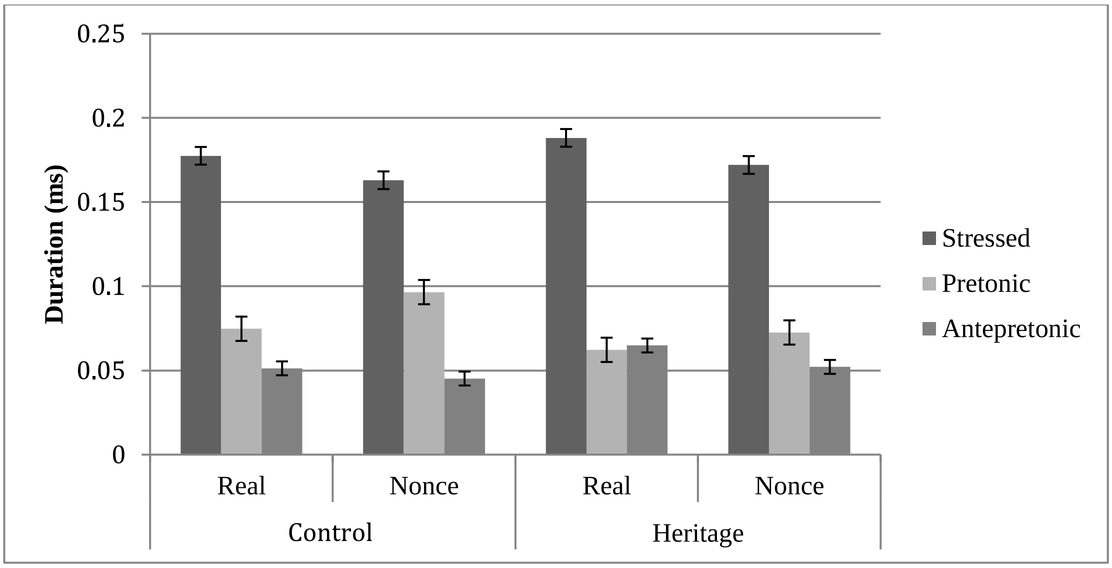
Vowel Quantity

Figure 6 illustrates that the control group and the IHRs showed different patterns of duration across prosodic positions, $F(1.4, 26.66) = 14.75$, $p < .001$, $\eta_p^2 = .44$. There was also an overall significant main effect of position on duration, $F(1.4, 26.66) = 1199.27$, $p < .001$, $\eta_p^2 = .98$.

Speakers in the control group showed an interaction between prosodic position and word type, $F(2, 8) = 7.4$, $p = .02$, $\eta_p^2 = .65$. However, there was an effect of position in both real, $F(2, 8) = 532.39$, $p < .001$, $\eta_p^2 = .99$, and nonce words, $F(2, 8) = 243.56$, $p < .001$, $\eta_p^2 = .98$. Post hoc Šidák tests revealed the same pattern in both real and nonce words: stressed vowels were longer than pretonic ones ($p < .001$ and $p < .001$, respectively), which, in turn, were longer than antepretonic ones ($p = .02$ and $p = .009$, respectively).

In IHRs, there was also an interaction between prosodic position and word type, $F(1.13, 17.04) = 24.45$, $p < .001$, $\eta_p^2 = .62$. Duration differed across prosodic positions in real words, $F(1.48, 22.17) = 1354.9$, $p < .001$, $\eta_p^2 = .99$. A post hoc Šidák test showed that stressed vowels were longer than both pretonic, $p < .001$, and antepretonic vowels, $p < .001$. There was no such contrast between pretonic and antepretonic vowels, $p = 0.9$. There was an effect of prosodic position in nonce words as well, $F(1.15, 17.24) = 651.09$, $p < .001$, $\eta_p^2 = .98$. A post hoc Šidák test showed that stressed vowels were longer than pretonic vowels, $p < .001$, which were then longer than antepretonic ones, $p < .001$.

Figure 6. Control Group's and IHR's Vowel Quantity by Word Type



DISCUSSION AND CONCLUSIONS

Our results showed that the control group's productions of both real and nonce words matched the patterns of monolingual native Russian speakers reported in previous studies. In both word types, they displayed fronting of unstressed vowels relative to stressed vowels, and raising of antepretonic vowels relative to pretonic vowels. IHRs, on the other hand, displayed the native-like pattern of reduction only when producing real words. When producing nonce words, IHRs showed no significant distinction in height within unstressed vowels, that is, between pretonic and antepretonic positions. These results are summarized in Table 6.

Table 6.

Vowel Raising

		Pretonic	Antepretonic
Monolinguals	Real	ɐ	ə
	Nonce	ɐ	ə
IHRs	Real	ɐ	ə
	Nonce	ɐ	ɐ

There are two steps in accounting for the observed departure of IHRs from the pattern displayed by native speakers. First, we must explain why nonce words differ from real words in the productions of IHRs. Second, we must explain why each group of words either matches (in the case of real words) or differs from (in the case of nonce words) the native pattern.

We adopt the standard assumption that nonce words undergo productive phonological processes similarly to real words (Griner, 2001; Halle, 1978; Ohala, 1974, Sanders, 2003). This assumption is supported by the results for the control group reported in the previous section. It follows from this assumption that where nonce words systematically fail to undergo a certain phonological process, the process in question is not, in fact, productive.

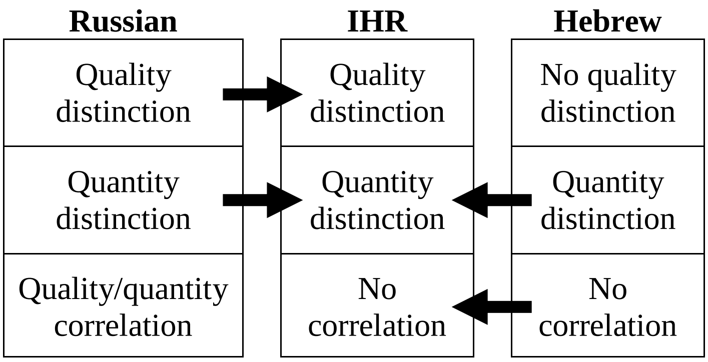
With this in mind, we may reexamine our results. Looking at the speakers in the control group, who treated real and nonce words alike, we now have novel evidence for the productivity of both vowel fronting and vowel raising. In the case of IHRs, in their productions of nonce words, only vowel fronting was observed, with no evidence of vowel raising. We conclude that only vowel fronting is indeed productive in IHRs.

In producing real words, IHRs did display both vowel fronting and vowel raising. We argue that this is not indicative of their productive grammar, but rather is the result of rote-learning (i.e., lexicalization). That is, these speakers store in their lexicon both the real noun stems and their suffixed forms in the forms in which they have heard them (i.e., phonetic representations). Recall that IHRs were probably familiar with the real word stimuli, including in their suffixed forms, as they were all high frequency.

Our claims regarding the productive grammar of IHRs are strengthened once we juxtapose the results for vowel height and vowel duration.[5] Experiments on native speakers (e.g., Barnes, 2006, 2007) showed an inverse correlation between duration and height of underlying /o/ in unstressed vowels, with longer vowels realized lower and, conversely, shorter vowels realized higher. This has been taken as evidence that vowel raising is not only motivated by shortening, but directly caused by it. Yet the results in the present study paint a different picture for IHRs. In real words, they displayed a contrast in vowel height between pretonic and antepretonic positions, but no contrast in duration, while in nonce words, the opposite holds true. Hence, IHRs departed from the native-like pattern in two ways. First, they displayed vowel raising in real words without the clear phonetic motivation of shortening, which suggests that the forms they produced are stored rather than derived. Second, they failed to display vowel raising in nonce words when it was expected, that is, in correlation with shortening.

In this respect, IHRs' system of vowel reduction is closer to the corresponding system in their DL. As we mentioned in the first section of this paper, in Hebrew, stressed and unstressed vowels contrast only in duration, not in quality. That is, the shortening of vowels does not lead to a change in quality (e.g., raising of a low vowel). We propose that IHRs' system is influenced by this feature of Hebrew, considering that it is the language the speakers use in most contexts and in which they feel more confident. We suggest that this influence has led to the formation of a mixed grammar in which there is qualitative reduction of unstressed vowels as in Russian, but similar to Hebrew, this reduction does not correlate with changes in duration. Figure 7 outlines these insights.

Figure 7. Mixed System of Vowel Reduction



The vowel reduction patterns of IHRs, when producing real words, matched those of a control group, but when producing nonce words they systematically differed from the control group's patterns. This reflects a common impression that heritage speakers sound almost but not quite native. That such subtle differences only emerged in nonce words illustrates the importance of including these words in production experiments, side by side with highly frequent real words. In this way, our methodology allowed us to tease apart phonological patterns that are productive from ones that are lexically stored. Another strength of our methodology was the auditory presentation of basic morphological paradigms. It allowed us to effectively obtain data from different phonological environments in a way suitable for speakers with varying proficiency in the HL. In particular, we were able to circumvent the wide range of diversity in reading ability among heritage speakers, as well as eliminate the potential influence of orthographic forms.

This study aims to inspire further research on phonological productivity in heritage speakers. Taking Russian vowel reduction as a case study, the claim that this pattern is not productive in IHRs could be further tested by examining speakers who vary in age of exposure to the DL. In addition, the nature of the difference between real and nonce words could be refined by testing the production of real words ranging in their frequency. Finally, an additional avenue for further investigating our mixed grammar proposal would be to conduct a similar study on a comparable group of heritage Russian speakers with a different dominant DL, in particular, one that displays a principally different system of vowel reduction (e.g., English).

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Appendix A: Personal Questionnaire (English translation from Hebrew)

Participant number:

Date: dd/mm/yyyy

Experimenter:

Interview: Russian Speakers

▶ General Information

Name:	First name: Last name:
Sex:	
Date of birth:	
City of birth:	
Current place of residence:	
Previous places of residence:	
Date of arrival to Israel:	
Parents' city of birth:	
Parents' current place of residence:	
Parents' previous places of residence:	
Education (city/country):	Kindergarten:
	Elementary:
	High school:
	Additional:
Employment:	

▶ **Language Proficiency**	Full proficiency %100	High proficiency %75	Medium proficiency %50	Low proficiency %25	No proficiency %0
Evaluate your proficiency in Chinese					
Evaluate your proficiency in Russian					
Evaluate your proficiency in Hebrew					
Evaluate your proficiency in English					
Evaluate your proficiency in _______					

Would you like to improve your Chinese?	Yes	No
Would you like to improve your Russian?	Yes	No
Would you like to improve your Hebrew?	Yes	No
Would you like to improve your English?	Yes	No

▶ Family

Who did you grow up with until the age of 18? ____________________

Number of sisters and brothers in Israel: ____________________

Ordering by age from eldest to youngest, where do you stand among your siblings (born first, second, etc.)? ____________________

▶ Language Use

Mother → You ____________________

You → Mother ____________________

Father → You ____________________

You → Father ____________________

You ↔ Siblings ____________________

You ↔ Partner ____________________

You ↔ _____ ____________________

You ↔ _____ ____________________

At work ____________________

Is it important to you that your children/grandchildren speak Chinese? ____________________

Is it important to you that your children/grandchildren speak Russian? ____________________

Is it important to you that your children/grandchildren speak Hebrew? ____________________

Is it important to you that your children/grandchildren speak English? ____________________

In what language do you read newspapers? ____________________

In what language do you read books? ____________________

In what language do you count? ____________________

In what language do you write SMS? ____________________

In what language do you write yourself ____________________

In what language do you listen to music? ____________________

Do you celebrate Novi-god? ____________________

Do you have relatives in Russia? ____________________

Do you have friends in Russia? ____________________

Have you ever visited Russia? ____________________

Would you like to visit Russia? ____________________

APPENDIX B: FILLERS

I-A. Fillers: Real Words

Noun		Frequency (IPM)
sad	'garden'	123.10
vrag	'enemy'	155.84
ʐar	'fever'	51.66
ʂar	'ball'	54.48
mir	'peace'	569.14
list	'sheet'	143.48
blin	'pancake'	21.00
grib	'mushroom'	52.03
ˈpasport	'passport'	59.13
ˈmaster	'master'	92.98
ˈvet͡ʂer	'evening'	391.01
ˈbereg	'shore'	240.44
duˈrak	'fool'	131.17
ruˈkav	'sleeve'	79.08
staˈrik	'old man'	313.64
ʐeˈnix	'groom'	37.77

I-B. Fillers: Nonce Words

Nonce word	Original real noun
xad	sad
kag	vrag
kar	ʐar
mar	ʂar
lir	mir
gim	list
xin	blin
vib	grib
ˈvaxox	ˈpasport
ˈdamer	ˈmaster
ˈket͡ʂer	ˈvet͡ʂer
ˈnereg	ˈbereg
duˈmak	duˈrak
ruˈnav	ruˈkav
xaˈpik	staˈrik
ʐeˈkix	ʐeˈnix

APPENDIX C: INSTRUCTIONS

a. Instructions, English translation

In this experiment, you create Russian words, both existing and non-existing ones. At first, you will hear two words in Russian. The second word consists of the first word and a suffix. Your task is to detect the suffix. Then, you will hear an additional word, either existing or non-existing. Please:

1. Say this word three times, with one second breaks between each time.
2. Add the suffix, which you detected earlier, and say the word with this suffix three times, with one second breaks between each time.

The words will be played automatically in every page of the questionnaire. However, you can replay the recording by clicking on "play" on the on-screen player.

Now you will hear two training questions. You will be able to listen to the correct answer. If you are ready, please continue to the next page.

b. Instructions, Russian Original

В этом эксперименте Вы создаёте русские слова, существующие или не существующие. В начале вопросника Вы услышите два слова на русском языке. Второе слово состоит из первого слова и окончания. Ваша задача определить окончание слова. Затем Вы услышите ещё одно слово (существующее или не существующее). Пожалуйста:

1. Скажите это слово три раза, с интервалами в 1 секунду
2. Добавьте окончание, которое Вы определили и скажите слово с окончанием три раза, с интервалами в 1 секунду.

Слова будут воспроизводиться автоматически на каждой странице опроса, однако, вы можете повторно воспроизвести запись, нажав на "Play" на экране проигрывателя.

Сейчас Вы услышите 2 упражнения. У Вас будет возможность прослушать правильный ответ. Если вы готовы то, пожалуйста, перейдите к следующей странице.

NOTES

1. We recorded two additional native speakers, but had to exclude them from the results: one speaker did not shift stress from the stem in nonce words, and the other speaker stopped the experiment in mid-session.

2. While *-ɐˈvoj* is a derivational suffix, *-ˈɨ*, *-ˈi* and *-ˈa* are all inflectional plural suffixes. However, the process of vowel reduction in Russian is not morphologically conditioned in any sense (Barnes, 2004; Crosswhite, 1999).

3. We also found a significant interaction between word type and distance from stress, $F(2, 8) = 5.6$, $p = .03$, $\eta_p^2 = .58$. However, a post hoc Šidák test showed that pretonic and antepretonic vowels contrasted in height in both real words, $p < .001$, and nonce words, $p = .04$, with pretonic vowels being lower than antepretonic vowels. The height of stressed vowels was intermediate, between that of pretonic and antepretonic ones, in both real and nonce words. This difference was significant only in relation to pretonic vowels in real words, $p < .001$.

4. In the present experiment, the difference in backness between pretonic and antepretonic vowels was expected due to coarticulation effects with the following consonant (Clements, 1991; Hume, 1992). In our stimuli (see Tables 1 and 2), antepretonic /o/ was in all cases followed by a front (coronal) consonant. In contrast, pretonic /o/ was followed by a front (coronal) consonant in only one out of four cases.

5. We thank one of the anonymous reviewers for bringing this point to our attention. We would like to note that our study is not intended, nor is it suitable, to make particular claims regarding the link between vowel height and duration in native speakers. This is because duration in our experiment is dependent on and thus highly correlated with prosodic position, unlike in experiments that directly manipulate speech rate (e.g., Barnes 2006, 2007). For the same reason, we make no claims regarding the phonological or phonetic nature of the pretonic-antepretonic contrast.