Phonology versus phonetics in loanword adaptations

A reassessment of English vowels in French*

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The question of whether loanword adaptation is based on phonological or phonetic proximity has been widely debated. Focusing on the adaptation of English vowels in French, I argue that on-line adaptations are based on perceived phonetic proximity, which is influenced by co-articulatory information. A perception experiment assessed French listeners' perception of English vowels presented both within and spliced out of CVC syllables; the results were compared to the on-line adaptations of the same vowels in the same consonantal contexts produced previously by French speakers (Vendelin & Peperkamp 2006). Vowel identification in the two conditions differed, and the on-line adaptations are reflected more closely by the condition with vowels presented in context. These results support the hypothesis that on-line adaptations are based on phonetic, not phonological, proximity. They also show that phonetic variability due to coarticulation influences perception and hence that consonantal context should be controlled for in cross-linguistic vowel comparisons.

1. Introduction

In situations of language contact, lexical borrowing is widespread. This process includes the transformation of non-native sounds onto the closest ones that are legal in the borrowing language. The question of whether such loanword adaptation is based on phonological or phonetic proximity has been widely debated (for a review, see Kang 2011). According to the phonological stance, one phonological

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representation — the one in the source language — is mapped onto a minimally different one that is legal in the borrowing language; phonetic details are assumed to be largely irrelevant for this process (e.g., Paradis & LaCharité 1997). According to the phonetic stance, by contrast, loanword adaptation mainly involves obtaining a minimal distance — typically taken to be a *perceptual* distance — between detailed phonetic representations in the two languages (e.g., Kang 2003). The purpose of the present article is to shed new light on the issue of phonological versus phonetic proximity by focusing on the adaptation of English vowels in French; in previous work, this adaptation has variously been argued to be phonological (LaCharité & Paradis 2005) and phonetic (Vendelin & Peperkamp 2006) in nature.

LaCharité & Paradis (2005) compared phonological and phonetic explanations of loanword adaptations in a variety of cases, and concluded that only a very small minority of adaptations is based on phonetic proximity. One of the case studies they presented concerns the adaptation of the English vowels /ɪ/ and /ʊ/ as /i/ and /u/, respectively, in French (and, for that matter, Spanish). The authors argued that phonetic proximity cannot explain these adaptations, since in the two varieties of French they considered, i.e., Parisian and Quebec French, /i/ and /u/ are not the segments that are acoustically closest to English /ɪ/ and /ʊ/, respectively. Rather, the acoustically closest segments are /e/ and /o/ in Parisian French and /ɛ/ and /ɔ/ in Quebec French. In order to account for the adaptation pattern, LaCharité & Paradis (2005: 236–237) proposed a phonological analysis according to which non-native segments are adapted as those native ones that are closest in terms of phonological feature specifications. The relevant feature specifications they provided for the case at hand are shown in Table 1.

Table 1. Relevant feature specifications of English /ɪ/ and /ʊ/ and of possible French adaptations (taken from LaCharité & Paradis 2005)

	[high]	[ATR]
English		
/ɪ/, /ʊ/	+	–
French		
/i/, /u/	+	+
/e/, /o/	–	+
/ɛ/, /ɔ/	–	–

Thus, English /ɪ/ and /ʊ/, which are [+ high, – ATR], are adapted as French /i/ and /u/, which are [+ high, + ATR], rather than as /e/ and /o/, which are

[– high, + ATR]; the former indeed involves one feature change, whereas the latter involves two. Concerning /ɛ/ and /ɔ/, which are [– high, – ATR] and hence are also only one feature away from English /ɪ/ and /ʊ/, LaCharité & Paradis (2005: 237) argued that they are dispreferred because of a general principle according to which the feature [high] takes precedence over the feature [ATR]; preserving the [+ high] specification of /ɪ/ and /ʊ/ is thus more important than preserving their [– ATR] specification.

Vendelin & Peperkamp (2006) also studied how English vowels are adapted in French, but they examined on-line adaptations instead of adaptations in established loanwords. In particular, they carried out an experiment in which (European) French-English bilinguals inserted English pseudo-words in French sentences. For each of eight English vowels, multiple CVC stimuli had been recorded by four speakers of different varieties of American English. The focus of this study being on the influence of orthography, the stimuli were presented in two conditions, one with and the other without an accompanying written representation. For the present purposes, we are interested in the condition with auditory input only. The results obtained for /ɪ/ and /ʊ/ were largely similar to what is found in established loanwords: /ɪ/ was adapted as /i/ in 95% of the cases, and /ʊ/ was adapted as /u/ in 77% of the cases. However, there was a fair amount of variability in the response patterns to /ʊ/ (with 13% of adaptations as /o, ɔ/ and 9% as /ø, œ/),[1] and some of the other vowels. The most variable response pattern was that for /ʌ/, with the most frequent adaptation /o, ɔ/ being provided in only 55% of the cases; other frequent adaptations were /ø, œ/ (32%) and /a, ɑ/[2] (11%). Furthermore, there was a considerable amount of talker-dependent variability. That is, when the results were separated by the four American English speakers who had recorded the stimuli, differences in the adaptation patterns emerged. The findings in this experiment are unexpected under a phonological analysis; Vendelin & Peperkamp (2006: 1004) rather argued that the variability in the adaptations reflected the

1. In the experiment, participants had to treat the CVC items as verbs and insert them as past participles in French sentences. For instance, the item /mʊb/ would be produced as /mVbe/ (cf. French *faxé* /fakse/ "faxed") in a sentence such as *Les syndicats ont … la proposition du gouvernement* "The unions have … the government's proposal". Thus, while the English vowels were presented in closed syllables, their adaptations were produced in open syllables. In French, however, the low-mid vowels /ɛ/, /œ/, and /ɔ/ are raised to /e/, /ø/, and /o/, respectively, in closed syllables, making it impossible for the participants to adapt the English vowels as low-mid French vowels; in the analyses, low-mid and corresponding high-mid vowels were therefore grouped together.

2. Due to dialectal variation in the use of /a/ and /ɑ/, these vowels were not distinguished in the analyses.

phonetic heterogeneity of the stimuli. More specifically, they hypothesized that the adaptations were based on perceived phonetic proximity.

Vendelin & Peperkamp's (2006) conclusion thus differed from that reached by LaCharité & Paradis (2005). One might want to argue that on-line adaptations, i.e., adaptations in foreign words that are borrowed 'here-and-now', are fundamentally different from established loanwords that are already part of the borrowing language's lexicon, and hence that experimental results with an on-line adaptation task do not bear on the question of whether loanword adaptations are phonological or phonetic in nature. There certainly are differences: not only do on-line adaptations typically show variation that is not reflected in the pronunciation of established loanwords, as shown by the data above, they also tend to preserve more non-native structure (Paradis & LaCharité 1997: 416). However, if we consider that a theory of loanword adaptations should account for why and how speakers adapt L2 sounds to the phonology of their native language, on-line adaptations are actually *more* informative than adaptations seen in established loanwords. Indeed, established loanwords do not undergo any adaptation in the synchronic grammar of the borrowing language; rather, their pronunciation is the stable outcome of a diachronic process that begins with on-line adaptation and by which all but the most common pronunciations tend to disappear.[3]

Of course, Vendelin & Peperkamp's (2006) conclusion raises the question of how a phonetic proximity account is to be reconciled with the observation in LaCharité & Paradis (2005) that among the French vowels, /i/ and /u/ are not acoustically closest to English /ɪ/ and /ʊ/. LaCharité & Paradis (2005) relied on Delattre (1981) for acoustic measurements of vowels in English[4] and Parisian French, and on Martin (2002) for such measurements in Quebec French. Both of these acoustic studies measured midpoint frequencies of the first two formants in vowels in words pronounced in isolation, and LaCharité & Paradis (2005: 234) defined acoustic distance as Euclidean distance in the F1xF2 vowel

3. This point was also made by Paradis & LaCharité (1997), who stated as their ultimate aim to account for on-line adaptations. Based on data from French loanwords in Fula, though, they argued that established loanwords are sufficiently similar to on-line adaptations to be used as a proxy in this endeavour.

4. Delattre did not mention the dialectal origin of the English speakers whose vowels he measured. LaCharité & Paradis (2005) infer that he probably included both American and British English speakers, as his article mentions some differences between the vowels of these two broad varieties.

space.[5] There are many reasons, though, why the data thus obtained are not necessarily adequate to test the phonetic proximity account. First, even though vowels are mostly distinguished on the basis of the first two formants, listeners are sensitive to differences in higher formants too (e.g., Fujisaki & Kawashima 1968). Second, vowels differ on more parameters than on midpoint formant frequencies; additional parameters to which listeners have been shown to be sensitive are duration (Hillenbrand, Clark & Houde 2000) and formant movement trajectories (e.g., Nearey & Assmann 1986, Hillenbrand & Nearey 1999). Third, F1 and F2 contribute equally to Euclidean distance, but F2 has been shown to be more important for vowel identification than F1 (e.g., Delattre et al. 1952, Pols et al. 1969). Fourth, formant frequencies are influenced by F0 (e.g., Miller 1953, Fujisaki & Kawashima 1968); hence, they should undergo speaker normalization. Fifth, the relationship between acoustic frequency and perceived pitch is not linear; formant frequencies should thus be transformed to an auditory scale (e.g., Stevens et al. 1937). Finally, formant frequencies are known to vary according to the surrounding consonants (e.g., Stevens & House 1963) and listeners are sensitive to this coarticulatory information (e.g., Lindblom & Studdert-Kennedy 1967, Hillenbrand, Clark & Nearey 2001). Given that the degree of consonant-to-vowel coarticulation differs across languages (Oh 2002), and that listeners are influenced by their native language in compensation for coarticulation in a non-native language (Levy & Strange 2008), acoustic comparisons should be made in contexts that are controlled for consonantal coarticulation.

A careful acoustic study comparing English and French vowels, taking all of the above-mentioned points into account, is thus to be awaited. Here, I follow a different approach, and test the hypothesis of Vendelin & Peperkamp (2006) that on-line adaptations are based on perceived phonetic proximity by means of a perception experiment. This approach has been used earlier to study the role of perception in established loanword adaptations (Takagi & Mann 1994, Kim & Curtis 2002, Peperkamp, Vendelin & Nakamura 2008). It is inspired by a wealth of speech perception research with both mono- and bilingual listeners, showing effects of the native language on the perception of non-native speech;

5. A small-scale, acoustic pilot study comparing the vowels in the American English stimuli of Vendelin & Peperkamp (2006) with French vowels recorded in the same consonantal contexts confirms the basic observation of LaCharité & Paradis (2005). That is, if acoustic distance is defined by Euclidean distance in the F1xF2 vowel space (with formants being measured at vowel midpoints), /ɪ/ and /ʊ/ as produced by the four American English speakers are not closest to French /i/ and /u/ as produced by four native speakers from France; rather, /ɪ/ is closest to French /e/ and /ʊ/ to French /ɔ/ (Inga Vendelin, personal communication).

in particular, non-native sounds and sound structures tend to be perceived as the phonetically closest ones in the listener's native language (for a review, see Sebastián-Gálles 2005).

In the experiment reported below, I use the same stimuli as Vendelin & Peperkamp (2006) to examine how French listeners perceive English vowels; these perception data are then compared to the on-line adaptations reported previously. Thus, I keep the broad focus of examining all eight English vowels selected by Vendelin & Peperkamp (2006), rather than /ɪ/ and /ʊ/ only. The experiment also addresses the issue of the influence of consonantal coarticulation on vowel identification, in that participants are presented with both the original CVC stimuli and stimuli that contain only their vocalic part.

2. Experiment

A forced-choice identification task was used to examine how French listeners map English vowels produced by American speakers onto their own native vowel categories. To ensure that performance in the task could not be influenced by knowledge of the phonology of English vowels, participants were monolingual speakers of French. In one condition, the vowels had been spliced out of CVC syllables; in the other, they were presented within their context. Hence, whereas in both conditions the vowels were subject to consonantal coarticulation, the source of coarticulation was fully present in only one of them. Crucially, the CVC stimuli were the same as those in Vendelin & Peperkamp (2006), which allows for a direct comparison of the results with the on-line adaptations obtained in that study. Given the hypothesis that on-line adaptations are based on perceived phonetic proximity, which is influenced by co-articulatory information, it is predicted that vowel identification in the two conditions differs, and that the on-line adaptations in Vendelin & Peperkamp (2006) are reflected more closely by the results in the condition with vowels presented in context. For example, /ɪ/ and /ʊ/ should be primarily perceived as /i/ and /u/, respectively, when they are presented in CVC stimuli, but could be perceived more often as /e/ and /o/ when they are presented as spliced vowels.

2.1 Methods

2.1.1 *Materials*

Half of the stimuli were the same as those in Vendelin & Peperkamp (2006), and consisted of twenty-four CVC items of the forms /fVp/, /mVp/, and /pVd/, with V one of the English vowels /i, ɪ, ɛ, æ, ʌ, ɔ, ʊ, u/ (Appendix 1) .[6] All items had been recorded by two male and two female native speakers of American English,[7] for a total of 96 stimuli. The use of multiple speakers guaranteed that, while being phonologically homogeneous, the stimuli presented phonetic variability. Four of the stimuli had been removed because their vowel had been judged (by another native English speaker) as different from the intended one. Overall, there were thus 92 CVC stimuli.

The other half of the stimuli consisted of the vocalic parts of the CVC stimuli. Vowel splicing was based both on visual inspection of the waveform and spectrogram and on auditory inspection; in particular, if after splicing based on visual inspection one (or both) of the surrounding consonants was still identifiable by ear, additional pitch periods of the waveform were removed, until no consonant could be identified.

2.1.2 *Participants*

Twelve native speakers of French, four men and eight women aged between 18 and 29 (mean: 22) participated. They were all born in France and lived in the Paris region. All had some school knowledge of English,[8] but none had started to learn English or any other foreign language before age nine, and none had visited any Anglophone country for an extended period of time.

2.1.3 *Procedure*

Participants were tested individually in a sound-proof booth. They were told that they would listen to vowels in isolation as well as to short words from a foreign language, and that their task would be to indicate which French vowel was most similar to the vowel they heard. The response vowels consisted of the ten stressed oral vowels of French (/i, y, u, e, ø, o, ɛ, œ, ɔ, a/). Stimuli were presented over

6. The consonantal frames had been chosen such as to minimize the presence of real words in both the English stimuli and the French candidate adaptations. Specifically, 17 of the items are pseudo-words in English, the remaining seven being low-frequency words; among the candidate adaptations in French, only one is a real word.

7. One talker had a Mid-West accent, one a New York accent, one a New England accent, and one a Mid-West accent with South-Eastern influences. Two of the talkers did not have /ɔ/ in their dialect, but had been trained to produce this vowel for the purposes of the experiment.

8. Note that little attention is paid to English pronunciation in the French school system. For instance, the presence of the lax counterpart /ʊ/ of /u/ goes unmentioned (the tense-lax pair /i/-/ɪ/, however, is taught, probably because of the presence of a fair amount of minimal pairs in the English lexicon).

headphones, and participants responded by pressing one of the ten number keys on a computer keyboard. These keys had been labelled with the French vowels, and a list with a sample monosyllabic French word for each of them was shown next to the keyboard (Appendix 2). If they wished, participants could re-listen twice to each stimulus before providing a response. All participants performed the task first on the spliced vowels and then on the complete CVC syllables.[9] Within each part, stimuli were presented in a random order. The experiment lasted about 15 minutes.

2.2 Results and discussion

Due to the presence of a large amount of regional and individual variation in the use of high-mid versus low-mid vowels in closed syllables in French, the responses /e/ and /ɛ/, /o/ and /ɔ/, and /ø/ and /œ/ were collapsed — as in Vendelin & Peperkamp (2006) — using the dummy symbols E, O and ∅, respectively. Table 2 shows the mean percentages of responses in the different vowel categories for the eight AmE vowels in the two conditions, together with the results of the condition with auditory input only of Vendelin & Peperkamp's (2006) on-line adaptation experiment. For each vowel, the most frequent response in each condition is indicated in boldface.

The analyses of these results involved two types of comparison. First, results on the perception of spliced and unspliced vowels were compared to one another. Second, results in both perception conditions were compared to the on-line adaptations.

2.2.1 *Perception of spliced vs. unspliced vowels*

First, the amount of variability in the response patterns was analyzed in two ways. One analysis compared the mean numbers of different response vowels per input vowel; a paired t-test showed that they were not different (spliced vowels: 3.9; unspliced vowels: 3.5; $t<1$). The other analysis compared the mean percentage of deviations from the most frequent adaptation given for each input vowel. For instance, the most frequent response for AmE /u/ in the spliced vowel condition is /u/. This response is given in 94.4% of the cases; hence, the deviation is 100−94.4=5.6%. As can be inferred from Table 2, the deviation from the most

9. This was done in order to avoid a possible influence of hearing the vowels within context upon their identification in isolation. While it seems less likely that, conversely, hearing spliced vowels influences their identification within context, the present design does allow for such an influence to occur. Note, however, that it would make it harder to confirm the prediction that the on-line adaptations in Vendelin & Peperkamp (2006) reflect the perception of the AmE vowels as presented in CVC stimuli.

Table 2. Mean percentages of responses in the different French vowel categories for the eight AmE vowels in the spliced ("V perception") and the unspliced condition ("CVC perception"), and mean percentages of adaptations in the condition with auditory input only of the experiment in Vendelin & Peperkamp (2006). For each input vowel, the most frequent response in each of the three conditions is shown in boldface

		French response vowels						
AmE input	**Condition**	**i**	**y**	**u**	**E**	**∅**	**O**	**a**
/i/	V perception	**95.1**	–	–	4.9	–	–	–
	CVC perception	**99.3**	–	–	0.7	–	–	–
	on-line adaptation	***100***	–	–	–	–	–	–
/ɪ/	V perception	27.8	6.9	2.8	**39.6**	21.5	1.4	–
	CVC perception	**75.0**	5.6	2.1	13.9	3.5	–	–
	on-line adaptation	***95.1***	–	*1.4*	*1.4*	*2.1*	–	–
/ɛ/	V perception	–	–	–	**59.7**	35.4	2.1	2.8
	CVC perception	0.7	–	–	***75.7***	13.9	1.4	8.3
	on-line adaptation	*1.4*	–	–	***76.4***	*13.9*	–	*8.3*
/æ/	V perception	–	–	–	33.3	14.6	–	**52.1**
	CVC perception	–	–	–	6.9	2.8	0.7	**89.6**
	on-line adaptation	–	–	–	–	*0.7*	*0.7*	***98.6***
/u/	V perception	–	–	**94.4**	–	0.7	4.9	–
	CVC perception	–	–	**100**	–	–	–	–
	on-line adaptation	–	–	***99.3***	–	–	*0.3*	*0.3*
/ʊ/	V perception	–	0.7	17.4	0.7	38.9	**41.7**	0.7
	CVC perception	–	2.1	**66.7**	–	12.5	18.8	–
	on-line adaptation	–	*1.0*	***76.6***	–	*9.4*	*12.9*	–
/ɔ/	V perception	–	–	–	–	3.1	29.2	**67.7**
	CVC perception	–	–	–	–	12.5	**61.5**	26.0
	on-line adaptation	–	–	*0.5*	–	*2.6*	***91.7***	*5.2*
/ʌ/	V perception	–	–	–	3.5	34.7	23.6	**38.2**
	CVC perception	–	2.1	–	–	**42.4**	**42.4**	13.2
	on-line adaptation	–	*0.7*	*2.1*	*0.3*	*31.6*	***54.5***	*10.8*

frequent adaptation was larger in the spliced than in the unspliced condition for all input vowels except /ɔ/. A paired t-test showed that the mean deviations in the two conditions were different (spliced vowels: 38.9%; unspliced vowels: 23.7%; $t(7)=2.7$, $p=.031$). Thus, responses to the spliced vowels were more variable than those to the unspliced vowels, in the sense that, overall, they differed more often from the most frequent response.[10]

Next, the distributions of the responses in the two perception conditions for the different AmE input vowels were compared to one another. Of course, differences in the variability of the response patterns in the two conditions yield differences in their distribution. But note that distributional differences cannot be reduced to differences in variability. Specifically, differences in variability as defined above are orthogonal to differences in the relative size of the response categories. The latter type of difference is easy to detect in Table 2. In particular, for four of the eight input vowels (/ɪ/, /ʊ/, /ɔ/, and /ʌ/), the most frequent response in the spliced condition was not the same as that in the unspliced condition. For instance, for /ʊ/, the most frequent responses in the spliced and the unspliced conditions were /O/ and /u/, respectively. Moreover, whereas for the majority of the input vowels the two most frequent responses were the same in the two conditions (modulo a possible difference in their rank), this was not the case for /ʊ/ and /ʌ/. For instance, for /ʊ/, the two most frequent responses were /∅/ and /O/ in the spliced condition and /u/ and /O/ in the unspliced condition. It was only when the *three* most frequent responses were considered that there no longer was a difference between the two conditions; thus, for /ʊ/, the three most frequent responses in both conditions were /u/, /∅/ and /O/.

To analyze the overall amount of distributional difference, the distributions in the two conditions were compared by means of χ^2 and Fisher's exact tests. The χ^2 statistic provides a direct measure of distributional overlap: the lower its value, the more overlap there is. Thus, high values of χ^2 are indicative of the distributions having little overlap. Fisher's exact test (here with Bonferroni correction for multiple comparisons) tells us whether they are *significantly* different from one another. The results are shown in Table 3.[11]

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10. To the extent that the spliced vowels can be very short and — per definition — lack speech context, this finding is not surprising. Note also that it is in accordance with data from native speech perception. In particular, Huang (1991) found that native English listeners are less accurate in identifying spliced English vowels than the same vowels presented in context. However, see Strange (1989) for an experiment with English listeners in which no such difference was found.

11. Note that χ2 computations are based on absolute numbers. For ease of reference, these numbers were transformed to percentages in Table 2.

Table 3. Comparison of distribution of responses to vowels in the spliced and the unspliced conditions; p-values are corrected for multiple comparisons

	χ^2	df	p
/i/	4.63	1	>.1
/ɪ/	70.2	5	.001
/ɛ/	21.4	4	.001
/æ/	51.8	3	.001
/u/	8.23	2	>.1
/ʊ/	76.7	5	.001
/ɔ/	34.2	2	.001
/ʌ/	34.3	4	.001
mean	*37.7*		

Thus, the distributions of the responses in the two conditions are different for all vowels except /i/ and /u/. In other words, all of the AmE vowels except /i/ and /u/ were responded to differently according to whether they were presented with or without their surrounding consonants. This difference was by far the highest for /ɪ/ and /ʊ/, with χ^2 values of 70.2 and 76.7, respectively.

These results show that French listeners are sensitive to coarticulation in English stimuli. More specifically, they suggest that the effect of coarticulation is 'undone' for the purposes of vowel identification whenever possible; that is, listeners take coarticulation into account when its source is fully present. Focusing on the two vowels that were discussed in LaCharité & Paradis (2005), i.e., /ɪ/ and /ʊ/, note that the way in which they are perceived when presented as spliced vowels mirrors the acoustic distance data of Delattre (1981). That is, the spliced vowels are perceived most often as /E/ and /O/, respectively, which according to Delattre are the closest French vowel categories. By contrast, when presented in their consonantal context, /ɪ/ and /ʊ/ are perceived as /i/ and /u/, reflecting their respective adaptations in loanwords. These data suggest that Euclidean distance at vowel midpoints in the F1xF2 vowel space is an adequate proxy for perceived phonetic distance, but only when the vowel is presented out of its context. Given that foreign sounds are always adapted within words, acoustic measurements *à la* Delattre are thus largely irrelevant for the question as to the role of phonetic proximity in loanword adaptation.

2.2.2 *Perception vs. on-line adaptation*

First, the amount of variability in the response patterns in the two conditions of the present experiment was compared to that of the on-line adaptations obtained in Vendelin & Peperkamp (2006). The mean number of response vowels in the on-line adaptations was 3.6; paired t-tests showed that this number was not significantly different from the mean number of responses in either one of the two perception conditions (both t's<1). The mean percentage of deviations from the most frequent adaptation given for each input vowel in the on-line adaptations was 13.5%. Paired t-tests showed that this was significantly lower than what was observed in the two perception conditions (on-line adaptation vs. spliced vowel perception: $t(7)=3.9$, $p=.006$; on-line adaptation vs. unspliced vowel perception: $t(7)=2.7$, $p=.030$). This finding will be discussed below.

Next, the response distributions in each of the two perception conditions were compared to those of the on-line adaptations. As to the relative sizes of the response categories, Table 2 shows that on-line adaptation closely matches the perception of unspliced vowels, while it differs from that of spliced vowels. Indeed, the most frequent response in on-line adaptation is the same as that in unspliced vowel perception for all input vowels, but differs from that in spliced vowel perception for /ɪ/, /ʊ/, /ɔ/, and /ʌ/. (Note that these are the exact same vowels that were shown above to differ in their most frequent response in the two perception conditions). The overall amount of distributional differences was again analyzed by means of χ^2. The results, with Bonferroni-corrected p-values, are shown in Table 4. Note that for all individual vowels, χ^2 is at least three times higher in the comparison concerning the identification of the spliced vowel than in the comparison concerning the identification of the unspliced vowel.

Table 4. Comparison of distribution of responses in the auditory condition of Vendelin & Peperkamp's (2006) on-line adaptation experiment with those in the two conditions of the present experiment; p-values are corrected for multiple comparisons

	on-line adaptation vs. V perception			**on-line adaptation vs. CVC perception**		
	χ^2	**df**	**p**	χ^2	**df**	**p**
/i/	7.17	1	.06	2.34	4	>.1
/ɪ/	140	5	.001	26.9	4	.001
/ɛ/	25.5	4	.001	1.00	1	>.1
/æ/	84.0	2	.001	10.8	3	>.1
/u/	8.17	2	>.1	1.00	1	>.1
/ʊ/	104	5	.001	4.40	3	>.1
/ɔ/	82.7	2	.001	26.2	2	.001
/ʌ/	49.4	5	.001	8.95	4	>.1
mean	*62.6*			*10.2*		

These results show that, for all AmE vowels except /u/, the distribution of responses in the spliced vowel condition of the perception experiment is different (or, for /i/, marginally different) from the distribution of on-line adaptations. Quite a different pattern is found for the comparison between on-line adaptation and unspliced vowel perception: for all vowels except /ɪ/ and /ɔ/, the response distributions do *not* differ. Hence, the French vowels produced in on-line adaptations of English items largely differ from the ones that French listeners consider most similar to the spliced vowels of these same items; by contrast, for six of the eight vowels, the on-line adaptations of the items directly reflect the way in which the vowels are perceived when they are not cut out of their consonantal context.

Overall, the comparison of perception and on-line adaptation suggests that loanword adaptation is based on perceived phonetic proximity of whole words. This is because, firstly, on-line adaptation is more similar to the perception of unspliced than of spliced vowels, both in terms of amount of variability and in terms of the distribution of the responses; and, secondly, for six of the eight vowels, the response distribution of on-line adaptation does not differ from that of unspliced vowel perception. Two questions concerning the present data, though, remain to be answered. First, why does unspliced vowel perception yield significantly more variability than on-line adaptation? One possible explanation is that the process of standardization that results in stable pronunciations of established loanwords is already effective in on-line adaptations, at least in a situation where the adapters are familiar with the source language. Thus, knowledge of how English vowels are adapted in loanwords in French could influence participants' performance in the on-line adaptation but not the perception task. Alternatively, the difference in variability of response patterns might be due to the fact that the on-line adaptations were provided by bilinguals, whereas participants in the perception experiment were monolingual. In particular, monolinguals and bilinguals might differ in the way in which they perceive English vowels. Although this explanation would be in accordance with the Speech Learning Model of Flege (1995), it is less likely. Indeed, experimental evidence suggests that it is only highly proficient bilinguals whose perception of L2 sounds differs from that of monolinguals (Fox, Flege & Munro 1995, Flege, Takagi & Mann 1996, Levy 2009), and the bilinguals who produced the on-line adaptations do not fall into this category. A final possibility is that performance on unspliced vowels was influenced by that on spliced ones. Indeed, recall that the two conditions were not counterbalanced across participants; spliced vowels were always presented first. Further research is necessary to tease apart these three possibilities.

The second open question is why the response distribution of on-line adaptation unexpectedly differs from that of spliced vowel perception for two vowels, i.e., /ɪ/ and /ɔ/. This question turns out to be related to the previous one, in the sense that /ɪ/ and /ɔ/ are also largely responsible for the difference in variability between on-line adaptation and unspliced vowel perception: without these two vowels the significance of this difference drops to p=.07.[12] While the same explanations evoked above could account for the deviant performance on these two vowels, it remains to be explained why it is that /ɪ/ and /ɔ/ and not some other vowel(s) yield diverging results. Thus, further research should specifically compare /ɪ/ and /ɔ/ to the remaining six vowels.

3. Conclusion

In previous research, perception experiments have been carried out to demonstrate the role of perceived phonetic proximity in several cases of loanword adaptation (Takagi & Mann 1994, Kim & Curtis 2002, Peperkamp, Vendelin & Nakamura 2008). The approach taken in the present study, however, is novel in that it focuses on on-line adaptation of auditory stimuli and directly compares the adaptations to the perception of the same stimuli. More specifically, an experiment with an identification task assessed the perception of AmE vowels presented both within and spliced out of CVC syllables by French listeners; the results were compared to the on-line adaptations of the same vowels in the same consonantal contexts produced previously by French speakers (Vendelin & Peperkamp 2006). Both experiments had only 12 participants and only 12 stimuli per AmE vowel; moreover, the on-line adaptations were produced by bilinguals, while the participants in the perception experiment were monolinguals. It is therefore quite striking that relatively strong results were obtained: for six out of eight English vowels, the way in which they are adapted reflects the way in which they are perceived, provided the consonantal context is present. By contrast, spliced vowel perception is different from both unspliced vowel perception and on-line adaptation for six out of eight vowels. It would be interesting to gather more data by raising the number of items and participants, and, especially, by using a complete intra-participant design. While the use of monolingual participants in the perception experiment was justified by the objective to avoid a possible confounding of knowledge of the English phonology, abandoning this constraint would make it possible to have the same (bilingual) participants perform both the on-line adaptation and the perception task. This, then, would allow us to examine whether the deviant results with some of the vowels reflect sampling errors or rather call for a principled explanation.

12. To appreciate the specific contribution of /ɪ/ and /ɔ/ to the overall difference in variability, note that the percentage of deviations from the most frequent adaptation in unspliced vowel perception minus that in on-line adaptation is 20.1% for /ɪ/ and 30.2% for /ɔ/; for all other vowels, this difference varies between –0.7% and 12.1%.

The differences in the perception of spliced and unspliced vowels provide evidence that French listeners compensate for coarticulation in English stimuli. Of course, the same holds for native English listeners (e.g., Lindblom & Studdert-Kennedy 1967, Huang 1991, Hillenbrand, Clark & Nearey 2001). Coarticulation is partly language-specific (Manuel 1999), and compensation for coarticulation similarly shows language-specific effects. Focusing on the perception of French vowels, Levy & Strange (2008), for instance, found that naïve English listeners — but not highly proficient English-French bilinguals — are influenced by contextual variation present in their native language. Specifically, discrimination of the French front and back rounded vowels /y/ and /u/ was more difficult when the vowels were followed by an alveolar than by a labial consonant. According to Levy & Strange (2008), this is due to the fact that AmE /u/ is fronted — and hence more confusable with French /y/ — in alveolar contexts. It would be interesting to compare, conversely, English and French listeners' perception of the AmE stimuli used in the present study. The prediction is that the groups of listeners will likewise be affected differentially by consonantal context.

There is one aspect of the data that has not yet been discussed. The set of AmE vowels studied by Vendelin & Peperkamp (2006) can be divided into two groups, one corresponding to four vowel phonemes that are also part of the French vowel inventory, i.e., /i, u, ɛ, ɔ/, and one consisting of four vowel phonemes that are not, i.e., /ɪ, ʊ, æ, ʌ/. According to a phonological theory of loanword adaptation such as the one advocated by Paradis & LaCharité (2005), the former should unambiguously be adapted as such. This prediction is borne out for /i/ and /u/, but not for /ɛ/ and, to a lesser extent, /ɔ/. In fact, /ɛ/ yielded almost a quarter of adaptations (23.6%) other than /ɛ/. Results of the present perception experiment reflect this pattern. The response distribution for unspliced vowels is indeed not different from that of on-line adaptations; the χ^2 value of this comparison is actually the lowest of all, i.e., 1 (see Table 4).[13] Note also that both /ɛ/ and /ɔ/ gave rise to more

13. Note, in passing, that the present results allow us to discard the explanation proposed by Vendelin & Peperkamp (2006) to account for the finding that /ɛ/ is adapted as /∅/ in a fair amount of cases (13.9%). Vendelin & Peperkamp proposed that this is related to a productive alternation between /ə/ (variably pronounced as [ø] or [œ]), and /ɛ/. That is, due to a phonotactic constraint that bans /ə/ in closed syllables, French has many verbs with a stem vowel /ə/ that appears in forms like the infinitive and the past participle (e.g., *mené* [mə.ne] '(have) lead'), but is changed to /ɛ/ in forms such as the first to third persons of the present tense (e.g., *je mène* [mɛn] 'I lead'). Since participants in the on-line adaptation experiment were to produce the CVC items as past participles and hence add the suffix -é, the adaptations of /ɛ/ as /∅/ could indicate that they were influenced by this alternation. This explanation should be discarded, given that in the present experiment /ɛ/ was perceived as /∅/ in exactly the same amount of cases when presented in the phonotactically legal CVC context.

variable adaptations than two of the vowels that are not part of the French vowel inventory, i.e., /æ/ and /ɪ/ (see Table 2). Language-specific phonetic realizations of phonemes are central to two influential models of non-native and L2 speech perception, the Perceptual Assimilation Model (Best 1995, Best & Tyler 2007) and the Speech Learning Model (Flege 1995), which therefore straightforwardly account for effects of phonetic as opposed to phonological distance. For instance, French listeners have difficulty discriminating English /r/ and /w/, despite the fact that their native language contrasts the same phonemes (Hallé, Best & Levitt 1999; see also Best, this volume). The present perception data suggest that vowels that are considered to be phonologically identical in English and French (in particular, /ɛ/ and /ɔ/) can likewise have quite different phonetic realizations. These differences would in turn induce modifications of English /ɛ/ and /ɔ/ in on-line adaptations that are unexpected from a phonological point of view.

Overall, the present results reinforce the hypothesis of Vendelin & Peperkamp (2006) that the on-line adaptation of English vowels into French is based on phonetic, not phonological, proximity. They also show that phonetic variability due to coarticulation influences perception and hence that consonantal context should be controlled for in cross-linguistic vowel comparisons. Strikingly, the strongest effects were obtained for the two vowels that were the focus of LaCharité & Paradis (2005), i.e., /ɪ/ and /ʊ/: these vowels yielded by far the largest differences between spliced vowel perception on the one hand and both unspliced vowel perception and on-line adaptation on the other hand.

Further research is necessary to define an adequate phonetic distance metric for cross-linguistic speech perception. Two sets of data provide some challenging conditions that such a metric should meet. First, as far as vowels are concerned, recent work has shown that, even when consonantal context is controlled for, and when formant frequencies are transformed onto an auditory scale and normalized for speaker variation, perceptual proximity does not reflect acoustic similarity based on mean vocalic duration and formant values (Strange et al. 2007, Strange, Levy & Law 2009, but cf. Escudero, Simon & Mitterer 2012 for a more successful comparison of perceptual and acoustic data). Interestingly, it appears that the extension of the vowel categories in the acoustic space plays a role. That is, a non-native vowel tends to be perceived as closest to a native one whose exemplars reach into the non-native category, even if there is another native vowel whose prototype is closer. For instance, American English listeners perceive French front rounded vowels more as English back vowels than as English front vowels (Levy & Strange 2008, Strange, Levy & Law 2009), despite the fact that the prototypes of the latter are phonetically closer (Strange et al. 2007). However, the acoustic measurements of Strange et al. (2007) also show that American English back vowels vary extensively on the front-back dimension, such that the French front rounded vowels are more similar to some of the AmE back vowel tokens than to even the closest of the front vowel ones. It appears that similar facts could play a role in the adaptation of AmE /ɪ/ and /ʊ/ in at least one variety of French, namely Canadian French. Indeed, in this variety /ɪ/ and /ʊ/ are contextual variants of /i/ and /u/, respectively, occurring in certain closed syllables (Martin 2002). Thus, the Canadian French vowels /i/ and /u/ likely include tokens that are phonetically closer to AmE /ɪ/ and /ʊ/ than any tokens of /e/ and /o/. As a consequence, Canadian French listeners would tend to perceive and — according to the perceived phonetic proximity hypothesis — adapt /ɪ/ and /ʊ/ as their native vowels /i/ and /u/, and this regardless of the context.[14]

The acoustic research by Strange and colleagues (2007) suggests that the standard method of comparing mean values of formants and duration is inadequate for measuring perceived phonetic distance and should be replaced by one that compares the *distribution* of these values.[15] Moreover, acoustic tokens should be gathered from vowels produced in utterances rather than in isolated words; it is indeed only within utterances that vowels display their full phonetic extension (Strange et al. 2007). There is a second challenge, though, for the definition of a metric for perceived phonetic distance: non-native listeners have been shown to sometimes outperform native listeners. In particular, Danish listeners are better at discriminating AmE /w/-/j/ than American English listeners, despite the absence of /w/ in the Danish phoneme inventory (Bohn & Best 2012); this is unexpected in all models of non-native speech perception. Bohn & Best's account of this finding is based on the fact that Danish has both rounded and unrounded front vowels. They hypothesize that Danish listeners are therefore highly sensitive to distinctions in lip rounding, the defining feature of the AmE /w/-/j/ contrast; consequently, they would discriminate this contrast better than American English listeners, whose language uses rounding in fewer contrasts. This is an extremely interesting proposal, which suggests that models of non-native speech perception should include broad systemic factors. At present, the relative strength of such factors is unknown. Under the hypothesis that loanword adaptations reflect non-native speech perception, it further suggests that, after all, phonological (as opposed to

14. To the best of my knowledge, no phonological analysis of loanword adaptation has relied on the presence of high vowel allophony in Canadian French to explain the adaptation of English /ɪ/ and /ʊ/. On the contrary, LaCharité & Paradis (2005) argue that contextual variants of phonemes, whether in the source language or - as in the present case - in the borrowing language, never play a role in loanword adaptation. They provide several examples to illustrate this point. Obviously, more research is needed to investigate this issue. It would be especially interesting to examine the cases mentioned by LaCharité & Paradis (2005) by means of perception and on-line adaptation experiments.

15. An appropriate measure could be the Mahalanobis distance (Mahalanobis 1936).

phonetic) aspects cannot be completely discarded to account for the transformations that illegal sounds undergo; in particular, the contrastive load of distinctive features in the borrowing language would play a role in loanword adaptations.

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Appendix 1: Materials

/fip/	/fɪp/	/fɛp/	/fæp/	/fup/	/fʊp/	/fɔp/	/fʌp/
/mib/	/mɪb/	/mɛb/	/mæb/	/mub/	/mʊb/	/mɔb/	/mʌb/
/pid/	/pɪd/	/pɛd/	/pæd/	/pud/	/pʊd/	/pɔd/	/pʌd/

Appendix 2: French vowel graphemes used for the response keys, and sample words shown throughout the experiment

y	é	ê	ou	eu	œu	i	ô	o	a
vue	nez	fête	tout	peu	peur	nid	beau	botte	patte