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Seinhorst, K.T.

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The Russian adaptation of [y] as L1 bimodal perception*

Klaas T. Seinhorst
ACLC, University of Amsterdam

Contributions to the loanword literature can traditionally be divided into two views: production-based ("phonological") vs. perception-based ("perceptual"). In an article from 2006, Paradis argues that the Russian adaptation of the vowel [y] *can only be explained in terms of phonological features, and that the adaptation cannot have arisen in perception because the resulting /C^{j}u/ sequence is "perceptually unnatural". This article aims to show that Paradis' premises are flawed, that a feature-based explanation actually makes incorrect predictions, and that the adaptation can be explained as first-language perception in both the auditory and visual modalities. I will present a Optimality-Theoretic formalization of this process within Boersma's model of bidirectional phonology and phonetics, in which perception is in fact phonological; I will also present evidence that suggests a crucial role for visual cues.*

Das uralt, alte Schlummerlied
Sie achtet's nicht, sie ist es müd

(Eduard Mörike — *Um Mitternacht*)

1 Introduction

Many accounts in loanword phonology hinge on highly specific assumptions about the adapting hearer and his grammar, e.g. bilingualism, or loanword-specific constraints or constraint rankings. The present article aims to avoid such assumptions in a formalization of the Russian adaptation of the rounded high front vowel [y]. This vowel is usually adapted as /u/ with palatalization of the preceding consonant, e.g. /men^{j}u/ < Fr. *menu* [məny] 'menu', /d^{j}una/ < Germ. *Düne* [dyːnə] 'dune', /t^{j}uk/ < Turk. *tük* [tyk] 'bundle'.[1] I will refute Paradis'

* This article is an extended version of my BA thesis, written in 2009. I gratefully acknowledge comments and advice from Paul Boersma and Silke Hamann, from which this article has greatly benefited. I would also like to thank the four native speakers for lending me their voices.

[1] For simplification, I will disregard vowel reduction in Russian unstressed syllables. Phonological surface representations are given in slashes / /, phonetic representations in square brackets [ ].

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(2006) claim that only a production-based explanation can deal with this adaptation, by formalizing it within Boersma's model of bidirectional phonology and phonetics (BiPhon), originally developed for L1 perception and production, in which the perception process is governed by phonological knowledge. In this formalization, a crucial role is assigned to visual cues; further support for this hypothesis is presented. After an exposition of different theoretic approaches to loanword adaptation (§2), I will discuss and criticize the feature-based explanation of the Russian adaptation of [y] (§3), introduce the Russian sound system and provide a formalization in the BiPhon model (§4), and discuss the role of the visual modality in §5. The conclusion and discussion remain for §6.

2 Models of loanword adaptation

Two well-known views on loanword adaptation are the phonological view and the perceptual view. The phonological view (e.g. LaCharité & Paradis 2002, 2005) argues that loanword adaptation is done by proficient bilinguals. Having access to the phonological surface forms of both languages, they adopt the form directly from L2, and 'repair' it in production according to the grammar of L1.

The perceptual stance (e.g. Peperkamp & Dupoux 2003; Davis & Cho 2006; Peperkamp, Vendelin & Nakamura 2008), in contrast, proposes that adaptation takes place in perception, on the basis of perceptual similarity with the donor form. The adapting hearer is not assumed to be bilingual; in fact, the adaptations are due to 'distortion' enforced by the L1.

Although the majority of the world population speaks two or more languages – a crucial argument in the phonological approach to loanword adaptation – a non-negligable part of them does not, and an even smaller part will have never even been confronted with a language other than their own. The premises of the phonological stance seem to imply that such individuals must be incapable of adapting loanwords, which is an untenable claim. It is true that loanword adaptation usually ensues from a situation of language contact (e.g. between neighbouring peoples or longer-distance trade relations), in which some degree of L2 proficiency may be presumed in the adapting hearer; however, as Peperkamp & Dupoux (2003: 369) point out, the adaptation will subsequently seep through into a community with members without any L2 knowledge.

Another prevailing issue in the loanword adaptation literature is the assumption of loanword-specific modules, constraints or constraint rankings (e.g. in Silverman 1992; Davidson & Noyer 1996; Yip 2006). The origin and ranking of such constraints is unclear, and the ranking cannot be motivated by a universal default (if any!) or the input data (Peperkamp 2005; Broselow 2009).

An account that does not crucially depend on such elements should be preferred, as well as explanations based solely on the grammar of L1.

This grammar, however, should also govern perception. The view that perception is extragrammatical is commonly held (e.g. Hume & Johnson 2001; Hyman 2001; Steriade 2001), and in fact also prevails in loanword phonology, where it is shared by researchers of both the phonological and perceptual stances (as noted by Boersma & Hamann 2009a). This often leads to situations where phonetic knowledge needs to be present in the phonology as well (Silverman 1992; Yip 1993), or where phonetically-based constraints evaluate phonological surface forms (Kirchner 1998).

A model that considers perception as grammatical is Boersma's BiPhon model (Boersma 2007). The BiPhon model is a bidirectional grammar of phonology and phonetics, in which the connections between levels of representation can be formulated in terms of Optimality-Theoretic constraints (Prince & Smolensky 1993/2004). In its minimal form, it assumes two discrete phonological representations, viz. an Underlying Form (UF) and a Surface Form (SF), and one continuous phonetic representation, viz. a Phonetic Form (PF).[2] UF is a phonologically specified morphemic representation, linked to the lexicon; SF is a prosodically detailed representation containing e.g. phonological feet, syllables and segments; PF is a representation of auditory events, such as formants, fricative noise, bursts etc., plus (in production) the articulatory gestures needed to realize these auditory events.

All constraints in the model apply bidirectionally, i.e. the language user uses the same constraints and constraint rankings in perception and production. The mapping from UF to SF is subject to faithfulness constraints (McCarthy & Prince 1995); the phonotactic wellformedness of SF is evaluated by structural constraints (Prince & Smolensky 1993/2004); in the production direction, PF is evaluated by articulatory constraints (Kirchner 1998; Boersma 1998), militating against excessive articulatory effort. The mapping from SF to PF is governed by cue constraints (Escudero & Boersma 2004; Boersma 2009), relating phonological structure to auditory events: an example would be *[*release burst*] /n/, which means 'a plosive release burst should not be perceived as the segment /n/' in perception, and 'the segment /n/ should not be produced with a plosive release burst' in production. As can be seen in Figure 1 (next page), the perception of an auditory-phonetic form (the bottom-right arrow) involves both cue constraints and structural constraints.

[2] The Phonetic Form can be further divided into an Auditory Form and an Articulatory Form (the latter only in production).

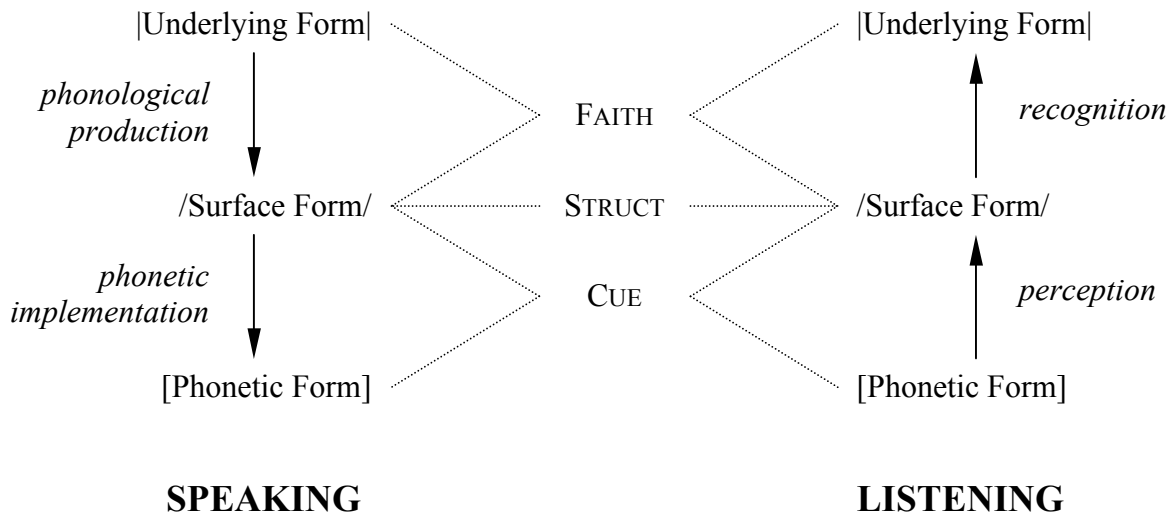

Figure 1. *The BiPhon model*.

In loanword adaptation, the path from a perceived L2 form to a produced L1 form proceeds through all the stages in Figure 1: the adapter perceives the foreign stream of sound as an L1-specific phonological surface structure through an interaction of cue constraints and structural constraints (bottom-right arrow); he maps this surface structure to an appropriate phonemic underlying representation, which he stores in his lexicon (top-right arrow); in production, he computes an SF from the stored UF using faithfulness and structural constraints (top-left arrow), and produces this SF as an overt auditory form mitigated by L1-specific cue and articulatory constraints (bottom-left arrow).

The BiPhon model has been implemented in loanword phonology by Boersma (2009), Boersma & Hamann (2009b) and Hamann & Li (this volume). Boersma (2009) formalizes observations by Polivanov (1931) and Dupoux et al. (1999) that Japanese hearers perceive [tak] and [ebzo] as /.ta.kɯ./ and /.e.bɯ.zo./ respectively: this can be explained by the bidirectional use of the structural constraint NOCODA, resulting in vowel epenthesis in Japanese perception. Boersma & Hamann (2009b) show that three levels of representation, rather than the traditional UF-SF pair, are necessary to account for apparent asymmetries in Korean loanword adaptation: these 'asymmetries' emerge automatically under the assumption that structural constraints interact with different families of constraints in comprehension and production (cue constraints and faithfulness constraints, respectively; cf. Figure 1). Hamann & Li (this volume) explain Hong Kong Cantonese adaptations as phonological perception and show that diachronic changes in these adaptations are likely due to changes in the L1 perception grammar. These three sources make use of the native grammar exclusively (although Hamann & Li suggest an influence of the

amount of exposure to English), so the BiPhon model does not raise the main objections against prevailing theories mentioned above.

3 The Russian adaptation of /y/: Paradis (2006)

Paradis (2006) explains the Russian adaptation of /Cy/ as /C^{j}u/ in terms of phonological features (note that /y/ is written in slashes here: according to the phonological model, bilingual borrowers access the surface form from L2 and adapt it in L1 production). /y/ is [+round, –back]; Russian does not allow for this combination, so the latter feature is delinked. As a repair mechanism, the feature [+back] is attached to the vowel, resulting in /u/, after which the floating feature [–back] is attached to a preceding consonant, yielding its palatalization. This way both of /y/'s distinctive features are maintained, in accordance with the Preservation Principle (Paradis et al. 1994; Paradis & LaCharité 1997).

Paradis further claims that only the phonological view is able to deal with the adaptation, since: (1) consonant palatalization before back vowels is rare cross-linguistically (Paradis supplies frequencies of occurrence for Russian), and therefore perceptually unnatural; any perceptual account of the phenomenon would fail to account for the data, since this view entails that the adapting hearer reconstructs a perceptually natural form; (2) according to the perceptual view, /y/ should be adapted identically in all positions; however, word-initially and after velar consonants (that reject palatalization before back vowels), it is adapted as /u/ (e.g. in the adaptations of Fr. *dégustation* and *unitaire*) where one would expect "/^{j}u/, /ju/ or even /uj/" (Paradis 2006: 980).

However, Paradis' arguments are flawed (cf. also Padgett 2010).

Ad (1): Paradis' findings that /C^{j}u/ is rare in Russian are due to unfortunate choices in her methodology: she based herself on a dictionary, whereas /C^{j}u/ sequences abound in inflected forms; also, languages tend to favour perceptually contrasting sequences, like the F2 contour of /C^{j}u/. /C^{j}u/, then, is not as 'unnatural' as she claims (if we want to equate 'rare' and 'unnatural' at all).

Ad (2): the difference between /^{j}u/ and /ju/ is not trivial in Russian. Moreover, /ju/ and /uj/ are not plausible candidates for the adaptation of /y/, as /y/ lacks the robust F2 transition that would mark /ju/ and /uj/; also, the duration of /y/ is probably much shorter than that of /ju/ or /uj/. Finally, velar consonants do not reject palatalization before back vowels, but even if they did, the examples *dégustation* and *unitaire* are poorly chosen. They are neologisms created from Latin roots, many of which were formed in the 15th, 16th and 17th centuries, subsequently spreading throughout the languages of Europe; it is doubtful whether such words have been directly borrowed from French. A counterexample at first sight would be /kuxn^{j}a/ 'kitchen', closely related to

German *Küche* [kʏçə];[3] however, /kuxnʲa/ was borrowed from Polish *kuchnia* /kuxnʲa/, not from German (Wade 1999; Podgajevskaja & Honselaar 2007). Podgajevskaja & Honselaar (2007: 46) point out that "if it had been borrowed directly from German, something like /kʲuxʲe/ were to be expected" (translation kts). Indeed, the French word *curie* [kyʁi] has been adapted as /kʲurʲi/, not /kurʲi/.

There are some Russian consonants (/t͡s ʂ ʐ/) that do reject palatalization; in those cases, the perceptual stance would probably fall short, because it does not consider perception to be phonological. However, if we assume that the perception process is governed by phonotactic constraints, we can easily explain such cases (cf. §4.2).

4 The Russian adaptation of [y]

In this section, I will formalize the Russian perception of [y] within the BiPhon model. To do so, we need to take a closer look at Russian phonetics and phonology (§4.1); in the remaining subsections, I will introduce the elements of the perception grammar and provide tableaux of the perception process in various phonological environments.

4.1 The Russian segment inventory

The Russian consonant system has a prominent distinction between so-called 'hard' (plain or velarized) and 'soft' (palatalized) consonants. Most consonants have both plain and palatalized variants, but some consonants are unpaired, i.e. either always hard or always soft. The perceptual contrast between both types of consonants is substantial: soft consonants have F2 positions higher than ca. 1700 Hz, hard consonants have F2 positions lower than ca. 1400 Hz (Halle & Jones 1971; Bolla 1981; Kochetov 1999). Vowels after palatalized consonants have higher F2 values than vowels after plain consonants (De Silva & Ullakonoja 2009: 26–29; Fant 1960: 110; Timberlake 2004: 31).

The Russian vowel system contains five vowels /a e i o u/. Of these, the high vowels /i u/ are of most interest to this article, since they share their low F1 with [y]: the large amount of acoustic energy in low-frequency regions that marks high vowels makes adaptations with non-high vowels unfeasible.

While most sources recognize two allophones of postconsonantal /i/, viz. [i] after soft consonants and [ɨ] after hard ones, I will follow Padgett's (2001) argument that /Cʲi/ does not contrast with /Cɨ/, but with /Cʸi/, i.e. the contrast

[3] This donor form has a lax vowel [ʏ]; for the sake of simplicity, I will ignore the tense-lax opposition here, thus treating [ʏ] and [y] alike. Considering the small differences in F1 and F2 between them, their Russian percepts are expected to be identical.

does not lie in the vowel but in the consonant, which can be either velarized or palatalized. The F2 transition from [ʏ] to [i] is much larger than that from [ʲ] to [i], and takes more time, as a result of which measurements in the midpoints of these vowels differ considerably: the F2 halfway the vowel is lower in [ʏi] than in [ʲi]. Table 1 lists the F2 frequencies of the Russian high vowels [i] and [u] after palatalized and velarized or plain consonants. The data of the female speaker are taken from Timberlake (2004: 31), the data of the male speaker were obtained for this article.[4]

Table 1. *F2 frequencies of Russian high vowels*.

	F2 (Hz) at vowel midpoint		
vowel	female	male	average
[ʲi]	2121	1999	2060
[ʏi]	1925	1605	1765
[ʲu]	1295	1213	1254
[u]	555	813	684

4.2 The elements of the perception grammar

Many borrowings containing [y] were adapted from French and German, languages in which [y] has an F1 of ca. 250 Hz and an F2 of ca. 1800 Hz[5] (for German: e.g. Wängler 1974; Hakkarainen 1995; Kohler 1995; for French: e.g. Pierret 1994; Léon 2005). A very salient property of [y] is found in the visual modality: high rounded vowels exhibit a large degree of lip protrusion (Benoît et al. 1992; Cosi & Magno Caldognetto 1995).

Let me hypothesize that the adaptation of [y] was done in everyday speech situations, since there was direct contact between speakers of French and German and speakers of Russian. In such settings, a hearer has both auditory and visual cues at his disposal, and visual cues profoundly affect perception (e.g. McGurk & MacDonald 1976; Massaro & Cohen 1993; Burnham & Dodd 1996). On the basis of the (mid-vowel) formant frequencies of [y], a Russian hearer might be inclined to perceive his native vowel /$^{(ʏ)}$i/, but this vowel lacks the lip protrusion present in [y]; the hearer is thus presented with conflicting cues. In such cases, "perception […] is dominated by the modality that provides the

[4] Recordings were made of one male native speaker of Russian (age 24 years), in a sound-proof booth with a Sennheiser MKH105 microphone at a sample rate of 44,100 Hz. The recordings were analyzed with the programme Praat (www.praat.org). The speaker read words of the structure /CVk/, where C could be {p, p', b, b', t, t', d, d', m, m', n, n'} and V could be {i, u}. This yielded a total of 24 words, each of which was recorded ten times.

[5] I will disregard vowel length in German donor forms, as length is not distinctive in Russian.

more reliable information" (Traunmüller & Öhrström 2007: 244), and "[…] roundedness [is] predominantly perceived in agreement with the optic rather than the acoustic stimulus" (Traunmüller 2006: 138). This effect is even stronger in foreign-language perception (Sekiyama & Tohkura 1993; Chen & Hazan 2007). In the Russian perception of [y], then, the visual modality is likely to have played a crucial role.[6]

A bimodal perception grammar in the BiPhon model contains visual cue constraints and auditory cue constraints, that interact with each other and with structural constraints (cf. Boersma 2006/2012 for a formalization of the McGurk effect).

Every language learner faces the task of figuring out how sensory events in his environment relate to phonological categories of his language: because of this, a formalization requires cue constraints evaluating all relations between cues and candidate percepts. In the initial state of the grammar, all constraints are ranked at the same height, and with every incoming piece of linguistic information the learner will update his grammar, for as long as it proves necessary. Formalizations of this Gradual Learning Algorithm are provided in e.g. Boersma (1998) and Boersma & Hayes (2001). The final constraint ranking will reflect the probability that a sensory event pertains to a phonological category: for instance, a vowel with a high F1 is unlikely to be intended as /u/, but very likely to be intended as /a/, so *[*high F1*]$_{V}$ /u/ >> *[*high F1*]$_{V}$ /a/.[7]

To a Russian perceiver, a high vowel with a midpoint F2 of 1800 Hz is most likely to be intended as /ʏi/, slightly less likely to be intended as /ʲi/, less likely to be intended as /ʲu/ and least likely to be intended as /u/ (cf. Table 1). This implies the constraint ranking *[*F2=1800 Hz*]$_{V}$ /u/ >> *[*F2=1800 Hz*]$_{V}$ /ʲu/ >> *[*F2=1800 Hz*]$_{V}$ /ʲi/ >> *[*F2=1800 Hz*]$_{V}$ /ʏi/.

To this same Russian perceiver, a high vowel that shows lip protrusion is most likely to be intended as /ʲu/ or /u/, since lip protrusion signals vowels that have the property [+round]; it is unlikely to be intended as /ʲi/ or /ʏi/, as these vowels are marked by the property [–round] and are never produced with lip protrusion. This implies the ranking *[*ROUNDED*]$_{V}$ /ʲi ʏi/ >> *[*ROUNDED*]$_{V}$ /ʲu u/.

The relevance of consonantal F2 for the Russian soft-hard contrast can be expressed in a cue constraint *[*high F2*]$_{C}$ /C[–pal]/ 'do not perceive a high (consonantal) F2 as a hard consonant' (in perception) or 'do not produce a hard

[6] In fact, visual cues contribute greatly even to L1 perception of [y]. In the absence of visual cues, French natives misperceive tokens of [y] with superimposed noise significantly more often than they do tokens of [a] and [i]; however, with visual input, tokens of [a] and [i] with superimposed noise are misperceived significantly more often than [y] (Benoît, Mohamadi & Kandel 1994; Robert-Ribes et al. 1998).

[7] Cues pertaining to vowels are indicated with a subscript $_{V}$, cues pertaining to consonants with a subscript $_{C}$. Visual cues will be given in SMALL CAPITALS.

consonant with a high F2' (in production). Considering the prominence of the palatalized vs. plain contrast in Russian, this constraint must be ranked high, or else the perceptual difference between such words as /mat^{j}/ 'mother' and /mat/ 'foul language' would be obscured. Since the learner must gain knowledge of all relations between a cue and candidate percepts, the grammar also includes a cue constraint *[*high F2*]$_{C}$ /C[+pal]/, which will come to be ranked low.

We now have eight constraints: four auditory cue constraints for the vowel F2, two visual cue constraints for the lip rounding in the vowel, and two auditory cue constraints for the consonant F2. I assume strict domination between the auditory cue constraints concerning the vowel F2, between the visual cue constraints and between the auditory cue constraints concerning the consonantal F2. These constraints can be divided into four strata. Given the saliency of the lip protrusion and the importance of the visual modality in case of incongruent cues, especially in foreign-language perception, *[*ROUNDED*]$_{V}$ /^{j}i ʏi/ is ranked in the highest stratum; in this stratum we also find *[*F2=1800 Hz*]$_{V}$ /u/ and *[*high F2*]$_{C}$ /C[–pal]/. The following two strata are occupied by *[*1800 Hz*]$_{V}$ /^{j}u/ and *[*1800 Hz*]$_{V}$ /^{j}i/, respectively; the lowest stratum contains three cue constraints that evaluate very strong and predictable relations between cues and segments, viz. *[*1800 Hz*]$_{V}$ /ʏi/, *[*high F2*]$_{C}$ /C[+pal]/ and *[*ROUNDED*]$_{V}$ /^{j}u u/. These constraints are ranked very low because the learner has come to know that they are never violated in Russian.

This grammar is sufficient to formalize most cases of the adaptation of [y], although we will see in the following subsection that it needs to be further refined.

4.3 The adaptation of [y] *in postconsonantal position*

In postconsonantal position, Russian offers four candidate percepts: /C^{j}i/, /CʏI/, /C^{j}u/ and /Cu/. Whether a Russian hearer perceives a hard or soft consonant depends on the F2 of the consonant in the donor form. Measurements were obtained of the F2 frequencies of the release bursts of German plosives before [y]:[8]

[8] Recordings were made of three native speakers of German, two females and one male (mean age 49 years, standard deviation 9 years, all raised in Standard German), in a sound-proof booth with a Sennheiser MKH105 microphone at a sample rate of 44,100 Hz. The recordings were analyzed with Praat. Each word was read ten times.

Table 2. *F2 frequencies of German plosive release bursts*.

F2 (Hz) at release		consonant						
		[p]	[b]	[t]	[d]	[k]	[g]	avg.
speaker	F_A	1825	1850	1875	1875	1725	1750	1825
	F_B	1700	1750	2175	2075	1525	1625	1800
	M_C	1800	1750	2025	1900	1500	1325	1700

Remember from §4.1 that the F2 of soft consonants typically lies above 1,700 Hz, and that of hard consonants below 1,400 Hz. The measurements from Table 2 show that the F2 positions of German plosives before [y], except perhaps velars, are such that they will probably be perceived as soft consonants by Russian hearers.

The ranking from §4.2 can be seen at work in Tableau 1, in which the adaptation of the Turkish word *tük* [tyk] 'bundle' is formalized. This tableau yields /tʲuk/ as the optimal candidate. The presence of lip protrusion in the vowel excludes /tʷik/ and /tʲik/; the competition between /tʲuk/ and /tuk/ is settled by the high consonantal F2 of [t] in [tyk] and by the fact that a vowel with an F2 of 1800 Hz is more likely to be intended as /ʲu/ than as /u/.

Tableau 1. *Russian perception of* tük [tyk].

[tyk] [high F2 release burst]$_C$ [*ROUNDED, F2=1800 Hz*]$_V$	*[*ROUNDED*]$_V$ /ʲi ʷi/	*[*1800 Hz*]$_V$ /u/	*[*high F2*]$_C$ /C[–pal]/	*[*1800 Hz*]$_V$ /ʲu/	*[*1800 Hz*]$_V$ /ʲi/	*[*1800 Hz*]$_V$ /ʷi/	*[*high F2*]$_C$ /C[+pal]/	*[*ROUNDED*]$_V$ /ʲu u/
/tʷik/	*(!)		*(!)			*		
/tʲik/	*!				*		*	
/tuk/		*(!)	*(!)					*
☞ /tʲuk/				*			*	*

Tableau 1 applies in the majority of cases, since most Russian consonants can be palatalized before /u/. Exceptions are /t͡s ʂ ʐ/: these consonants cannot be palatalized in native Russian words, nor in loanwords. For instance, Germ. *Zürich* [t͡syːʁɪç] has been adapted as /t͡surʲix/, not /t͡sʲurʲix/; Fr. *parachute* [paʁaʃyt] has been adapted as /paraʂut/, not /paraʂʲut/; and Fr. *jury* [ʒyʁi] has

been adapted as /zʲurʲi/, not /zʲurʲi/ (Timberlake 2004: 54; Podgajevskaja & Honselaar 2009: 36). This is due to structural constraints */t͡sʲ/, */ʂʲ/ and */zʲ/. The ranking of these constraints with respect to the constraints in Tableau 1 is difficult to infer from the Russian lexicon, but the loanword data clarify that they must outrank *[*F2=1800 Hz*]$_V$ /u/: although /u/ is a worse match than /ʲu/ for a vocalic F2 of 1800 Hz, it is still preferable to palatalizing /t͡s/. The addition of a new top-ranked stratum containing *[*ROUNDED*]$_V$ /ʲi ɤi/ and *t͡sʲ/ is required. The perception of *Zürich* can then be formalized as in Tableau 2:

Tableau 2. *Russian perception of* [t͡sy:ʁɪç].

[t͡sy:ʁɪç] [high F2 release burst]$_C$ [*ROUNDED, F2=1800 Hz*]$_V$	*[*ROUNDED*]$_V$ /ʲi ɤi/	*t͡sʲ ʂʲ zʲ/	*[*1800 Hz*]$_V$ /u/	*[high F2]$_C$ /C[– pal]/	*[*1800 Hz*]$_V$ /ʲu/	*[*1800 Hz*]$_V$ /ʲi/	*[*1800 Hz*]$_V$ /ɤi/	*[*high F2*]$_C$ /C[+pal]/	*[*ROUNDED*]$_V$ /ʲu u/
/t͡sirʲix/	*!			*			*		
/t͡sʲirʲix/	*(!)	*(!)				*		*	
☞ /t͡surʲix/			*	*					*
/t͡sʲurʲix/		*!			*			*	*

We now have all the components of our grammar. Note that none of the constraints is loanword-specific, and that their ranking is feasible for native Russian perception and production.

4.4 The adaptation of [y] *in word-initial position*

In a formalization of the adaptation of word-initial [y], not all constraints from §5.1–5.2 are relevant. Obviously, the structural constraints *t͡sʲ/, */ʂʲ/ and */zʲ/ do not apply, and neither do the cue constraints about the consonantal F2. Also, because palatalization and velarization are properties of consonants, only /i/ and /u/ can occur word-initially: the cue constraints about /ɤi/ and /ʲu/ can thus be left out. The cue constraint about /u/ is still relevant, as well as the cue constraint about /ʲi/, since the midpoint F2s of postconsonantal [u] and [ʲi] are usually identical to that of word-initial [u] and [i] (Halle & Jones 1971: 162; Timberlake 2004: 32). The candidate set can also be reduced.

To my knowledge, very few Russian words that begin with /u/ have been borrowed in perception from a donor form starting with [y]. The examples

provided by Paradis & Thibeault (2004) and Paradis (2006), such as *université* and *unitaire*, have probably not been directly borrowed from French, i.e. with [y] (cf. §3). The only apparent exception, to my knowledge, is Germ. *Übermensch*, which has been borrowed with word-initial /u/. This would have proceeded as in Tableau 3:

Tableau 3. *Russian perception of* Übermensch [yːbɐmɛnʃ].

[yːbɐmɛnʃ] [*ROUNDED*, *F2=1800 Hz*]$_V$	*[*ROUNDED*]$_V$ /i/	*/t͡sʲ ʂʲ ʐʲ/	*[*1800 Hz*]$_V$ /u/	*[high F2]$_C$ /C[– pal]/	*[1800 Hz]$_V$ /ʲu/	*[*1800 Hz*]$_V$ /i/	*[1800 Hz]$_V$ /ʏi/	*[high F2]$_C$ /C[+pal]/	*[*ROUNDED*]$_V$ /u/
/.i.bʲer.mʲenʂ./	*!					*			
☞ /.u.bʲer.mʲenʂ./			*						*

The Russian grammar will thus map word-initial [y] to /u/. Further evidence for this formalization comes from Paradis & Thibeault (2004), who found that Russian hearers produced the French non-word *uque* [yk] as /uk/.

5 The role of bimodal perception

One might wonder whether a more elaborate perception grammar than the one presented in §4 would suffice to explain the Russian adaptation of [y] without resorting to the visual modality. For instance, auditory cues other than F2, such as F3, are known to play a role in the perception of both frontness (Carlson, Granström & Fant 1970) and roundedness (Stevens 1998; Ménard et al. 2002). Perhaps [y] is more similar in this respect to [ʲu] than to other candidate percepts, in which case we could do away with any visual cue constraints. Table 3 lists the F2 and F3 frequencies of the vowels of the male Russian speaker from Table 1, as well as the differences between F2 and F3:[9]

[9] Halle & Jones (1971) report F2 and F3 frequencies of all Russian vowels in several environments, but the measurements for [ʲu] appear to be taken in the steady part of the vowel (this is not specified), leading to identical values for [ʲu] and [u]. Fant (1960) also provides F2 and F3 frequencies, but does not report measurements of [ʲu].

Table 3. *F2 and F3 frequencies and F2-F3 differences of Russian vowels*.

vowel	F2 (Hz)	F3 (Hz)	F3 – F2 (Hz)
[ʲi]	1999	2720	721
[ʏi]	1604	2242	638
[ʲu]	1213	2098	885
[u]	813	2274	1461

The F2-F3 difference of [y] is known to be small: it varies cross-linguistically between ca. 200 and 500 Hz (Carlson, Granström & Fant 1970; Schwartz et al. 1993; Vaissière 2006). Table 3 shows that such a difference is most compatible with front vowels, and perhaps also with [ʲu]: however, F3 cannot determine this choice, so another cue must be dominant over it. Besides experiments investigating L1 and L2 bimodal perception, cited in §4.2, three observations about loanwords point to the visual modality.

Firstly, in a number of cases, we find more than one variant of an adaptation. For instance, the German word *Fürst* [fʏʁst] 'prince, ruler' was borrowed into Russian as both /fʲurst/ and /fʲirst/ (Preobrazhensky 1951), and besides the standard form /t͡surʲix/ (from German *Zürich*), we also find /t͡sirʲix/.[10]

Tableaux 1–3 show that the forms with /i/ would be the optimal candidates if the adapter relied mostly on auditory perception. The emergence of these forms could be due to a number of reasons. The degree of cue integration is known to vary between perceivers: not every individual is equally sensitive to visual cues, and in general women are more sensitive to visual cues than men (Irwin, Whalen & Fowler 2006; Traunmüller & Öhrström 2007; Traunmüller 2009). The degree of cue integration depends on speaker style as well (Munhall et al. 1996; Traunmüller & Öhrström 2007), and variation must have been present in the input, for instance because of differences in speech setting. Finally, perceivers may sometimes have had deteriorated access to visual cues.

A decreased influence of visual cues can be formalized by lowering the ranking of the visual cue constraints in the previous tableaux. Tableau 4 is a modified version of Tableau 1: it shows the adaptation of [tyk] if *[*ROUNDED*]$_V$ /ʲi ʏi/ is ranked below *[*F2=1800 Hz*]$_V$ /ʲu/, in which case the winner is /tʲik/ instead of /tʲuk/: the high F2 of [t] results in the perception of a palatalized [t], and the F2 of the vowel is more likely to be intended as /ʲi/ than as /ʲu/.

[10] A Google search for "Цирих" site:.ru on August 1, 2016 returned 2,380 hits.

Tableau 4. *Russian perception of* [tyk] *with lower-ranked visual cue constraints.*

[tyk] [high F2 release burst]$_C$ [*ROUNDED, F2=1800 Hz*]$_V$	*[t͡sʲ ʂʲ ʐʲ]/	*[*1800 Hz*]$_V$ /u/	*[*high F2*]$_C$ /C[–pal]/	*[*1800 Hz*]$_V$ /ʲu/	*[*ROUNDED*]$_V$ /ʲi ʏi/	*[*1800 Hz*]$_V$ /ʲi/	*[*1800 Hz*]$_V$ /ʏi/	*[*high F2*]$_C$ /C[+pal]/	*[*ROUNDED*]$_V$ /ʲu u/
/tʏik/			*!		*		*		
☞ /tʲik/					*	*		*	
/tuk/		*(!)	*(!)						*
/tʲuk/				*!				*	*

The relatively low incidence of the /i/-forms may be explained by a number of factors, e.g. analogy effects and the fact that the degree of lip protrusion in [y] is probably still quite salient to less sensitive perceivers.

However, adaptations with /i/ seem to be more frequent if the [y] in the source form occurs after a labial consonant. This provides a second indication for the relevance of visual cues in the adaptation of [y]: Russian perceivers may have erroneously associated the labial gestures of the sequence [fy] only with Russian /f/, and relied on auditory perception for the vowel.

Table 5 sheds some light on the amount of variation between forms with /$^{(j)}$u/ and /$^{(j)}$i/. Unfortunately the sample is very small, as it was often the case that one of the possible variants (also) had a different meaning.

Table 5. *Incidence of forms with /i/ after consonants with and without visible labial gestures*.

after consonant with visible labial gesture		after consonant without visible labial gesture	
donor form	*% forms with* /i/	*donor form*	*% forms with* /i/
amuse-bouche [amyzbuʃ]	19.8	*costume* [kɔstym]	0.12
Flügel [flygəl]	92.8	*manicure* [manikyʁ]	0.009
jupon [ʒypɔ̃]	47.5	*ouverture* [uvəʁtyʁ]	0.20

Further support for the relevance of visual cues in loanword adaptations can be found in adaptations of front rounded vowels other than [y]. The degree of lip protrusion is correlated with vowel height: more open front rounded vowels

show less lip protrusion than more closed front rounded vowels (Cosi & Magno Caldognetto 1995). [y] thus takes one extreme on this scale. When protrusion is less visually salient, as in the non-high rounded vowels [ø] and [œ], the adapter may be less likely to perceive a rounded vowel. This appears to hold true for Russian: for instance, the German proper names *Goethe* [gøːtə] and *Röntgen* [rœntgən] have been adapted with /e/, i.e. as /gʲetʲe/ and /rʲentgʲen/ respectively. More evidence for this pattern can be found in other languages: in Polish and Japanese, *Röntgen* is also adapted with [e]; in Vietnamese, Fr. *bleu* [blø] 'blue' and *nœud* [nø] 'knot' are adapted with unrounded vowels, viz. as [lə] and [nə] (Barker 1969); in Polish, words with [ø] and [œ] are commonly adapted with /e/, e.g. Germ. *Flöte* [fløːtə] 'flute' and Fr. *chauffeur* [ʃofœʁ] 'chauffeur' have been borrowed as /flet/ and /ʂofer/, respectively; in Italian, the adaptation of Fr. *bleu* was pronounced [blɛ] (Hope 1971: 380), and Fr. *chauffeur* was borrowed as e.g. *sofèr* or *scioffè* (Hope 1971: 481). The vowels in the source forms are phonologically [+round], but the adaptations violate the Preservation Principle: note that for Russian, in analogy with /Cʲu/ < /Cy/, the phonological stance would erroneously predict adaptation of *Goethe* as /gʲotʲe/ ([–back] from /ø/ attaches to the preceding consonant, and [+back] is attached to the vowel as a repair mechanism, yielding /o/). In the BiPhon model, on the other hand, we can assume that the visual cue constraints of non-high front vowels are lower ranked because of the moderate degree of visible rounding.

Note that a feature-based model also cannot explain adaptations like /fʲirst/ < [fʏɐst]: again, the feature [+round] has not been preserved in the adapted form. Interestingly, the opposite pattern occurs as well: the German word *schirmen* has been borrowed in Russian as /ʂurmovatʲ/, meaning that the vowel has been rounded while there was no feature [+round] present in the input. This is most likely due to the fact that German [ʃ] is pronounced with visible rounding, but crucially, /ʃ/ has no featural specification for roundedness.

6 Conclusion and discussion

This article has shown that all instances of the Russian adaptation of the vowel [y] can be explained by making use of the L1 perception grammar. If [y] is preceded by a consonant, the high F2 of the consonant and the F2 and visual roundedness of [y] will be mapped onto a sequence of a palatalized consonant and /u/; if there is no preceding consonant, or if this consonant resists palatalization in Russian, the adaptation yields mere /u/. The present account shows that an explanation without loanword-specific constraints or rankings is possible, and that it is not necessary to assume that the hearer is bilingual (even though she might be). The framework within which this explanation is crucially embedded, Boersma's BiPhon model, assumes that perception is not

extragrammatical, but a process governed by cue constraints and structural constraints.

The hypothesis that visual cues may have played a decisive role in the adaptation is supported by a number of observations: (i) when confronted with conflicting information in bimodal perception, perceivers pay attention to the most reliable cue (in the case of [y]: the salient lip protrusion), and this effect is stronger in foreign-language perception; (ii) the auditory cue of F3, that listeners use to signal vowel roundedness, does not favour the perception of /ʲu/ over /ʲi/ or /ɤi/, and thus cannot serve as an explanans; (iii) alternative forms exist of some loanwords, which may be due to differences between adapters in sensitivity to visual cues, and/or may have arisen in situations where the borrower did not have optimal access to visual cues; (iv) alternative forms seem to be more frequent if [y] occurs in the donor form after a consonant that is marked by a visual labial gesture, suggesting that the Russian perceiver mistakenly conflated the labial gestures of the consonant and [y] and relied on auditory perception for the vowel; (v) while adaptations of [y] with a visually rounded segment are cross-linguistically frequent, front rounded vowels with less salient visual cues, such as [ø] and [œ], are often borrowed as unrounded vowels.

Paradis' (2006) claim that only the phonological view of loanword adaptation can explain the Russian data has been invalidated. Many of her arguments turned out to be incorrect, and a feature-based explanation actually makes predictions that are not borne out by the linguistic facts.

The present article has aimed to show why /ʲu/ or /u/ is the best option for the adaptation of [y] in Russian. The majority of languages adapt [y] by maintaining a visually rounded segment, such as /u/ or /w/, plus a segment with a high F2, such as /i/ or /j/, in spite of the F2 mismatch. Whether a language adapts only /u/, perhaps /ju/ or /wi/, or even just /i/, depends on a number of factors, such as its phonological inventory, phonotactic restrictions on perceived surface structures, considerations of morphological distinctivity, and language-specific weighting of perceptual cues. These cross-linguistic tendencies can be described here, but not fully explained: detailed accounts of the different strategies that languages employ, and of apparent exceptions, require close scrutiny of the languages at hand.

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Correspondence:

Klaas Seinhorst
Spuistraat 134
1012 VB Amsterdam
seinhorst@uva.nl