Reverse Engineering: Emphatic Consonants and the Adaptation of Vowels in French Loanwords into Moroccan Arabic*

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Abstract
On the basis of two large corpora of French (and Spanish) loanwords into Moroccan Arabic, the paper documents and analyzes the phenomenon noted by Heath (1989) in which a pharyngealized consonant is introduced in the adaptation of words with mid and low vowels such as *moquette* > [MokeT] = /MukiT/ 'carpet'. It is found that French back vowels are readily adapted with pharyngealized emphatics while the front vowels tend to resist this correspondence. The implications of the phenomenon for general models of loanword adaptation are considered. It is concluded that auditory similarity and salience are critical alternative dimensions of faithfulness that may override correspondences based on phonologically contrastive features.

Keywords
pharyngealization, enhancement, auditory salience, weighted constraints, harmony

1. Introduction

One of the most interesting questions in the theory of loanword adaptation concerns the role of redundant features. It is well known that phonological contrasts on consonants are often correlated with the realization of the same or a related (enhancing) feature on adjacent vowels. Such redundant properties are known to play a role in speech perception and frequently share or take

over the burden of signaling the contrast in the adjacent consonant, which is often weakened or eliminated entirely – a common category of phonological change. For example, the voicing contrast in English stops is correlated with a length difference in the preceding vowel. Speakers can utilize the redundant vowel length to recover the underlying contrast in the following consonant even if the latter is weakened or eliminated in casual speech (for example, when the final stops of *write* vs. *ride* are not released). This phenomenon has also been demonstrated experimentally where subjects can guess the identity of a downstream consonant on the basis of cues in the preceding vowel. Lahiri & Marslen Wilson (1991) showed that subjects with different language backgrounds perform differently in such experiments depending on whether the relevant feature (vowel nasality in their case) is redundant and hence predictive of the identity of the following consonant (English) or distinctive and hence not predictive (Bengali). In loanword adaptation similar cases arise in which the redundant, enhancing feature on the vowel matches a phonemic distinction in the source language. The adapter is then faced with a conflict between remaining faithful to the consonant or to the vowel. For example, in Mandarin Chinese the feature [back] is not contrastive in mid and low vowels. Rather, its value is determined by the following coda consonant, with [n] calling for a front vowel and [ŋ] for a back vowel by a well-known enhancement relation between coronal vs. dorsal place in consonants and backness in vowels (Flemming 2003). Hsieh, Kenstowicz, and Mou (2006) show that when words from English with conflicting values for vowel backness and coda place such as [dæŋ] and [dɑn] are borrowed into Mandarin, it is the backness of the vowel (redundant in Mandarin) that determines the outcome at the expense of the place feature of the coda consonant (the site of the phonemic contrast in Mandarin). For example, the [ɑn] of (*ra)don* and *canto* appears as [ɑŋ] in Mandarin *dang* and *kangtuo* while the [æŋ] of *bank* and *Langley* appears as [an] in Mandarin *banke* and *lanle*. They attribute this outcome to the relative phonetic saliency of the backness feature in the vowel as compared to the place difference in the nasal coda: Id-V[back] » Id-CPlace[nasal].

Moroccan Arabic (MA) offers another potential example of this phenomenon. Like other Arabic dialects, MA has an underlying three-vowel inventory /i/, /u/, and /a/ along with epenthetic schwa and a contrast between plain vs. pharyngealized (aka emphatic) consonants. The vowels are realized with notable lowering and backing in the context of an emphatic. In his ground-breaking study of loanword adaptation, Heath (1989:75) notes that French *moquette* [mɔkɛt] is adapted as MA [MokeT] by inserting emphasis on the adjacent consonants in order to create the phonological context in which the underlying high vowel phonemes /i/ and /u/ of /MukiT/ can be realized with the allophones that approximate French (and Spanish) mid vowels. It is clear that

the French vowels are interpreted as reflexes of underlying emphatics in the MA borrowings. For when the loan is integrated into the language's rich templating morphology, the emphatic consonant remains in the face of radical changes in the vocalic and syllabic structure. For example, Fr *boîte* 'tin can' is adapted as MA *bwaT*, from which the diminutive *bwiyT-a* and measure-II verb *bwwəT* are formed based on the radicals /bwT/. As observed by Heath (1989:4), the MA situation makes for a particularly interesting case study for a theory of loanword adaptation since it is "almost entirely unmediated by literacy (i.e. with few or no spelling pronunciations and with virtually no institutional orchestration)." Thus, for example, the final silent consonants of French words such as *gros, bandit*, etc. are never realized: *gRu*, *BanDe* (cf. *biznis* from Fr *business* [biznɛs] and *bwaT* from Fr *boîte* [bwat] 'tin can'). Hence, we can be more certain in this case that phonological and phonetic factors are the primary determinants of the adaptation. Moreover, there is a large amount of data available and words continue to be borrowed every day making the MA case worthy of an in-depth investigation. Accordingly, our goal in this article is to analyze this phenomenon in detail based on the data in Appendix C to Heath's monograph (c. 700 words) and our own more extensive corpus of c. 1,800 French loanwords.

The remainder of the article is organized as follows. In section 2 we review the phonological and phonetic reflexes of the emphatic contrast in MA. Section 3 documents the correspondences between Fr and MA vowels in monosyllabic loans. Section 4 contains our OT analysis of this portion of the loanword grammar. Section 5 examines the correspondences found in disyllabic loans, focusing on the effect of stem harmony for emphasis. Section 6 looks at differences in place of articulation of surrounding consonants on the rate of emphaticization. Section 7 presents the results of a modeling of the data in a Harmonic Grammar with weighted constraints. Section 8 is a brief summary and conclusion.

2. Phonological and Phonetic Background

Moroccan Arabic (MA) differs from many other modern colloquial Arabic dialects in having radically reorganized the vowel system of Classical Arabic (CA). The latter—more or less faithfully reflected in the pandialectal Modern Standard Arabic (MSA)—has three vowel phonemes /i/, /u/, and /a/ that contrast for length. In most modern (urban) colloquial Arabic dialects the diphthongs /aw/ and /ay/ are realized as long mid vowels [oo] and [ee]. In the development of Moroccan Arabic, on the other hand, the CA short vowels neutralized to schwa or deleted while the long vowels appear as simple [i], [u], and [a]. In addition, the CA diphthongs /ay/ and /aw/ are reflected as MA [i] and [u], respectively.

(1)	MSA	MA	
	baab	bab	'door'
	tiin	tin	'figs'
	ħuut	ħut	'fish'
	ʒanna	ʒənna	'paradise'
	bint	bənt	'daughter'
	nukta	nʷəkta	'joke'
	sayf [seef]	sif	'sword' (cf. pl. syuf)
	lawn [loon]	lun	'color' (cf. pl. lwan)

Finally, an exceptionless phonotactic constraint bars the schwa from an open syllable, creating consonant clusters in positions where many other dialects preserve the short term of the long:short contrast.

(2)	MSA	MA	
	maktab	məktəb	'desk'
	katab	ktəb	'he wrote'
	kitaab	ktab	'book'

As in other dialects, a subset of the consonantal phonemes of MA contrast for "emphasis" (aka *mufaxxama*), an articulatory maneuver that "darkens" or "thickens" the consonant. The phonetic basis of this secondary articulation has been extensively investigated and found to vary dialectally among velarization, uvularization, pharyngealization, and even glottalization. See Shoul (2007) for an overview. The MA consonants that exhibit the contrast are shown below with a few examples. We transcribe the emphatics in upper case.

(3)	tab	'repent'	Tɑb	'cooked'
	sif	'sword'	Sef	'summer'
	dima	'always'	Dem	'chagrin'
	riħ	'wind'	Req	'saliva'
	zaʒ	'glass'	ZɑZ	'chick'
	br-a	'needle'	BR-ɑ	'letter'
	bk-a	'cry'	Bq-ɑ	'remain'

In the native vocabulary the emphatic contrast is found primarily in the coronal obstruents /T, D, S, Z/ vs. /t, d, s, z/ and in the rhotics /R/ vs. /r/. It occurs marginally in the lateral (*LLah* 'God'). In labials we find /M/ and /B/ in some kin terms such as *BBa* 'father' and *MM-e* 'my mother'. As mentioned above, the emphatic contrast is reflected in adjacent vowels. The MA /i/, /u/ and /a/

phonemes take lowered and retracted allophones, transcribed here (following Heath 1989:19) as [e], [o], and [ɑ], respectively, when tautosyllabic with an emphatic consonant. In Arabic dialects, the emphatic feature tends to be realized over domains larger than the syllable--maximally the phonological word. Emphasis can spread in both directions and dialects differ as to which segments if any block (or minimize) the propagation. In MA the process is restricted to the stem and does not affect inflectional suffixes except that a CV sequence must be realized uniformly as plain or emphatic (Laaboudi 2006). Thus, in the verbal and nominal paradigms in (4) the suffixes remain nonemphatic except that the vowel of the feminine/plural suffix /-at/ appears as *-at* after an emphatic. The absence of emphasis on the inflectional suffixes is particularly noticeable for the MA /t/ phoneme, which has a noisy, aspirated release when plain.

(4)		/ktb/ 'write'	/fTr/ 'eat breakfast'
1 sg.		ktəb-t	FTəR-t
2 sg.f.		ktəb-ti	FTəR-ti
3 sg.m.		ktəb	FTəR
3 sg.f.		kətb-at	FəTR-ɑt
1 pl.		ktəb-na	FTəR-na
2 pl.		ktəb-tu	FTəR-tu
3 pl.		kətb-u	FəTR-o

ydid-a	'hand' dimin.	BeD-ɑ	'egg'
ydid-at pl.		BeD-ɑt pl.	

In (5) we show the placement of the MA vowels in F1/F2 acoustic space. These data are based on ten sample words for each vowel that were recorded under laboratory conditions by two male MA speakers. Each word was repeated to yield a set of forty observations per vowel. Measures in Hz were taken by hand at the vowel mid point using Praat (Boersma & Weenink 1992-2008).

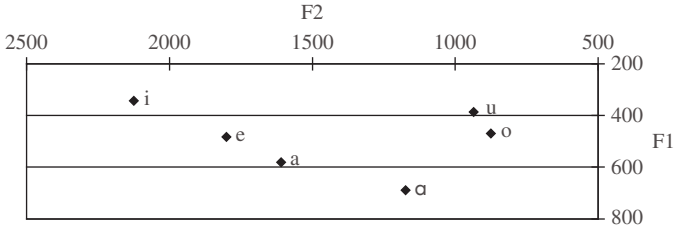| (5)		plain			emphatic		
		i	u	a	e	o	ɑ
F1	av	343	386	582	483	470	689
	sd	46	24	62	60	58	49
F2	av	2125	935	1609	1801	875	1176
	sd	257	175	85	150	87	119

Figure 1. MA Vowels in F1-F2 Space (Hz).

The following observations can be made. First, for the plain vowels [i,u,a] the F1 span of 239 Hz for [i] vs. [a] is quite a bit less than the 290 Hz span reported by Ladefoged (2001) for American English (AE) lax [æ] vs. [ɪ]. This difference between the two languages makes sense on the grounds of dispersion theory (Flemming 1995, 2002) since MA lacks the intermediate mid vowel of English. The 1192 Hz F2 difference between [i] and [u] approaches the 1388 span for AE [i]-[u] tense vowels and considerably exceeds the 890 distance between AE lax [ɪ] and [ʊ]. Second, for the high vowels the F1 differences between the plain vs. emphatic contextual allophones [i] vs. [e] and [u] vs. [o] (124 Hz and 79 Hz, respectively) are comparable to the differences found in the Kenstowicz (2009) study of Kinande [ATR] harmony, where the primary acoustic difference between the [+ATR] high vowels [i̇] and [u̇] and the [–ATR] [i] and [u] was c. 100 Hz in F1. This in turn raises the question of whether the differences in the MA emphatic vs. plain context are due solely to expansion vs. contraction of the space in the pharyngeal cavity or are also tied to an associated difference in the tongue body that alters the volume of the oral cavity. It is in the nonhigh vowels that the two languages diverge. For Kinande [a̙] vs. [a] and [o̙] vs. [o] there is virtually no difference in F2, while for MA [a] vs. [ɑ] there is a considerable divergence in this dimension as well. This suggests that the constriction in the pharynx formed by the tongue dorsum/root is coupled with a retraction of the tongue body.[1]

In Figure 2 we have plotted the same MA vowels on the perceptually more relevant Bark scale in which Hertz differences at higher frequencies are minimized using the formula from Traunmüller (1990). Our results here are very close to the F1-F2 plot of MA vowels in Barks reported by Al-Tamimi (2007).

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[1] Shoul (2007:25) cites a fiberoptic study of MA by Zeroual (2000) who finds that pharyngeal consonants are articulated with a constriction at the lower level of the pharyngeal cavity between the back wall of the pharynx and the epiglottis while uvulars are articulated at a higher point in the pharynx. The constriction locus for emphatic consonants lies between these two points and thus seems to implicate both a tongue body lowering and a retracting component.
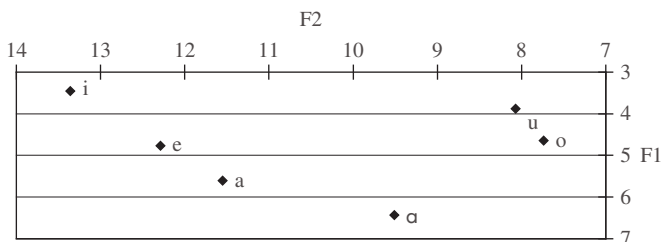
Figure 2. MA Vowels in F1-F2 Space (Bark Scale).

We can thus place some confidence in their accuracy for the larger MA speech community. This chart indicates that the primary difference between the [a] vs. [ɑ] realizations of the low vowel phoneme in the plain vs. emphatic contexts lies in F2, while for [u] vs. [o] the difference lies more in F1. For [i] vs. [e], both dimensions seem relevant. This interpretation agrees with the results of a perception experiment reported by Shoul (2007) in which 9 MA subjects categorized as emphatic vs. plain a set of synthesized vowels. In Shoul's study the vowel stimuli were decremented in five steps (20 Hz. intervals for F1 and 100 Hz for F2 in [i] and [a]). For the /a/ vowel, he found that changes in the F2 dimension altered the judgments of the subject between plain and emphatic with a crossover point between the second and third steps on the six-point scale. But F1 modulation failed to modify the judgment towards emphatic. Shoul concludes that the [a] vs. [ɑ] difference is primarily found in the F2 dimension. For the [u] vs. [o] contrast Shoul found that F1 was the relevant dimension with a 50% crossover point between second and third steps. Finally, for [i] vs. [e] both F1 and F2 dimensions contributed to the subjects' judgments.

   In sum, MA has three vowel phonemes /i/, /u/, and /a/, epenthetic schwa, and a plain vs. emphatic contrast in coronal and labial consonants. Vowels adjacent to an emphatic are strongly colored by this property: /a/ is retracted (decreased F2) while /u/ is lowered (increased F1). For /i/ both lowering and retraction occur, increasing F1 and decreasing F2. These darkening effects in the vowel affect the MA speaker's categorization of an adjacent consonant as plain vs. emphatic.

3. Loanword Adaptation: Monosyllables

A basic question of loanword adaptation is the representations over which the sound correspondences are computed. Two extreme positions have appeared in the recent theoretical literature. According to the Phonological approach of

LaCharité and Paradis (2005), loanword adaptation is performed by bilinguals who utilize their knowledge of both the donor and recipient languages to abstract away from the details of phonetic realization to discern equivalences in terms of the contrastive phonological categories of the two languages. The alternative Phonetic approach of Peperkamp and Dupoux (2003) and Peperkamp et al. (2008), following Silverman's (1992) important study, sees the initial stages of adaptation as a pregrammatical matching of the segments of the source language as located in perceptual, auditory space with the closest phonetic categories of the native L1 grammar. An intermediate position advocated by Kenstowicz (2006), Yip (2006), Boersma and Hamann (2008) and others, is that the input to adaptation is primarily phonetic but that phonological as well as phonetic and even orthographic factors compete in determining the adaptation in an Optimality Theoretic grammar.

If the MA [e], [o], [ɑ] vowels that appear in the context of emphatic consonants are redundant and predictable variants of basic /i/, /u/, /a/, then according to the strongest version of the Phonological model they should play no role in loanword adaptation. Furthermore, since French lacks emphatic consonants, we predict that the [e], [o], [ɑ] series should be absent entirely from French and Spanish loanwords. But this prediction is immediately falsified by the large number of loans in which such vowels appear. In addition to *moquette* > [MokeT] = /MukiT/ 'carpet', Heath cites *moda* >[moDa] = /muD-a/ 'fashion' and *morceau* > [moRSo] = /muRSu/ 'piece'.[2] On the other hand, Heath also cites loans in which such vowels might be expected to occur but do not: Sp *libro* > [nibru] = /nibru/ and *muñeca* > [munika] = /munika/. Much of the task of analysis is to determine the factors that lead to this variable outcome.

The data for our investigation consist of a corpus of c. 1,800 French loanwords collected over the past several years by the second author from personal observations of MA speakers. Our results agree *grosso modo* with the findings of Heath's (1989) study. To preview, we find that Fr /i,u,y,ø/ are adapted as MA plain /i,u/ while Fr /e,ɛ,o,ɔ,a/ are adapted primarily as the MA allophones appearing in an emphatic context and hence require the insertion of emphasis on an adjacent consonant. However, competing factors such as the suitability of the adjacent consonant as a pharyngeal host as well as harmony from

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[2] Heath phonemicizes with an emphatic consonant only when it is required to produce the associated mid/low vowel allophone. Since /k/ has no emphatic counterpart, the nasal in *moquette* > [MokeT] must be the site of pharyngealization: /MukiT/. In *moda* > *moDa* and *morceau* > [moRSo] the primary coronal consonants /D/ and /R/ are available to host the pharyngealization and so the initial labial nasal is phonemicized with a plain consonant: /muD-a/ and /muRSu/.

neighboring syllables lead to variability. Finally, we find an asymmetry in the adaptation of Fr/Sp /e,ɛ/ vs. /o,ɔ,a/ with respect to emphasis: the latter are much more regularly adapted as emphatic allophones while the former typically resist this outcome.

We begin our analysis with monosyllables since here the effect of surrounding syllables can be factored out. If the substitutions are regular here, we can use them as a baseline for multi-syllabic loans where the effect of adjacent syllables comes into play.

As might be expected, the French (and Spanish) point vowels [i], [u], [a] are mapped to their MA counterparts. These are the vowels that lie at the extremes of the F1-F2 space and are presumably salient in the speaker's phonological consciousness. This expectation is fully confirmed. We find that French [i] and [u] are consistently adapted as MA [i] and [u]. Some examples appear in (7). In the tabulation of the results we report the correspondence rates in our corpus. We also show the analogous rates from Heath's corpus based on our hand count of the loans listed in Appendix C to Heath's study. In MA feminine nouns are marked by the suffix /-a/ or the prefix /la-/.

(7)	Fr		MA		rate
	[i]		[i]		41/41 (1.0)
					(Heath: 30/31 (.97))
	[i]	pile	[i]	pil	'torch'
	[i]	gris	[i]	gri	'gray'
	[i]	style	[i]	stil	'style'
	[i]	piste	[i]	la-pist	'runway'
	[i]	pipe	[i]	pipp-a	'pipe'
	[u]		[u]		19/21 (.90)
					(Heath: 13/14 (.93))
	[u]	fou	[u]	fu	'fool'
	[u]	couche	[u]	la-kuʃ	'diaper'
	[u]	blouse	[u]	bluz-a	'blouse'
	[u]	coupe	[u]	la-kup	'haircut'
			[u]	kupp-a	
	[u]	coude	[u]	kud	'elbow'
	exceptions:				
	[u]	course	[o]	koRS	'course'
	[u]	soupe	[o]	SoBB-ɑ	'soup'

For French monosyllables with the low vowel [a], the MA adaptation is consistently the [ɑ] allophone that is found in the context of emphatic consonants in the native grammar. This correspondence is found in words where the neighboring consonant can be identified with one of the MA native emphatics (T, S, Z, R) as well as in loans with consonants that are primarily plain in the native system.

(8)   <u>Fr</u>   <u>MA</u>   <u>rate</u>
       [a]   [ɑ]   65/69 (.94)
                                                          (Heath: 45/50 (.90))
       [a]   stage   [ɑ]   STɑʒ   'training'
       [a]   salle   [ɑ]   SɑL-ɑ   'Moroccan style room'
                             [ɑ]   Lɑ-SɑL   'gymnasium'
       [a]   glace   [ɑ]   Lɑ-gLɑS   'ice-cream'
       [a]   table   [ɑ]   TɑBL-ɑ   'table'
                                    TəBL-ɑ
       [a]   tarte   [ɑ]   Lɑ-TɑRT   'cake'
       [a]   lamme   [ɑ]   LɑM-ɑ   'blade'
       [a]   panne   [ɑ]   PɑN   'car breakdown'
                             [ɑ]   PɑN-ɑ
       [a]   bac   [ɑ]   l-Bɑk   'baccalaureat'
       [a]   plage   [ɑ]   Lɑ-PLɑʒ   'beach'

We have four exceptions in our corpus where a French [a] in a monosyllable is adpated as the nonemphatic, more front MA vowel [a]: *cave* > [la-kab] 'cave', *cale* > [kal-a] 'wedge', *châle* > [ʃan] 'shawl', *gaz* > [l-gaz] 'gas'.

Earlier varieties of Parisian French distinguished a front vs. back low vowel somewhat comparable to the MA [a] vs. [ɑ] contrast. But in the contemporary language this distinction has largely disappeared (Gottfried 1984). In any case, the loans give no evidence that this distinction was preserved in the speech of the speakers who provided the source of the adaptations. There is thus a puzzle as to why the MA back [ɑ] that is found in emphatic contexts is chosen as the adaptation. This is a direct counterexample to the predictions of the Phonological model and leads to the expectation that the French [a] is closer in phonetic space to MA [ɑ] than to MA [a]. Before examining this question further, we survey the adaptations of the remaining French vowels.

Fr (and Sp) back mid vowels are consistently identified with the MA [o] allophone of the /u/ phoneme that appears in emphatic contexts. As far as we know, this vowel does not appear outside of the emphatic context in the native

grammar. Its consistent correspondence with French [o] and [ɔ] is thus another prima facie case of phonetic approximation.[3]

(9)   <u>Fr</u>   <u>MA</u>   <u>rate</u>
       [ɔ]   [o]   22/25 (.88)
                                                        (Heath: 15/18 (.83))
       [ɔ]   botte   [o]   BoT   'boot'
       [ɔ]   code   [o]   koD   'code'
       [ɔ]   col   [o]   koL   'collar'
       [ɔ]   drogue   [o]   La-DRog   'drug'
       [ɔ]   port   [o]   PPoR   'port'

       [o]   [o]   5/6 (.83)
                                                        (Heath: 16/18 (.89))
       [o]   taupe   [o]   ToBB-ɑ   'rat'
       [o]   dose   [o]   La-DoZ   'portion'
       [o]   tôle   [o]   ToL-ɑ   'sheet iron'
       [o]   jauge   [o]   La-ʒoʒ   'gauge'
       exception:
       [o]   faute   [u]   la-fut   'defect'

The adaptation of the French mid front vowels [e] and [ɛ] in monosyllables is more varied. In our corpus we find ten cases where they are substituted with MA [i], four with the [e] that appears in the context of emphatics, three with front [a], and handful of miscellaneous forms with [ɑ] or schwa. The Heath corpus contains more examples of the emphatic [e] correspondence. Also, the larger number of loans with /e/ in the Heath corpus arise from Spanish: e.g. *rey* > [Rey] = /Riy/ 'king' (card game), *tres* > [tris] = /tris/ ≈ [TReS] = /TRiS/ 'three' (card game).

(10) <u>Fr</u>   <u>MA</u>   <u>rate</u>
       [e]   [i]   1/1 (1.0)
                                                        (Heath: 6/10 (.60))
       [e]   régler   [i]   rigl-a   'to sort out'

       [ɛ]   [i]   9/19 (.47)
                                                        (Heath: 5/15 (.33))
       [ɛ]   veste   [i]   fist-a   'suit jacket'
       [ɛ]   fraise   [i]   friz   'strawberry'

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[3] The larger number of loans with /o/ in the Heath corpus arise from Spanish: e.g. *ronda* > [Rond-ɑ] = /RunD-a/ 'a card game'.

Fr		MA		rate
[ɛ]	ferme	[i]	firm-a	'farm'
[ɛ]	greffe	[i]	grif-a	'graft'
[ɛ]	caisse	[i]	la-kis	'cashier'
[ɛ]		[e]		4/19 (.21)
				(Heath: 8/15 (.53))
[ɛ]	tête	[e]	TeT	'head'
[ɛ]	traite	[e]	TReT-ɑ	'draft, bill'
[ɛ]	hôtel	[e]	wTeL	'hotel'
			LoTeL	
[ɛ]		[a]		3/19 (.16)
				(Heath: 2/15 (.13))
[ɛ]	chef	[a]	ʃʃaff	'head, chief'
[ɛ]	chèque	[a]	ʃʃak	'cheque'
[ɛ]	pièce	[a]	byas-a	'room'
[ɛ]		[ɑ]		2/19 (.10)
[ɛ]	pelle	[ɑ]	Bɑl-ɑ	'shovel'
[ɛ]	raie	[ɑ]	RRɑy-ɑ	'line, stripe'
[ɛ]		[ə]		1/19 (.05)
[ɛ]	merde	[ə]	mərd-a	'shit, lowest rank' mil.

When we turn to polysyllables (section 4.2), we will see that MA [i] is the favored adaptation for French front mid vowels. There is thus a rather clear asymmetry in the treatment of French front [e] and [ɛ] vs. back [o] and [ɔ]. The former are assigned primarily to MA [i] and thus call for a nonemphatic consonantal environment while the latter are assigned to MA [o] and call for an emphatic consonantal environment. We return to this difference momentarily, after surveying the rest of the vowel correspondences in monosyllables.

As far as their behavior with respect to the plain vs. emphatic contrast is concerned, the Fr front rounded vowels /y/ and /ø/ are uniformly adapted as MA [i] or [u]. In monosyllables /y/ varies between [i] and [u] while [ø] is generally [u]. In longer words the default mappings are French [y] and [ø] to MA [i] and [u], respectively. When viewed in terms of distinctive features, this treatment is puzzling. Why should the presence of [round] in a mid vowel lead to [u] but to [i] in a high vowel?

(11)   <u>Fr</u>   <u>MA</u>   <u>rate</u>

[y]		[i]		4/7 (.57)
				(Heath: 1/3 (.33))
[y]	jupe	[i]	ʒipp-a	'skirt'
		[u]	ʒupp-a	
[y]	but	[i]	bit	'score' football
[y]	pute	[i]	pit	'prostitute'
[y]		[u]		3/6 (.50)
				(Heath: 2/3 (.66))
[y]	luxe	[u]	luks	'luxury'
		[i]	liks	
[y]	grue	[u]	gruw-a	'building crane'
[y]	flûte	[u]	flut-a	'flute, baguette'
[ø]		[u]		5/6 (.83)
				(Heath: 3/3 (1.0))
[ø]	pneu	[u]	pnu	'tire'
[œ]	meuble	[u]	mubəl	'furniture'
[ø]	meule	[u]	la-mun	'grindstone'
[ø]		[i]		1/6 (.16)
[ø]	feutre	[i]	fitər	'felt'

Finally, French has three contrasting nasal vowels: [ɛ̃], [ɑ̃] and [ɔ̃]. They are clearly distinguished in MA adaptations. Fr [ɛ̃] maps to plain [a]N while [ɑ̃] maps to emphatic [ɑ]N or [o]N – with "unpacking" of the nasal feature N = [m] or [n] (Paradis and Prunet 2000). For the Fr mid back nasal vowel [ɔ̃] there is also fluctuation in height between adaptation as [o]N and [u]N. The height differences between plain and nasal vowels are plausibly attributed to the fact that nasal vowels add a spectral peak in the region of the corresponding F1 of lower vowels that can interfere with the height categorization.

(12)   <u>Fr</u>   <u>MA</u>   <u>rate</u>

[ɛ̃]		[an]		8/8 (1.0)
				(Heath: 7/8 (.87))
[ɛ̃]	coin	[an]	kwan	'corner'
[ɛ̃]	train	[an]	tran	'train'
[ɛ̃]	pince	[an]	pans	'clip'

Fr		MA		rate
[ɛ̃]	joint	[an]	ʒwan	'junction'
[ɛ̃]	plein	[an]	plan	'full'
[ɑ̃]		[ɑn]		8/14 (.57)
				(Heath: 8/8 (1.0))
[ɑ̃]	plan	[ɑn]	BLaN	'plan'
[ɑ̃]	franc	[ɑn]	FRaNk	'franc'
[ɑ̃]	bande	[ɑn]	BaND-ɑ	'band'
[ɑ̃]	planche	[ɑn]	BLaNS-ɑ	board'
[ɑ̃]	lampe	[ɑm]	Lamb-ɑ	'lamp'
[ɑ̃]		[on]		6/14 (.43)
[ɑ̃]	chambre	[om]	ʃoMBR-ɑ	'room'
[ɑ̃]	tranche	[on]	TRoNʃ	'slice'
[ɑ̃]	centre	[on]	SonTər	'center'
[ɔ̃]		[on]		3/8 (.38)
[ɔ̃]	ombre	[om]	lomBəR	'shadow'
[ɔ̃]	thon	[on]	TTon	'tuna'
[ɔ̃]		[un]		5/8 (.62)
[ɔ̃]	bon	[un]	bun	'good'
[ɔ̃]	non	[un]	nun	'no'
[ɔ̃]	pompe	[um]	bumb-ɑ	'pump'

The table in (13) summarizes the regular correspondences in monosyllables. As we shall see, they hold as the default mappings in polysyllabic words but can sometimes be overridden due to harmony for emphasis.

(13)

Fr	i	u	e	ɛ	o	ɔ	a	y	ø	ɛ̃	ɑ̃	ɔ̃
MA	i	u	i	i	o	o	ɑ	i	u	an	ɑn	on

These correspondences are problematic for the Phonological model of loan-word adaptation. As we have seen, under its strongest form in which [e], [o], and [ɑ] are allophones in the MA system, they should be systematically absent from loans. Their regular correspondence with French (and Spanish) nonhigh back vowels is thus quite puzzling. Also puzzling are the different treatments

of the French front rounded vowels in the default mapping: [+high, +round] [y] loses its round feature but remains front [i] while [–high, +round] [ø] preserves [round] but changes to a back vowel [u].

These asymmetries find a better--but still not totally satisfactory – explanation under the Phonetic approach of Silverman (1992) and Dupoux and Peperkamp (2003) according to which the adapter tries to match the French vowels with the closest MA vowel in auditory, perceptual space. We can get a sense of the merits of this approach by plotting the vowels of MA and French in F1-F2 space measured in terms of Barks. The data below show the relative spacing of the oral vowels of the two languages. The French data (male Parisian speakers) are taken from Strange et al. (2007) while the MA data are from the recordings of the two male speakers from section 2. We have replotted the F2 dimension as F2–F1 in order to be commensurate with the display in Strange et al. (2007).
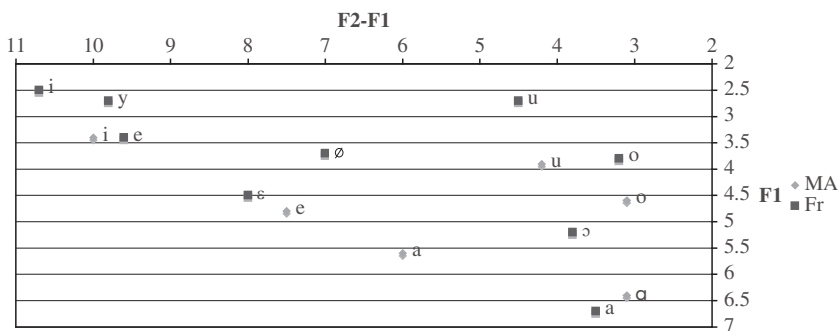

Figure 3. MA and Fr Vowels (Male Speakers, Bark Scale).

The following observations can be made. First, for the MA plain vowels the triangle formed by [i], [u], [a] lies well inside the region formed by the same phonemes in French (as would be expected from dispersion theory since French has two additional mid vowel series). Second, the adaptation of Fr [i,y,e] as MA [i] makes sense as the latter is the closest vowel in auditory space. Third, the adaptation of French [a] as the emphatic allophone [ɑ] now makes sense as well since this vowel is much closer to MA [ɑ] than to MA [a]. Fourth, adaptation of Fr [ɔ] as MA emphatic [o] can also be explained as the closest vowel if we accept Shoul's (2007) finding that F1 is the basic dimension over which the plain vs. emphatic distinction is made for the back vowel. Fifth, the contrasting behavior of Fr [y] and [ø] becomes at least somewhat more comprehensible since the latter lies halfway between

MA [i] and [u] while the former is squarely in the region of MA [i]. Taking seriously the relative locations of the vowels in phonetic space can also make sense of the asymmetry in the treatment of French [ɛ] vs. [ɛ̃]. The latter is systematically adapted with the MA nonemphatic low vowel [a]. While Strange et al. (2007) give no data for this vowel, it is plausible that the nasality adds a formant in the region of 800 Hz making the vowel sound lower.

In sum, most of the adaptations can be interpreted as mapping the French vowels to the closest MA vowels within the auditory space defined by the first two formants. The one glaring exception is its failure to equate French [ɛ] with the MA [i]. As we can see from the chart in Figure 3, French [ɛ] is very close to MA [e]. Nevertheless, it shows a strong tendency to adapt as MA [i]. In comparison, Fr [ɔ] systematically adapts as the emphatic allophone. We return to this difference in the next section.

4. Analysis

We begin our OT analysis of the Fr > MA vowel adaptations with respect to emphasis by situating the constraints operating in the loanword grammar relative to those in the native MA grammar. First, some notation. $C^ˤ$ denotes an emphatic consonant and $V^ˤ$ the set of vowels $[e^ˤ, o^ˤ, a^ˤ]$ that occur adjacent to an emphatic. They differ from the corresponding plain [i,u,a] V that occur in nonemphatic contexts by being [+constricted pharynx] as well as in possessing the increased F1 and decreased F2 enhancing differences seen in Figure 2 that "darken" the vowel. We label the latter as [F1↑] and [F2↓].

First, the constraints in (14) define a vocalic inventory in which [F1↑&F2↓] and [+constricted pharynx] entail one another. They are undominated. The first penalizes a vowel with the enhancing features that lacks the [+constricted pharynx] trigger while the second penalizes a [+constricted pharynx] vowel that lacks the enhancing features.

$$(14) \quad * \begin{bmatrix} +\text{vocalic} \\ -\text{constr ph} \\ +\text{F1}\uparrow \& \text{F2}\downarrow \end{bmatrix} \qquad *ɑ, *e, *o$$

$$* \begin{bmatrix} +\text{vocalic} \\ +\text{constr ph} \\ -\text{F1}\uparrow \& \text{F2}\downarrow \end{bmatrix} \qquad *a^ˤ, *i^ˤ, *u^ˤ$$

Second, we assume that the consonants are the site of the emphatic contrast in the input lexical representations. Thus, for the emphatic feature [+constricted pharynx], consonants are F » M (faithfulness dominates markedness) while vowels are M » F. We also assume that that MA has a C//V harmony constraint for the feature [constricted pharynx] that requires any tautosyllabic CV and VC sequence to agree for this feature. Given a /CˤV/ input, the harmony constraint is satisfied by preserving the [constricted pharynx] feature of the consonant at the expense of introducing the otherwise marked pharyngealized vowel. Thus, *Vˤ is ranked below Id-C-[CPh], ensuring that emphasis is spread to the vowel and entailing the enhancing [F1↑&F2↓] by the inventory constraint. The constraints and the rankings composing the analysis are stated in (15).

(15)   F » M: Id-C-[CPh] » *Cˤ
         M » F: *Vˤ » Id-V-[CPh], Id-V-[F1↑&F2↓]
         M: C//V-Harmony: tautosyllabic C and V must agree for the feature
         [constricted pharynx]
         ranking:
                 *ɑ, *ɑˤ, C//V-Harmony, Id-C-[CPh] »
                 *Vˤ »
                 *Id-V-[CPh], Id-V-[F1↑&F2↓], *Cˤ

The tableaux below show how an underlying /tˤa/ structure is realized as [tˤɑˤ] with the spread of pharyngealization to the vowel. The faithful [tˤa] candidate violates C//V-Harmony while Id-C-[CPh] ensures that pharyngealization is spread to the vowel. In keeping with OT's Richness of the Base premise, any pharyngealized vowels that might occur in the input will be filtered out by the M » F ranking of *Vˤ over faithfulness (unless they happen to occur adjacent to an emphatic).

(16)

/tˤa/	C//V Harm	Id-C-[CPh]	*Vˤ
>tˤɑˤ			*
tˤa	*!		
ta		*!	
/tɑˤ/			
> ta			
tɑˤ	*!		*
tˤɑˤ		*!	*

Given transitivity of ranking (Id-C-[CPh] » *V$^\Omega$ » Id-V-[CPh]), if a vowel is identified as [+constricted pharynx] adjacent to a plain consonant then faithfulness to the consonant should predominate, entailing a loss of pharyngealization and the enhancing [F1↑&F2↓] on the vowel. But this is precisely the wrong outcome in the loanword adaptation case. Here a Fr [tɑ] sequence is adapted as/mapped to MA [tˤɑˤ] with the introduction of pharyngealization on both the consonant and the vowel. (We now transcribe the Fr low vowel as [ɑ] in light of the proximity to MA [ɑ] seen in Figure 3). The point of similarity between the two structures—Fr [tɑ] and MA [tˤɑˤ]—is in the acoustic F1 and F2 vocalic features. Their pharyngeal states are presumably different. Moreover, pharyngealization is the phonologically contrastive category in MA while the [eˤ], [oˤ], [ɑˤ] vowels are phonetic enhancements of /iˤ/, /uˤ/, /aˤ/ that we know from Shoul's (2007) results are used by the MA speaker as cues for the phonological category of emphatic consonant analogous to the way in which the Mandarin speaker uses phonologically redundant F2 vowel differences as cues to identify the following coda nasal. Evidently to the MA loanword adapter the F1-F2 similarity in the adjacent vowel overrides the dissimilarity in pharyngealization in both the vowel and the adjacent consonants. We conclude that the vocalic F1-F2 features are more salient and override the disparities in pharyngeal cavity state in both the vowel and adjacent consonant.[4] One would eventually hope to be able to derive these judgments from a general theory of enhancement and speech perception. For the purposes of the present analysis they are stipulated as descriptive generalizations in the form of special rankings in the loanword phonology.
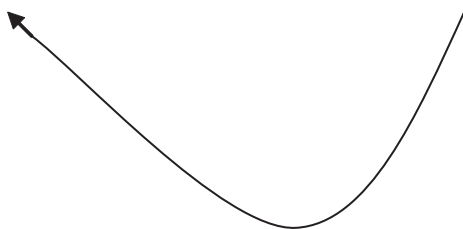
Our analysis is cast in the framework of Kenstowicz (2005), where the adaptations found in loanword phonology are treated as the product of Output-Output faithfulness constraints. On this view the L1 native OT grammar consists of some ranking of markedness and IO faithfulness constraints: ….M » F » M » F…. The normal input-output mapping can be deflected by Output-Output faithfulness constraints that are sensitive to salient information in a related word. Such constraints were originally proposed to express cyclic effects. A classic example is Levantive Arabic [fihímna 'he understood us' where the normal syncope of unstressed high vowels in

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[4] An interesting follow up to Shoul's (2007) experiment involves asking MA speakers to categorize as plain vs. emphatic stimuli spliced from [CV] and [CˤVˤ] utterances in which the onsets are interchanged (i.e. [CˤV] and [CVˤ]) to see whether the vowel or the consonant determines the judgment. A pilot study with six subjects performed by the second author indicates that the vowel is uniformly the determining factor.

open syllables seen in *fhím-na* < /fihim-na/ 'we understood' is blocked due to faithfulness to the corresponding (stressed) vowel in the base word *fíhim* 'he understood'. Following Kenstowicz (1996) and much subsequent work, this state of affairs has been analyzed as follows. A constraint penalizing a short high vowel in unstressed open syllables (*Ci.) dominates the input-output faithfulness constraint Max-V, entailing syncope. But the latter process is blocked in [fihím]na 'he understood us' by ranking the output-output faithfulness constraint Max-V́ ("penalize the deletion of a vowel that has a stressed vowel correspondent in a related word of the inflectional paradigm") that ranks above *Ci.

   In the MA loanword case the input-output mapping that would drive a /tɑ/ sequence to [ta] by faithfulness to the consonant is subverted by an output-output constraint that is faithful to the low, back vocalic features of the French source word (the "output" [tɑ]). This constraint is activated by "cloning" a copy of the low-ranked Id-V-[F1↑&F2↓] that is keyed to the Fr/Sp output and ranking it ahead of faithfulness to [constricted pharynx] in the consonant.

(17) Id-V-[F1↑&F2↓]$_{Fr/Sp-MA}$ » Id-C-[CPh] » Id-V-[F1↑&F2↓]

The result is preservation of the [ɑ,e,o] vowel qualities, entailing the introduction of emphasis on the vowel in order to satisfy the inventory requirements in (14), which in turn implies the insertion of emphasis on the adjacent consonant to satisfy C//V-Harmony. The tableau in (18) shows how the Fr input /tɑ/ is now mapped to an [tˤaˤ] output.

(18)	/ tɑ/$_{Fr}$	*ɑ	C//V-Harm	Id-V-[F1↑&F2↓]$_{Fr/Sp-MA}$	Id-C-[CPh]
	tɑ	*!			
	ta			*!	
	tɑˤ		*!		
	>tˤaˤ				*

The fully faithful candidate [tɑ] violates the inventory requirement that a dark vowel carry the feature [+constricted pharynx]. Changing the vowel to plain [a] now violates the high-ranking output-output constraint for faithfulness to the [F1↑&F2↓] vocalic features of the Fr/Sp source of the loanword. Finally, inserting [+constricted pharynx] on the vowel without doing so on the adjacent consonant [tɑˤ] violates the C//V-Harmony constraint that requires emphasis to span a syllable. The result is the introduction of emphasis on the consonant to preserve the more salient [F1↑&F2↓] vowel identity and still satisfy C//V-Harmony. It is worth observing that the fact that native grammar markedness constraints like C//V-Harmony figure into the adaptation challenges the purely extra-grammatical acoustic phonetic matching model of Peperkamp and Dupoux (2003), a point also made by Boersma and Hamann (2008).

The analysis to this point models the adaptation of the loan before it is lexicalized into MA grammar. Lexicalization will treat the loan [Tɑ] just like native grammar, analyzing the consonants into radicals that can be input to the native templating grammar, as in the example of Fr *boîte* 'tin cans' but *bwiT*-ɑ diminutive, measure-II verb *bwwət*, based on /bwT/.[5]

With this framework in place, we return to the relative dispreference for the emphatic adaptation of Fr [e] and [ɛ] vis a vis [o], [ɔ], and [ɑ]. The first possibility is that this is simply a markedness effect: *eˤ » *oˤ, *ɑˤ. Several factors speak in favor of this interpretation. First, in various Arabic dialects the spread of emphasis is inhibited by palatal elements such as [i,j,ʃ], as in Palestinian (Davis 1995) and in the MA dialect described by Laaboudi (2006). In the OT analysis of harmony, opaque segments that arrest the spread of a harmonic feature are typically viewed as a markedness effect, as in the low vowel blocking ATR harmony in many African languages (cf. Archangeli and Pulleyblank 2007). Second, the incompatibility between a palatal element and emphasis is presumably grounded in an articulatory antagonism between a [−back] vowel, which pulls the tongue dorsum forward, and the constriction in the pharynx that pulls in the opposite direction. While we are not aware of any evidence internal to the phonology of MA that supports the markedness distinction between [eˤ] vs. [oˤ], [ɑˤ], it does show up in loanword phonology from Classical Arabic. Heath (1989:49) notes that CA does not distinguish plain from emphatic rhotics. When words are borrowed from the classical language into MA the adjacent vocalic context determines whether the rhotic surfaces as plain versus emphatic, with [i] favoring a plain adaptation and the back vowels [a] and [u] an emphatic one.

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[5] See Boersma and Hamann (2009) for an OT modeling of loanword adaptation that formally distinguishes the lexicalization and perceptual adaptation stages by introducing a level (Surface Representation) that stands at the interface between phonology and phonetics.

(19) <u>Cl Ar</u>   <u>MA</u>
      xaarij   xariʒ   'result'
      ʃawaari9   ʃawari9   'streets'
                      ʃwar9
      barak-a   bɑRɑk-a   'blessing'
      haraar-a   hɑRɑR-ɑ   'heat'
      furuu9   foRo9   'branches'
      duruus   DoRoS   'studies'

The main problem this solution faces is the relative ranking in the native MA grammar. In the approach to loanwords we are adopting, the only loanword specific mechanisms available are the Fr-MA output-output faithfulness constraints. The ranking of the markedness constraints is assumed to be the same as in native grammar; hence, C//V-Harmony plays a direct role in the adaptations. In order to allow native grammar /tˤi/ to surface as [tˤeˤ], we require the ranking {C//V-Harmony, Id-C-CPh} » *eˤ. But if *eˤ dominates Id-V-[CPh]$_{Fr/Sp-MA}$ then by transitivity *eˤ must also dominate Id-C-[CPh], entailing a ranking paradox. While loanword-specific markedness constraint rankings may be required, we prefer at this stage to retain the more restrictive model.

The alternative possibility is that the output-output faithfulness constraint Id-V-[F1↑&F2↓]$_{Fr/Sp-MA}$ is not monolithic but is rather keyed to particular vocalic contexts such that Id-[a,o]$_{Fr/Sp-MA}$ » Id-C-[CPh] » Id-[e]$_{Fr/Sp-MA}$. Fluctuation or uncertainty with respect to the Id-C-[CPh] » Id-[e]$_{Fr/Sp-MA}$ ranking would yield both [i] and [e] outputs and thus account for most of the variation seen in (10). The relative stability of the Id-[a,o]$_{Fr/Sp-MA}$ » Id-C[CPh] ranking may reflect a state of affairs in which the presence or absence of pharyngealization on a consonant is more difficult to detect in the context of a low back vowel [a,o] than when adjacent to a front vowel [e]. For the better studied secondary articulations of palatalization and labialization, a Cʲ vs. C or Cʷ vs. C contrast is often suspended before the cognate front/round, respectively, vowel.[6] Nailing down whether the asymmetry between the adaptation of Fr/Sp [a] and [o] vs. [e] is a matter of markedness or faithfulness is a task for future research.

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[6] Discrimination tests over MA [Se]-[se] vs. [So]-[so] stimuli would help to resolve this question.

5. Disyllables

In the adaptation of disyllabic loans we see a conflict between the sound substitutions that operate in monosyllables on the one hand and the requirement of the native grammar that syllables of the stem harmonize for emphasis on the other. As we will see, the conflict is resolved in intricate ways; and sometimes alternative outcomes are found for equivalent inputs, a situation that can be modeled by weighted constraints.

We begin with loans whose two syllables contain vowels that behave uniformly with regard to emphasis in the monosyllables. Other things being equal, we expect the monosyllabic adaptation patterns of (13) to carry over to the disyllables. And indeed this is what is largely found.

In (20) we show French words containing an /a/ or /ɑ̃/ in the Fr source. Our corpus contains some 60 words of this structure. They are adapted as harmonic emphatic over 90 percent of the time. A similar high rate is found in the Heath corpus.

(20)   Fr   MA
    harmonic emphatic: 56/60 (.93) (Heath: 45/50 (.90))
    [a]   [a]   barrage   [ɑ]   [ɑ]   BɑRɑʒ   'barrage'
    [a]   [a]   cascade   [ɑ]   [ɑ]   kɑSkɑT   'cascade'
    [a]   [a]   tabac   [ɑ]   [ɑ]   Tɑbɑ   'tobacco'
    [ɑ̃]   [a]   sandale   [ɑ]   [ɑ]   SSɑnDɑL-ɑ   'sandal'
    [a]   [ɑ̃]   satan   [ɑ]   [ɑ]   SSɑTɑ   'satan'

    harmonic plain: 4/60 (.07)
    [a]   [a]   madame   [a]   [a]   madam   'madam'
    [a]   [a]   bagage   [a]   [a]   bagaʒ   'luggage'

The number of disyllables drawing on Fr [o], [ɔ], and [ɔ̃] is much smaller. But once again the mapping is heavily biased to an emphatic context.

(21)   Fr   MA   .
    harmonic emphatic: 9/10 (.90)   (Heath: 18/21 (.86))
    [ɔ]   [o]   polo   [o]   [o]   BoLo   'ice cream'
    [o]   [o]   auto   [o]   [o]   L-oTo   'car'
    [o]   [ɔ̃]   saumon   [o]   [o]   Somo   'salmon'

The corpus contains 85 disyllabic loans whose MA vowels correspond to a combination drawn from the sets containing {[a], [ɑ̃]} and {[o], [ɔ̃]}. The emphatic adaptation rate of .82 approximates very well the .90 x .90 that holds for monosyllables and homogeneous {[a], [ɑ̃]} and {[o], [ɔ], [ɔ̃]} disyllables.

(22)   <u>Fr</u>   <u>MA</u>
      emphatic harmonic: 70/85 (.82)   (Heath: 65/73 (.89))
      [a]   [ɔ]   passeport   [ɑ]   [o]   BɑSpoR   'passport'
      [a]   [ɔ̃]   caleçon   [ɑ]   [o]   gɑRSon   'boxer'
      [a]   [o]   gâteau   [ɑ]   [o]   gɑTo   'gâteau'
      [a]   [ɔ̃]   klaxon   [ɑ]   [o]   kLɑkSon   'beep'
      [ɔ]   [a]   clochard   [o]   [ɑ]   kLoʃɑR   'bum'
      [o]   [a]   sauvage   [o]   [ɑ]   Sofɑʒ   'savage'

      plain harmonic: 10/85 (.12)
      [a]   [ɔ]   alcool   [a]   [u]   lankul   'alcohol'
      [a]   [ɔ̃]   wagon   [a]   [u]   fagu   'car'

      disharmonic: 5/85 (.06)
      [a]   [ɔ̃]   savon   [ɑ]   [u]   SSɑbun   'soap'
      [a]   [o]   maillot   [ɑ]   [u]   Mɑyyu   'swimsuit'

French disyllables containing [i], [y], [u], and [ø]—the vowels which are adapted with the nonemphatic high vowels in monosyllables—exhibit the same bias towards a nonemphatic context in the loan.

(23)   <u>Fr</u>   <u>MA</u>
      harmonic plain: 40/41(.98)   (Heath: 24/27 (.89))
      [i]   [i]   clinique   [i]   [i]   klinik   'clinic'
      [i]   [y]   tribune   [i]   [i]   tribil   'tribune'
      [u]   [i]   boutique   [u]   [i]   butik-a   'shop'
      [u]   [u]   nounours   [u]   [u]   nunus   'teddy bear'
      [y]   [u]   surtout   [i]   [u]   sirtu   'especially'

We now consider the behavior of [e] and [ɛ]. These vowels had the most diverse behavior in monosyllables, but with a tendency to favor nonemphatic [i]. This default mapping is more evident in disyllables. First, there are only a handful of disyllabic loans that fill both syllables with one of these vowels; but they all have the expected adaptation as [i].

(24)   <u>Fr</u>   <u>MA</u>
      [e]   [ɛ]   dessert   [i]   [i]   disir   'dessert'
      [ɛ]   [e]   serrée   [i]   [i]   siri   'tight'
      [ɛ]   [ɛ]   vaisselle   [i]   [i]   la-fisil   'dishes'

Second, when [e] or [ɛ] are combined with the [i,u,y,ø] that lead to nonemphatic, we expect a strong bias towards nonemphatic. As shown below in (25), this is what is found. There are some 75 words of this structure. The vast majority adapt both syllables as nonemphatic. A minor trend in the opposite direction occurs in the context of a Fr coda rhotic—a uvular consonant that can be expected to color the vowel of French to «dark». In our more extensive data, the rate of nonemphatic harmony is higher than that found in Heath's corpus.

(25)   <u>Fr</u>   <u>MA</u>

    harmonic plain: 70/75 (.93)   (Heath: 19/26 (.73))

[e]	[i]	képi	[i]	[i]	kipi-ya	'kepi'
[ɛ]	[œ]	secteur	[i]	[u]	siktur	'sector'
[ɛ]	[y]	cellule	[i]	[u]	silun	'cell'
[i]	[ɛ]	bidet	[i]	[i]	bidi	'bidet'
[u]	[ɛ]	bouquet	[u]	[i]	buki	'bouquet'
[y]	[ɛ]	duvet	[u]	[i]	dufi	'sleeping bag'
[u]	[e]	poupée	[u]	[i]	puppiy-a	'doll'
[e]	[u]	séjour	[i]	[u]	siʒur	'stay' n.

    harmonic emphatic:

[u]	[ɛ]	fourchette	[o]	[e]	foRʃeT-a	'fork'
[u]	[e]	journée	[o]	[e]	ʒoRne	'day'
[e]	[i]	guérite	[ɑ]	[e]	gɑReT-ɑ	'sentry box, shelter'

Thus, Fr [e] and [ɛ] have very little capacity to impose emphatic harmony on a high vowel. As well, they offer very little resistance to harmony in the direction of nonemphatic. Thus, the asymmtery between the nonhigh back vs. front vowels observed in monosyllables carries over to disyllables.

    Since in monosyllables Fr [e] and [ɛ] disfavor an emphatic adaptation at a higher rate than [a], [ɔ] and [o] do, we expect that when the former are combined with the latter in disyllables, the emphatic rate should decline when compared to the emphatic rate of .82 for disyllabic combinations drawn from the back [a], [ɔ], [o]. The following table shows the details.

(26)   <u>summary</u>: {e,ɛ} + {a,ā,o,ɔ,ɔ̃}

emphatic harmony:	61/96	(.64)	(Heath: 41/63 (0.65))
plain harmony:	27/96	(.28)	19/63 (0.30)
disharmonic:	/8/96	(0.08)	3/63 (0.05)

    <u>examples</u>

    {[e,ɛ]} + {[a,ā]}

	Fr			MA		
harmonic emphatic: 43/72 (.59)			(Heath: 24/36 (.66))			
[e]	[ɑ]	pédale	[e]	[ɑ]	BeDɑL-ɑ	'pedals'
[ã]	[e]	chantier	[ɑ]	[e]	ʃɑNTe	'workshop'
[ɛ]	[a]	terrace	[e]	[ɑ]	TerɑS	'terrasse'
[ɛ]	[ã]	essence	[e]	[ɑ]	leSɑnS	'petrol'
[a]	[ɛ]	cassette	[ɑ]	[e]	kɑSeT-ɑ	'cassette tape'
harmonic plain: 21/72 (.29)			(Heath: 9/36 (.25))			
[a]	[ɛ]	l'adresse	[a]	[i]	l-adris-a	'address'
[e]	[a]	maréchal	[i]	[a]	mriʃan	'marchal'
[a]	[e]	marée	[a]	[i]	mari-ya	'tide'
[e]	[ã]	agrément	[i]	[a]	grima	'approval'
disharmonic: 7/72 (.09)			(Heath: 9/36 (.25))			
[ã]	[e]	étranger	[ɑ]	[i]	TRɑnʒi	'abroad'
[a]	[e]	marché	[ɑ]	[i]	maRʃi	'market'
harmonic emphatic: 18/24 (.75)			(Heath: 17/27 (.63))			
[o]	[ɛ]	hôtel	[o]	[e]	L-oTel	'hotel'
[e]	[o]	réseau	[e]	[o]	RReZo	'network'
[ɔ]	[ɛ]	omelette	[o]	[e]	L-omleT	'omelette'
[ɔ]	[ɛ]	problème	[o]	[e]	BRobLem	'problem'
harmonic plain: 6/24 (.25)						
[ɔ]	[e]	fossé	[u]	[i]	fusi	'pit'
[ɔ]	[ɛ]	bonnet	[u]	[i]	buni	'bonnet'
[e]	[o]	dépôt	[i]	[u]	dippu	'depot'

Thus, in both our corpus as well as in Heath's combining [e] or [ɛ] with {a,ã,o,ɔ,õ} depresses the rate of emphatic harmony to about the same value: .64 vs. .65. The graph below shows the effect of combining {e} with the {a,ã,o,ɔ,õ} set that favors an emphatic adaptation and with the {i,y,u,ø} set that favors a nonemphatic plain context given as a percentage of emphatic harmony. We see that combining {e} with {i,y,u,ø} has hardly any effect on the level of emphatic adaptation, showing that {e} has minimal capacity to impose emphatic harmony. A chi-square test for independence realved no significant difference between the two conditions: chi sq = 3.03, df = 2, p > 0.10. On the other hand, when combined with {a,ã,o,ɔ,õ}, we see that {e} reduces the rate of emphatic harmony by 0.23 evidencing the bias against the emphatic front vowel noted
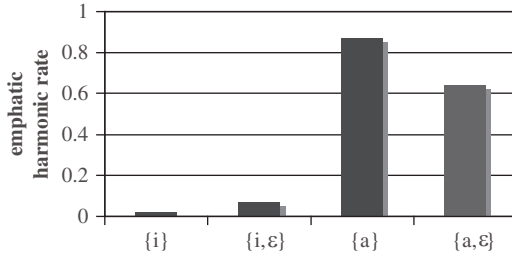
Figure 4. Effect of Adding [ɛ] on Emphatic Harmony Rate.

in the monosyllables. A chi-square test for independence showed the two conditions to be significantly different: chi sq = 16.93, df = 2, p < 0.005.

Finally, we review the harmonic outcomes in the corpus when the emphatic inducing Fr [a] and [o,ɔ] are combined with Fr [i] and [u]. These are the vowels that in monosyllables and in disyllabic combinations pull in opposite directions with respect to emphatic harmony. We thus expect some intermediate rate of emphatic harmonization when they are combined. We can also ask if there are differences among the vowels as to their capacity to trigger and to resist emphatic harmony. The tables below show the details.

(27) <u>summary</u>
{[a,ā,o,ɔ,ɔ̃]} +{[i,u]}

emphatic harmony:	64/188 (.34)	Heath: 22/70 (.31)
plain harmony:	91/188 (.48)	30/70 (.43)
disharmonic:	33/188 (.17)	18/70 (.25)

<u>Fr</u>   <u>MA</u>

{[a,ā]} + {[i]}
emphatic harmony: 30/112 (.27)   (Heath: 9/36 (.25))

[i]	[ā]	accident	[e]	[ɑ]	kSeDɑ	'accident'
[a]	[i]	chassis	[a]	[e]	ʃɑSe	'steel frame'

plain harmony: 55/112 (.49)   (Heath: 18/36 (.50))

[a]	[i]	valise	[a]	[i]	baliz-a	'suitcase'
[i]	[a]	amical	[i]	[a]	mikal	'friendly'

disharmonic: 27/112 (.24)   (Heath: 9/36 (.25))

[a]	[i]	trafic	[ɑ]	[i]	TRɑfik	'cheating'
[i]	[a]	zigzag	[i]	[ɑ]	zigZɑg	'zigzag'
[i]	[a]	histoire	[i]	[ɑ]	zisTwɑR	'story'

	Fr			MA	

{[o,ɔ]} + {[i]}

emphatic harmony: 6/37 (.16)   (Heath: 2/16 (.12))

[ɔ]	[i]	droguerie	[o]	[e]	DRogRe	'drugstore'
[o]	[i]	saucisse	[o]	[e]	SoSeS	'sausage'

plain harmony: 24/37 (.64)   (Heath: 9/16 (.56))

[o]	[i]	motif	[u]	[i]	muntif	'ground'
[ɔ]	[i]	police	[u]	[i]	bulis	'police'
[i]	[ɔ]	bricole	[i]	[u]	brikul	'trifles'
[i]	[ɔ̃]	siphon	[i]	[u]	sifun	'siphon, trap'

disharmonic: 7/37 (.19)   (Heath: 5/16 (.31))

[ɔ]	[i]	électronique	[o]	[i]	TRonik	'electronic'
[i]	[ɔ]	microbe	[i]	[o]	mikRob	'microbe'

{[a,ã]} + {[u]}

emphatic harmony: 21/34 (.62)   (Heath: 3/7 (.43))

[a]	[u]	casse-croûte	[ɑ]	[o]	kaSkRoT	'snack'
[ã]	[u]	pantoufle	[a]	[o]	panTof-a	'slipper'
[u]	[a]	foulard	[o]	[ɑ]	foRaR-a	'scarf'
[u]	[ã]	courant	[o]	[ɑ]	koRa	'current'

plain harmony: 8/34 (.24)   (Heath: 2/7 (.28))

[u]	[a]	tournoi	[u]	[a]	turnwa	'tournement'
[a]	[u]	cartouche	[a]	[u]	kartuʃ-a	'cartridge'

disharmonic: 5/34 (.15)   (Heath: 2/7 (.28))

[a]	[u]	carrefour	[ɑ]	[u]	kaRfur	'crossroads'
[u]	[a]	journal	[o]	[a]	ʒoRnan	'newspaper'

{[o,ɔ,ɔ̃]} + {[u]}

emphatic harmony: 7/11 (.64)   (Heath: 8/11 (.73))

[u]	[ɔ̃]	bouton	[o]	[o]	BoTon-a	'button'
[u]	[o]	fourneau	[o]	[o]	foRno	'furnace'
[ɔ̃]	[u]	bonjour	[o]	[o]	BoʒoR	'hello'

plain harmony: 4/11 (.36)   (Heath: 1/11 (.09))

[u]	[ɔ̃]	bouchon	[u]	[u]	buʃun-a	'lid'

	Fr				MA	
[u]	[ɔ̃]	coupon		[u]	[u]	kuppu 'voucher'

disharmonic: 0/11 (.00)   (Heath: 2/11 (.18))

Thus, in the tug of war between the emphatically biased low back vowels and the nonemphatically biased high vowels, the latter have a slight advantage: .48 plain vs. .34 emphatic. This mirrors a similar but much smaller bias observed in monosyllables where the plain adaptations of [i] and [u] are virtually unanimous while the rate of emphatic adaptation for [a] and [o,ɔ] is slightly lower. A similar disparity shows up in the homogenous disyllables where those drawn from the {[i,u,y,ø]} set are virtually never emphatic (0.02) while those drawn from {[a,ã,o,ɔ,ɔ̃]} are harmonically biased but show some slippage towards plain (.82). More generally, these differences are presumably due to the inherent markedness of pharyngeal consonants and vowels over plain ones.

Another important point is that the higher rate of nonemphatic harmony is largely attributable to a bias against emphatic [eˤ]. When we look at [u] in combination with [a,o] in (28) then the situation reverses: the emphatic harmonic rate predominates while harmony for nonemphasis declines. A similar effect is found in the Heath corpus.

(28)

	[a]+[i]		[a]+[u]	
emphatic harmony	30/112	.27	21/34	.62
plain harmony	55/112	.49	8/34	.24
disharmonic	27/112	.24	5/34	.15

	[o]+[i]		[o]+[u]	
emphatic harmony	6/37	.16	7/11	.64
plain harmony	24/37	.64	4/11	.36
disharmonic	7/37	.19	0/11	.00

chi-square tests for independence

[a]+[i] vs. [a]+[u]	chi sq = 14.14, df = 2, $p < 0.005$
[o]+[i] vs. [o]+[u]	chi sq = 10.30, df = 2, $p < 0.005$
[a]+[i] vs. [o]+[i]	chi sq = .19, df = 2, $p > 0.10$
[a]+[u] vs. [o]+[u]	chi sq = 2.14, df = 2, $p > 0.10$

This suggests that harmony is primarily due to a propagation of the emphatic feature rather than an evenhanded spread of both values of [constricted pharynx]. Nevertheless, harmony for nonemphatic cannot be dismissed entirely since it holds for about one-fourth of the corpus.

In sum, a major result of our survey has been to document a bias against emphatic [eˁ] in comparison to [oˁ] and [ɑˁ]. Let us review the evidence. First, in monosyllables Fr [ɛ] is adapted as emphatic at a significantly lower rate (.21) than Fr [a] (.94) and [ɔ] (.88) are. Second, when combined with a high vowel, Fr [ɛ] largely fails to impose emphatic harmony (.07) while [a] and [ɔ] tend to do so (.34). Third, when Fr [ɛ] is combined with [a] or [ɔ] in a disyllable, the rate of emphatic harmony declines (.64) compared to (.82) when the word is composed of [a] and [ɔ]. Fourth, when Fr [i] is combined with [a] or [ɔ], the rate of emphatic harmony is significantly less (.27 and .16 respectively), than when [u] is combined with [a] or [ɔ] (.62 and .64, respetively).

6. Consonantal Context

Finally, we turn to the consonantal context and its effect on the adaptation of Fr and Sp [e,o,a]. If these vowels are adapted as the allophones of underlying /i,u,a/ in an emphatic consonantal context (as suggested by the templating morphology) then asymmetries in the distribution of the MA emphatic contrast should have an effect on the adaptations. As mentioned in section 2, MA inherited the emphatic contrast from Cl Ar coronals and extended it to labials. But it is not found in palatals, velars, and pharyngeals. Do these differences show up in the loanword corpus?

Let us first return to the monosyllables. We recall that Fr [a] is adapted as MA [ɑ] in 65/70 (.93) loans. In fact, the five exceptions have a velar or palatal onset consonant.

(29) | Fr | MA | |
|------|------|--------|
| châle | ʃan | 'scarf' |
| gaz | l-gaz | 'gas' |
| cave | la-kab | 'cave' |
| cale | kal-a | 'wedge' |
| cage | la-kaʒ | 'cage' |

And the three exceptions to the Fr [ɔ] > [o] correspondence in our corpus have a velar onset or coda. The Heath corpus also has the example of Sp *español* > MA [spanjul] where a palatal onset blocks the expected [o].

(30) | | Fr | | MA | |
|------|------|------|------|--------|
| [ɔ] | gomme | [u] | gum-a | 'rubber' |
| [ɔ] | corde | [u] | kurd-a | 'rope' |
| [ɔ] | boxe | [u] | buks | 'boxing' |

Finally, the two loans in which Fr [ɛ] is adapted as MA plain [a] have palatal onsets and nonprimary codas: chef > [ʃʃaff] 'head, chief' and chèque > [ʃʃak] 'cheque'.

While palatal and velar onsets can inhibit the expected emphaticization, they do not always do so if there are other consonants available to host the pharyngealization. A few examples appear below.

(31)   Fr   MA
     [ɔ]   code   [o]   koD   'code'
     [a]   câble   [ɑ]   kɑBl   'cable'
     [a]   casque   [ɑ]   l-kɑSk   'helmet'
     [o]   jauge   [o]   Lɑ-ʒoʒ   'gauge'
     [ã]   chambre   [oN] ʃoMBR-ɑ   'room'
     [ã]   jante   [aN] ʒɑnT-ɑ   'wheel rim'

When the surrounding consonants lack an anterior or labial host then the word generally has a nonemphatic vowel (though care must be taken to distinguish code-switched pronunciations from integrated loans).

(32) Fr   MA
     cache-cache   kaʃkaʃ   'hide and seek'
     cage   kaʒ   'cage'
     les gants   ligan   'gloves'
                      ligat

A task for future research will be to give a more fine-grained analysis of these cases in which individual consonants as well as such factors as onset vs. coda are taken into account.

Turning to disharmonic words, we noted earlier that previous researchers have identified palatal segments such as [i], [j], and [ʃ] as blocking emphatic harmony in various Arabic dialects. We might then expect that disharmonic words will tend to have a medial palatal or velar consonant. In fact a sizable number do. We list some in (33). A few such as *curetage > kirTaʒ* have an initial onset that is inhospitable to pharyngealization.

(33)   Fr   MA
     [a] [i]   l'archive   [ɑ] [i]   lɑRʃif   'archive'
     [a] [œ]   tailleur   [ɑ] [u]   Tɑyyur   'tailor'
     [a] [e]   marché   [ɑ] [i]   mɑRʃi   'market'
     [i] [a]   zigzaq   [i] [ɑ]   zigZɑg   'zigzag'

	Fr				MA	
[ã]	[e]	étranger	[ɑn]	[i]	TRɑnʒi	'abroad'
[ã]	[i]	tranquille	[ɑn]	[i]	TRɑNkil	'quiet'
[a]	[o]	radio	[ɑ]	[u]	RRɑdyu	'radio'
[y]	[a]	curetage	[i]	[ɑ]	kirTɑʒ	'curettage'
					koRTɑʒ	

Nevertheless there remain a substantial number of disharmonic forms that have no obvious explanation in terms of the surrounding consonants. We list a few here. Like the other generalizations in our corpus, the harmonic effect is statistical in nature rather than a general sound change that generative grammars are customarily designed to express.

(34)		Fr				MA	
	[i]	[ɔ]	piston		[i]	[o]n pisTon	'piston'
	[ã]	[u]	tambour	[ɑ]m	[u]	Tambur	'drum'
	[i]	[a]	histoire	[i]	[ɑ]	zisTwɑR	'story'
	[u]	[a]	journal	[o]	[a]	ʒoRnan	'newspaper'
	[y]	[a]	surface	[i]	[ɑ]	sirfɑS	'surface'

7. Harmonic Grammar

In its classical form, the ranking of constraints in an OT grammar is fixed and so a given input always leads to the same output. But recent developments in the model have introduced various devices to express variation in the input-output mapping, following the lead of Boersma (1998). The GLA of Boersma and Hayes (2001) as well as the weighted constraint models of Jaeger (2006) and Potts et al (2007) are designed to allow phonologically equivalent inputs to lead to variable outputs. We were interested to see if these approaches could be used to model some of the data in our corpus. Listed below in (35) is the harmonic grammar that emerged after 50,000 trials for a simplified set of constraints over the data in our loanword corpus. It is based on a script due to Adam Albright that is based on the algorithm described in Jäger (2006). We assumed five faithfulness constraints for the five Fr input vowels [i], [u], [e], [o], and [ɑ] and three markedness constraints penalizing the emphatic vowels [e], [o], and [ɑ] as well as a Harmony constraint banning disyllables that combine {[i],[u]} with {[ɑ],[e],[o]}. The training frequencies that mirror the proportion of input-output mappings in our corpus are shown as well. The weights assigned to the constraints after 50,000 trials appear in (35c).

(35) a. <u>constraints</u>

      harmony: *{[i],[u]} + {[ɑ],[e],[o]}

      *ɑ, *e, *o

      Faith-V (V= i,u,e,o,ɑ)

  b. <u>training frequencies</u>

/a,i/	7765	/o,e/	1649	/o,a/	5757	/a/	4764
/a,u/	2358	/i,i/	1356	/e,a/	4686	/i/	2795
/i,o/	2565	/u,i/	1416	/u/	1403		
/u,o/	718	/a,a/	4103	/e/	1122		
/i,e/	5145	/o,o/	740	/o/	1659		

  c. <u>obtained weights</u>

Faith-a	5.66
*a	4.00
Faith-o	2.14
Harm	1.88
*e	1.48
*o	0.97
Faith-e	0.88
Faith-i	0.74
Faith-u	0

We make the following observations. The relative markedness of [e] is reflected in various ways. First, [e] ranks below [a] and [o] in faithfulness. Second, for both [a] and [o] faithfulness outweighs markedness while for [e] the reverse situation obtains. Third, even though [e] is more frequent than [o] in the corpus, faithfulness for [o] is over twice as strong as faithfulness for [e].[7] Also, faithfulness for [i] is higher than faithfulness for [u], reflecting the difference in the resistance to emphatic harmony—another aspect of the markedness of [e]. We conclude that an OT grammar with weighted constraints is a promising approach to the analysis of the data in our corpus. A thorough investigation with a larger number of constraints is a task for future research.

8. Summary & Conclusion

In this paper we have documented and analyzed in some detail the reverse engineering by which French loanwords with mid and back low vowels are

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[7] The higher weights assigned to [a] relative to [o] reflects the greater frequency of the former compared to the latter in the corpus.

adapted into Moroccan Arabic by the introduction of pharyngealization on the adjacent consonants. Our principal findings are that this phenomenon is systematic with the French back vowels [a,ɑ,o,ɔ,ɔ̃] but meets with considerable resistance for the front vowels [e,ɛ]. This difference also shows up in the different rates of harmony for emphasis in disyllabic loanwords. The general conclusion is that auditory salience and similarity constitute an alternative and complementary dimension of faithfulness that can override correspondences based on the contrastive phonological features of the native grammar. Tasks for future research include resolving whether the bias against [eˤ] is a markedness or faithfulness effect as well as a more fine-grained statistical analysis of harmony in disyllables taking into account such factors as directionality, consonant type, and onset vs. coda position.

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