Acoustics of Epenthetic Vowels in Lebanese Arabic*

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Abstract: We show that epenthetic and lexical vowels in Lebanese Arabic, which are often transcribed as identical, are acoustically distinct: epenthetic vowels are either shorter or backer or both. We argue that this incomplete neutralization is the result of phonetics optionally accessing an intermediate level of phonological derivation. This is formalized in Optimality Theory with Candidate Chains (OT-CC): epenthesis requires a multi-step candidate chain, and phonetics can access any step of the chain. Furthermore, we suggest that the acoustic distinction helps learners construct the correct candidate chains for words with epenthetic vs. lexical vowels.

1   Introduction

Phonological accounts of epenthesis normally assume that epenthetic vowels are phonetically identical to lexical vowels—that is, that epenthesis fully neutralizes the underlying distinction between the presence and the absence of a vowel. We present experimental evidence showing that the epenthetic vowel that Lebanese Arabic inserts into final CC clusters, which is usually transcribed [i], is backer and shorter in duration than Lebanese lexical [i] for some speakers. We propose a way to understand these phonetic findings within the version of Optimality Theory with Candidate Chains (McCarthy to appear). We suggest that phonetics can draw on the intermediate stages of derivation that these candidate chains represent. This view of the relationship between phonetics and phonology offers a new way to tackle the learning problem presented by stress-epenthesis interactions.

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A long line of phonetic research shows that phonological processes which have traditionally been described as neutralizing contrasts actually leave phonetic traces of the underlying distinctions, a phenomenon sometimes called incomplete neutralization. Incomplete neutralization has been found for final devoicing in Polish, German, and Catalan (for a recent review, see Warner et al. to appear, 2004), vowel deletion in French (Fougeron & Steriade 1997), vowel epenthesis in English (Davidson, in press), and stop insertion in English (Fourakis & Port 1986). While near-neutralization effects are sometimes too slight to be perceptible (Jongman 2004), Port & O'Dell (1985) show that listeners are better than chance at distinguishing supposedly neutralized words. Whether incomplete neutralization reflects underlying morphophonemic distinctions or just orthography is still controversial.

The finding of incomplete neutralization in vowel epenthesis is particularly interesting because vowel epenthesis is often involved in opaque interactions with other processes, particularly stress. If listeners can make use of incomplete neutralization to tell which vowels are epenthetic and which are not, this simplifies the problem of learning the opaque interaction. We emphasize, however, that opaque stress-epenthesis interactions do not depend on the existence of a phonetic difference between epenthetic and underlying vowels; we found some speakers who completely neutralize the distinction yet still avoid stressing epenthetic vowels.

The paper is structured as follows. In §2, we review the grammar of epenthesis and stress in Lebanese. In §3, we present our experiment, which found acoustic differences between epenthetic and lexical [i]. In §4, we propose a way to model incomplete neutralization in a Optimality Theory with Candidate Chains (McCarthy to appear), and we propose a modified learning strategy that can make use of the acoustic difference between epenthetic and lexical vowels to determine underlying representations.

2 Epenthesis and stress in Lebanese Arabic

The description of Lebanese phonology given here is based on Abdul-Karim (1980) and Haddad (1983, 1984). Lebanese has three short vowels, standardly transcribed [a, i, u] (although they are actually fairly centralized), and five long vowels [aː eː oː iː uː]. Syllable structure is restricted: onsets are obligatory; codas are permitted; complex codas are limited to two consonants and can only occur word-finally and only following short vowels. Coda clusters are also subject to further restrictions, especially sonority sequencing constraints, and these are often enforced through epenthesis.

Epenthesis applies in two circumstances. First, Lebanese breaks up three or four-consonant clusters (which only arise through morpheme concatenation). Epenthetic vowels are underlined.

(1)   Epenthesis in /CCC/ clusters

/katab-t-l-a/   ka.tá.bi̱t.la   'I wrote to him'   cf. katábt 'I wrote'

/ʔalf-na/   ʔá.li̱f.na   'our thousand'   cf. ʔálf 'thousand'

/ʔibn-na/   ʔí.bi̱n.na   'our son'   cf. ʔíb.n-i 'my son'

Second, Lebanese often breaks up two-consonant clusters word-finally. According to Haddad (1983:60), epenthesis is possible in any final CC cluster as long as neither consonant is a glide.[1] In some clusters, epenthesis is obligatory, in others optional. Haddad presents an exhaustive discussion covering every final CC cluster occurring in the language; our summary here omits some subpatterns involving cluster types that do not occur in our experimental data.

Epenthesis is obligatory in clusters consisting of an obstruent followed by a sonorant, as below.[2]

(2)   Obstruent-sonorant final clusters: epenthesis required

/mitl/   mítil̩   'like' (preposition)   /ʒisr/   ʒísir̩   'bridge'

/nidr/   nídir̩   'low'   /ʔifl/   ʔífil̩   'lock'

/ʔibn/   ʔíbin̩   'son'   /ʔism/   ʔísim̩   'name'

The situation of two-obstruent or two-sonorant clusters is more complicated. Haddad reports that

epenthesis is obligatory in a cluster of two coronal fricatives, and when a stop is followed by [f]

or by a non-coronal stop. Examples of such clusters are given in (3a). In a cluster of a coronal

fricative followed by [f], the realization without epenthesis is possible but 'questionable,' as

shown in (3b). In other non-guttural obstruent-obstruent clusters, realizations without epenthesis

are acceptable, as shown in (3c). Among sonorant-sonorant clusters, epenthesis is required in

/mn/, /rl/, /rm/, /nl/, and /ml/ (see (3d)), but not in /mr/ or /lm/; /rn/ without epenthesis is

questionable.

(3)   Epenthesis required in some obstruent-obstruent and sonorant-sonorant clusters

(a)	/mazʒ/	máziʒ	'mixing'	(c)	/dist/	dísit~dist	'boiler/tub'
	/kitf/	kítif	'shoulders'		/rakdˤ/	rákidˤ~ rakdˤ	'running'
	/rikb/	ríkib	'riding'		/nafs/	náfis~nafs	'self'
(b)	/nasf/	násif~nasf	'detonation'	(d)	/naml/	námil̩	'ants'

In clusters of a sonorant followed by an obstruent, like those in (4), epenthesis is optional but not

required.

(4)   Epenthesis optional in obstruent-sonorant clusters

/bint/   bínit ~bint   'girl'   /fils/   filis ~fils   '1/1000 of a
                                                                                   dinar'

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| /ramz/ | rámiz~ramz | 'symbol' | /kalb/ | kálib~kalb | 'dog' |
| /ʔird/ | ʔírid ~ʔird | 'monkey' | /ʔalf/ | ʔálif~ʔalf | 'one thousand' |

Epenthesis interacts opaquely with stress. Lebanese Arabic has the Latin Stress Rule (Mester 1994) with the added complication that superheavy syllables (CVVC, CVCC) attract stress in final position (see (5a)). A word that has no final superheavy syllables will be stressed on a penult if it is heavy and on the antepenult otherwise. In a disyllable with no final superheavy syllable, the first syllable is stressed.[3]

(5) (a) Stress a final superheavy syllable

ʔa.kált   'I ate'   bi.xal.líːk   'he lets you'

naz.zált   'I brought down'   mak.ta.báːt   'libraries'

(b) Else a heavy penult

náz.zal   'he brought down'   ma.ʕáː.rik   'battles'

ma.lák.na   'our king'   mak.táb.ti   'my library'

(c) Else the antepenult (or penult in two-syllable word)

ʔá.ka.lit   'she ate'   ʔá.kal   'he ate'

sá.ħa.bit   'she withdrew'   sá.ħab   'he withdrew'

These patterns are disrupted if the penult or the antepenult contains an epenthetic vowel. In most such cases, stress is assigned as if the epenthetic vowel weren't there, which can result in unstressed closed penults as in (6a,b), or penultimate stress where antepenultimate stress might be expected as in (6c) (McCarthy, to appear). There is one systematic exception, shown in (6d): a vowel inserted into an underlying four-consonant cluster does receive stress.

(6)   Stress-epenthesis interactions

    (a)   /ʔibn-na/   ʔí.bin.na   'our son'

    (b)   /katab-t-l-a/   ka.tá.bit.la   'I wrote to him'

    (c)   /katab-t/   ka.tá.bit   'I wrote' (cf. /katab-it/ → ká.ta.bit 'she wrote')

    (d)   /katab-t-l-ha/   ka.tab.tíl.ha   'I wrote to her'

Opaque stress-epenthesis interactions are interesting for a number of reasons. They have

been brought to bear on rule-ordering (Broselow 1982), representational differences between

epenthetic and lexical vowels (Piggott 1995), parallelism (Alderete 1999, Broselow to appear),

contrast preservation (Lubowicz 2003), and issues in learnability (Alderete & Tesar 2002), which

we discuss in §4.2. Whatever the account of stress-epenthesis interactions, phonological

treatments assume that epenthetic vowels are phonetically identical to lexical vowels in most

dialects of Arabic. We set out to test this assumption for Lebanese.

3   Phonetic study

We aim to identify the phonetic characteristics of epenthetic vowels in Lebanese Arabic and to

compare them to lexical vowels. Although there is plenty of descriptive work on Arabic by

native speakers (Haddad 1984, 1983, Nasr 1959, 1960, Abdul-Karim 1980 for Lebanese alone),

epenthetic vowels of Arabic have never been studied instrumentally (to our knowledge). The

available descriptions of Levantine epenthesis give an impressionistic transcription of both

vowels as [i], so our null hypothesis is that epenthetic and lexical [i] are acoustically identical.

Haddad (1983) notes, however, that 'this representation is rather inadequate since an inserted

vowel is more prone to suprasegmental features such as 'guttural' and 'emphatic'

[pharyngealized] than an underlying vowel is' (p.61) and that 'a precise description of the quality

of the epenthetic vowel. . . is too complicated to deal with here' (p.87) This suggests that some phonetic difference between the vowels might exist.

If any difference does exist, we would expect, based on results from other work on incomplete neutralization (Warner et al. 2004), that the difference would be in the direction of preserving the underlying vowel-zero constrast. Thus, we might expect the epenthetic vowel to be more "slight" than lexical [i]: shorter duration, less peripheral/more centralized, and lower intensity.

3.1 Design

3.1.1 Materials

The experiment compared near-minimal pairs of words. One word in each pair had the underlying form /CVCC/, and would be pronounced 'CVCiC if epenthesis occurred. Its match was a word of the underlying form /CVCiC/, which would be pronounced CVCiC. The second vowel in each word is the one being measured.

In Arabic, word shape relates to morpho-syntactic class. /CVCC/ words are usually singular nouns, although our list also includes a preposition and two adjectives. The /CVCVC/ word was usually a /CiCiC/ verb, known as form I in the Arabic verbal morphology system, in the masculine singular past. Every item was a bare stem form, without prefixes or suffixes.

A few pairs were perfect minimal pairs (e.g. /libs/ 'clothing' vs. /libis/ 'he wore'), but most pairs were near matches, where every phoneme except the initial consonant was the same (e.g., /mitl/ 'like' vs. /ʔitil/ 'he got killed'). For three pairs, the voicing of the middle consonant was not matched (e.g., /kizb/ 'lies' vs. /kisib/ 'he earned'), but this was not expected to affect the following vowel's quality or duration.[4] The pairs were also matched for the quality of the first

vowel in order to avoid any difference due to vowel-to-vowel coarticulation effects. Two pairs had /a/ in the initial syllable; the rest had /i/. Neither the middle nor the last consonant were pharyngealized in any of the target words, since it is well-known that pharyngealization lowers F2 (Herzallah 1990, Zawaydeh 1999). The first consonants in each pair were matched for pharyngealization: /ʕilm/ 'knowledge' could be compared to /ʕilim/ 'he knew' but not to /silim/ 'he was safe.' Stress was always initial, so the vowels being measured were in unstressed position.

We found in pilot work that speakers (even from the same city) vary in whether or how they produce certain words, for several reasons. First, epenthesis is optional in many of the /CVCC/ words, and some speakers epenthesize more often than others. Second, form I verbs fall into two arbitrary phonological classes, /CaCaC/ and /CiCiC/, and speakers vary as to which vowel pattern goes with which CCC root. For example, some people say [kifil] for 'he guaranteed,' some say [kafal] (and some people can say both). First syllable vowels in the nominal forms also sometimes varied (e.g., /rakb/ for /rikb/ 'riding'). Third, speakers sometimes simply rejected a word as a colloquial lexical item. For example, several speakers accepted [ʔitil] for 'he got killed,' but other speakers had no form I for this verb root, preferring to use form VII, [nʔatal]. Fourth, some speakers tended to drift into the classical register, which has different consonants: for example, [kiðib] rather than [kizib] for 'lies.' If speakers produced any of these variant forms of a test item, or failed to produce an item, the whole pair had to be excluded for that speaker. This variability was part of the reason that we decided to attempt to record as many pairs as possible, rather than recording many repetitions of a small number of pairs (as in Dinnsen & Charles-Luce 1984). It was impossible to be sure in advance that any

given pair would work on all subjects. In fact, out of a maximum of 29 possible pairs, each speaker produced only 9 to 23 in usable form.

To minimize this problem, we also included rhyming 'backup' words in the list where available, to be analyzed only if a target word was produced in unusable form. For example, if a speaker failed to produce [ʔifɪl] 'lock' (perhaps by not epenthesizing, or by using classical [q] instead of colloquial [ʔ]), we substituted their token of [tifɪl] 'coffee grounds.' The full list of target items and backups is given in Table 1. Fillers were added to bring the word total up to 140.[5]

Table 1: Underlying forms of target items, including 'backups'

Epenthesis		Lexical [i]	
ʃibl, ʔibl	'cub,' 'doe'	ʔibil, dibil	'accepted,' 'withered'
mitl	'like' (preposition)	ʔitil	'got killed'
ʔifl, tifl	'lock,' 'coffee grounds'	kifil	'guaranteed'
mitr, sitr	'meter,' 'modesty'	kitir	'increased'
kibr	'size'	kibir	'grew'
fikr, zikr, bikr	'thought,' 'belly button,' 'firstborn'	sikir	'got drunk'
nidr	'low'	ʔidir	'was able to'
kifr, zifr	'blasphemy,' 'greasy food'	wifir	'became abundant'
ʒisr, nisr, kisr	'bridge,' 'eagle,' 'break'	xisir, ʒisir	'lost,' 'dared'
ʔidm	'the old (plural)'	ʔidim, nidim	'became antiquated,' 'regretted'
ʔism, ʒism	'name,' 'body'	lizim, disim	'was required,' 'was fattening'
ħiʒn	'sadness'	ħiʒin	'felt sad'
libs, dibs	'clothing,' 'syrup'	jibis, libis	'dried up,' 'wore'
wisx	'dirty'	bizix	'spent freely'
rikb	'riding'	rikib	'rode'
dibʔ	'glue'	dibiʔ	'stuck'

kizb	'lies'	kisib, risib	'earned,' 'failed'
naml	'ants'	xamil	'languid' (adj.)
nimr	'tiger'	ximir	'rose (bread)'
film	'film'	silim	'was safe'
ʕilm, ħilm	'knowledge,' 'dream'	ʕilim	'knew'
ʒild	'leather'	wilid	'was born'
ʔird	'monkey'	birid	'caught cold'
kils, fils	'whitewash,' 'fils (coin)'	ʒilis	'became straight'
ʔalf	'thousand'	ʔalif	'alif' (letter)

3.1.2 Orthographic issues

The list of words was presented in ordinary Arabic consonantal script. Short vowels are not

normally written in Arabic, which is in one way convenient for our study: since the

orthography gives speakers no clue to the vowel's underlying status, it less likely to affect

production (but see §3.3.1 for qualification of this point). The lack of orthographic distinctions

does, however, introduce a methodological problem. A vowelless written word is frequently

ambiguous, out of context, between two or more words (لبس "l-b-s" can be either /libis/ 'he

wore' or /libs/ 'clothing'). This could lead speakers to produce the wrong words.

We took several steps to remove this ambiguity. We presented each word with an English

translation (similarly, Dinnsen 1985 used Spanish glosses of Catalan homographs in his study of

incomplete neutralization; see also Broselow et al. 1997 for use of English glosses of Arabic

words). The speakers looked through the entire list before recording, to make sure they knew

which words we meant. However, it was not clear whether speakers actually used the translations

during recording; jumping between two languages (particularly with different alphabets) is

difficult, and one speaker had limited English. So we also divided the words into alternating

blocks of about 20 items, where the words in each block (both test items and fillers) were either

all nouns (plus a few adjectives or prepositions, since a few /CVCC/ target items are of these

classes), or all form I /CVCVC/ verbs. Forms within each block were pseudo-randomized; the first and the last item in each block was a filler. We explicitly pointed out to subjects that most of the words in each block were a single part of speech. This strategy was largely successful in preventing part of speech mixups.

3.1.3   Participants

The participants were eight speakers of Arabic from Lebanon, who currently live in the US (Washington, DC area) or UK (Essex). All speakers consider Lebanese Arabic their native language, although all speak English (and probably French, although we did not confirm this with all of them). All of the speakers are literate in Arabic and familiar with Modern Standard Arabic. While we did not systematically collect sociological information (for example, for several speakers we did not ask about their religion), the following gives an idea of their backgrounds. Women are identified as W, men as M. **W1** is a university student in her mid-20's, from a village in Southern Lebanon near Palestine, and has also lived briefly in Kuwait. **W2** is a university student in her early 20's, Muslim, from a village near Beirut. She has also lived in Norway and speaks Norwegian. **W3** is an administrative assistant in her 40's, from a village in Northern Lebanon. She formerly taught Standard Arabic and is a rather prescriptive speaker. **W4** is an administrative assistant in her late 20's, from Beirut, who has also lived in Palestine. **W5** is a graduate student in her late 20's, Christian, who grew up in Byblos and Beirut, only leaving Lebanon for graduate school. **M1** is a restaurant owner in his late 30's, Christian, from Beirut. **M2** is a restaurant owner in his mid 50's, from a village in Northern Lebanon, who has also lived in Beirut (he offered to 'speak Beiruti' for us but was asked to use his native variety). **M3** is a restaurant owner in his 60's, from Beirut, who also spent some time in Palestine. His knowledge of English is limited, so M1 sometimes translated for him during the recording

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session. A fourth man was also recorded, but had trouble speaking colloquially to the microphone and did not produce enough tokens with epenthesis for analysis.

The subject group is not completely linguistically homogeneous. Colloquial Arabic shows considerable microvariation, some of which correlates with region, urban/rural origin, religion, age and gender. In recruiting subjects abroad, we were not able to control for these factors. However, we do not see this as a problem, because our subjects are probably typical of the mix of people one might encounter in a city like Beirut, where most subjects had lived at some time. Linguistic heterogeneity is the reality in many Arabic-speaking cities (Holes 1995), and hence a study of a somewhat heterogeneous group is quite relevant for understanding dialect-wide features such as stress-epenthesis interaction.[6]

3.1.4   Procedure

Recordings were made in 2005 in Washington DC and Colchester, UK, in quiet rooms at the speakers' workplaces or universities. Subjects W2 and W5 were recorded directly into a laptop computer; the other subjects were recorded using a Sony cassette tape recorder and a Sehnheiser MD 511 microphone.

Each speaker looked through the word list to familiarize him/herself with all the words, crossing out or replacing any words that did not belong to his/her own colloquial dialect, and then read the word list once. Speakers were asked to use their own colloquial pronunciations (which some speakers referred to as 'slang' in English) rather than classical or standard forms, and we discussed the difference to make sure speakers understood what we intended. One speaker, W2, asked and was given permission to make notes on her list to remind herself to use colloquial pronunciations. Besides changing classical consonants to colloquial, she wrote in the epenthetic vowels. Several speakers nevertheless tended to drift into the formal register

during recording. If we noticed speakers producing non-Lebanese features such as interdental fricatives, we asked them to repeat the words in their colloquial dialect (cf. Broselow et al. 1997). Speakers read the list of words in a frame sentence. For speakers W1 and W2, the frame sentence was [ʔúːli___ʔawáːm] 'Say (feminine.singular.imperative) quickly.' The feminine imperative was imagined to be directed at the experimenter. The word [ʔawáːm] (which W2 pronounced [ʔaweːm]) is rather colloquial, and we hoped that its presence in the frame would help speakers remain in the colloquial register. However, W3 found [ʔawáːm] ungrammatical in this position, so she and W4, who was recorded in the same session, used the word [ʕamáhalak] 'slowly.' However, we decided later that the initial pharyngeal was undesirable, as it could conceivably affect the epenthetic vowel's F2 (even though pharyngealization spread across word boundaries is not reported). For the remaining speakers, the word 'twice' ([marratéːn], or [martéːn] with syncope) was used instead. While the change of frames is not ideal, it induced no noticeable changes in pronunciation of the target words. Nor did the frame sentence seem to affect speech rate; W2 spoke the slowest despite using the word 'quickly.'

To check the speakers' stress grammars, we elicited some test words, such as 'our son,' 'we understood,' and 'I wrote to her.' All speakers stressed them as in (6).

The recordings were digitized at 44,100 Hz in acoustic analysis software *Praat* (Boersma & Weenink 2005). Vowels were segmented manually by visually inspecting the spectrograms and waveforms. A vowel boundary was judged to coincide with a sharp change in energy and the onset or offset of clear formant structure. Formants were measured using Praat's Burg algorithm. We collected average measurements for the first three formants, since the vowels appeared in a

variety of contexts, which undoubtedly affected their quality in different ways. We also

measured the duration of the entire rhyme of the second syllable of the word, just in case vowel

segmentation turned out to be difficult in different consonantal contexts (which it didn't).

3.2 Results

We performed separate factorial analyses of variance (ANOVA) for each measure as a

dependent variable. The independent variables were underlying status (epenthetic vs. lexical) and

subject. There was a significant main effect of underlying status for vowel duration and F2

($p \leq .001$); underlying status was marginally significant for rhyme duration ($p=.070$), and not

significant for F1 or F3. Table 2 gives the combined ANOVA results; Table 3 gives ANOVAs

for the formants broken down by speaker gender.

Table 2: ANOVA main effects of underlying status: combined genders

	Epenthetic		Lexical			
	mean	s.d.	mean	s.d.	$F(1,240)$	p
F1 (Hz)	467	76	462	69	.78	.377
F2 (Hz)	1728	201	1809	222	21.12	*<.001
F3 (Hz)	2768	263	2770	250	.19	.667
Rhyme dur (ms)	252	72	264	83	3.31	.070
V duration (ms)	76	27	85	25	10.94	*.001

ep: N=128; lex: N=128. A star indicates that the differences are significant at $\alpha = .05$

Table 3: ANOVA main effects of underlying status: formants by gender

	Epenthetic		Lexical			
	mean	s.d.	mean	s.d.		p
Men					$F(1,100)$	
F1 (Hz)	435	55	420	64	1.26	.264
F2 (Hz)	1606	155	1711	216	6.93	*.010
F3 (Hz)	2547	154	2554	138	.273	.603
Women					$F(1,140)$	
F1 (Hz)	489	82	492	56	.10	.757
F2 (Hz)	1813	185	1879	200	16.78	*<.001
F3 (Hz)	2924	207	2922	192	.03	.863

Men: ep: N=53, lex: N=53; Women: ep: N=75, lex: N=75

A Tukey HSD post-hoc test revealed a significant interaction between subject and underlying status for F2, and no interaction for any of the other measures. To explore this variation, we performed a two-tailed t-test for each subject to determine whether epenthetic and lexical vowels differ. Results are shown in Table 4, and individual performances on duration and F2 are graphed in Figures 1 and 2. (In both figures, error bars show standard error.)[7]

Table 4: Individual two-tailed paired t-tests for F2

Subject	Epenthetic mean	Lexical mean	Difference mean	s.d.	T	p	N (pairs)
W1	1566	1559	7	137	0.173	.866	12
W2	1947	2124	**−177**	128	−4.165	***.003**	9
W3	1708	1979	**−271**	213	−4.588	***.001**	13
W4	1937	1939	−2	99	−0.093	.927	20
W5	1845	1838	8	83	0.422	.677	21
M1	1615	1718	**−103**	256	−1.919	**.068**	23
M2	1637	1804	**−167**	182	−3.901	***.001**	18
M3	1545	1559	−14	106	−0.469	.648	12

A star indicates that the differences are significant at $\alpha = .05$ ($p < .00625$, with Bonferroni adjustment).

Subjects appear to fall into two groups as regards F2. Subjects W2, W3 and M2 each have a significant difference between epenthetic and lexical vowels. Subject M1 has a difference that does not reach significance, but is still strong. We can call this group, whose results are boldfaced in Table 4, the 'differentiators.' Subjects W1, W4, W5, and M3 are 'non-differentiators'; they have differences that are extremely small. The groups are not defined by any sociological factor such as religion, age, gender or region of origin; nor do they correlate with the choice of frame sentence. Thus, we cannot say what factors affect this variation in the epenthetic vowels' F2; only that some variation exists.[8]
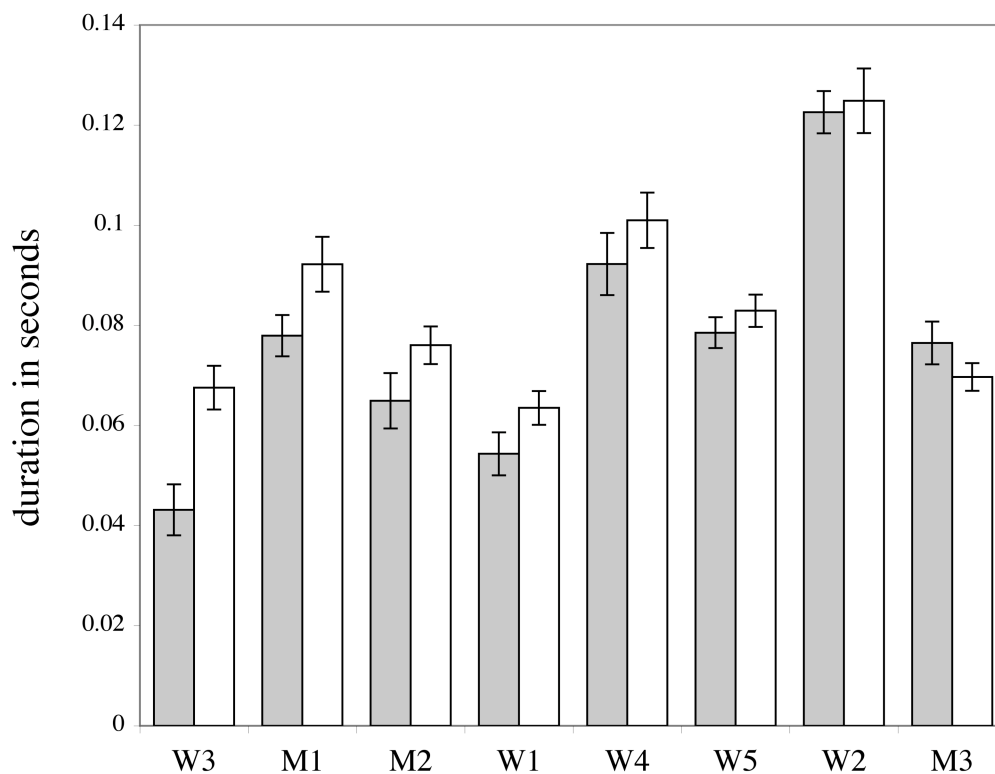
Figure 1: Individual results for duration

With respect to vowel duration, the other measure that came up significant in the
ANOVA, subjects range from having a very slight (but non-significant) trend towards longer
epenthetic vowels to having a strong trend towards shorter epenthetic vowels. However, the
subjects seem to vary along a continuum; there is no clear grouping into differentiators and non-
differentiators as there is with F2. The subjects who differentiate F2 tend to also have fairly large
differences in duration, except W2, who has only a very small difference in duration although
her difference in F2 is significant.
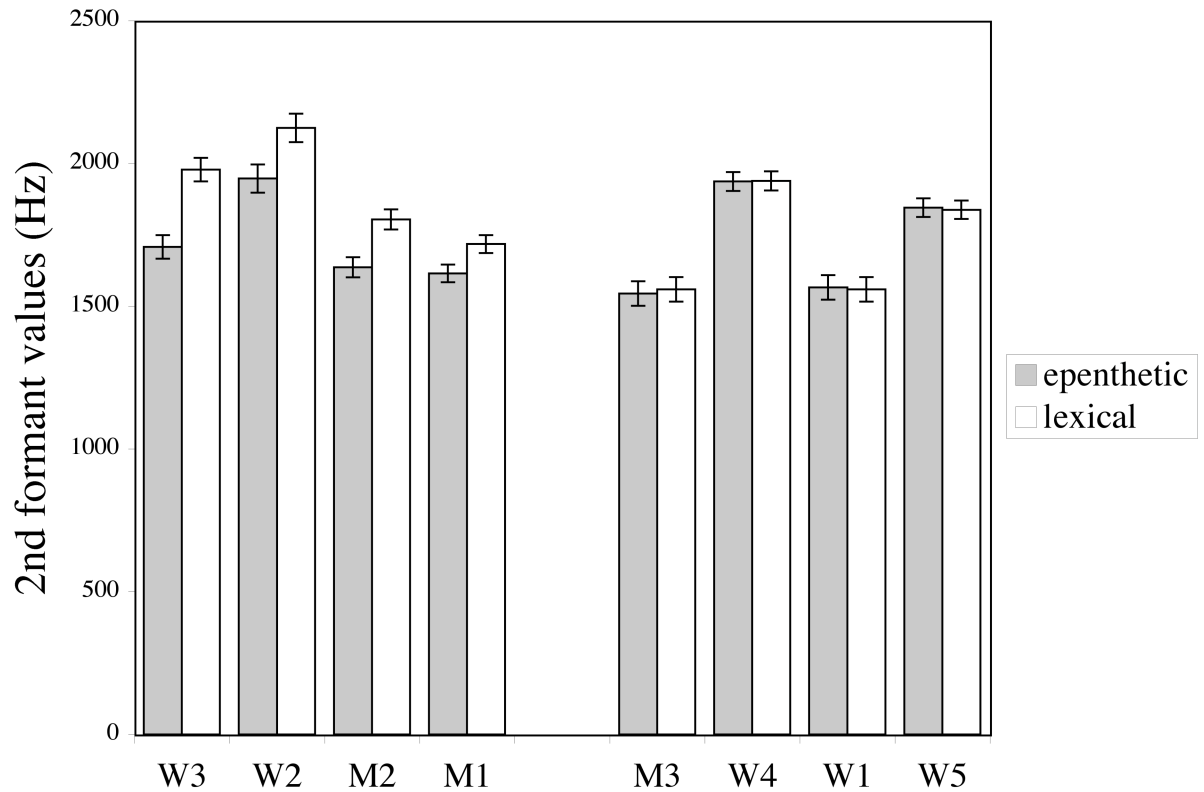
Figure 2: Individual results for F2

3.3   Discussion

We have found that Lebanese speakers, as a group, produce epenthetic "[i]" with a shorter

duration than lexical [i]. Furthermore, half of our speakers produced the epenthetic vowel with a

significantly lower F2 than lexical [i], suggesting that it might be more appropriately transcribed

[ɨ] for them. This finding is in keeping with other studies of incomplete neutralization, which

have shown phonetic traces of underlying distinctions. The differences between lexical and

epenthetic vowels go exactly in the expected direction. For speakers who differentiate,

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epenthesis introduces something *less than an [i]*: the vowel is backer and shorter, all properties that would make this vowel closer to [ɨ] or [ə]—and, arguably, to zero.

3.3.1   The role of orthography

Lebanese Arabic raises orthographic issues not seen in any of the incomplete neutralization studies on other languages. Whether incomplete neutralization is an artefact of orthography is a subject of ongoing debate; thus, some argue that when a contrast is not represented orthographically, neutralization is complete.

In Dutch, Warner et al. (to appear) find complete neutralization for the underlying contrast between a singleton /t/, as in /he:t/, and a fake (morphological) geminate composed of a past tense morpheme /-t/ and a word-final /t/ as in /he:t-t/, a distinction that is not represented orthographically. Conversely, Warner et al. (2004) found that a purely orthographic difference between double and single consonants did trigger incomplete neutralization in Dutch, despite not corresponding to any underlying distinction. Kopkalli (1993) finds a complete neutralization of final voicing in Turkish, where the final devoicing is represented in the language's orthography, but Dinnsen & Charles-Luce (1984) find incomplete neutralization of final voicing in Catalan, whose orthography also represents final devoicing. Fourakis & Iverson (1984) find that neutralization of final voicing is complete in German when the experimental task does not involve reading; Jassem (1989) has similar results for Polish.

Arabic differs from all of these cases in that the everyday orthography represents neither neutralization nor non-neutralization of the short vowel–zero contrast: it doesn't represent short vowels at all. In this sense, our written stimuli should not bias the subjects either towards or against neutralization, and we believe this is the only study of incomplete neutralization where the orthography has this characteristic.

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The situation in Arabic is complicated by the fact that there is an optional way to write vowels, using diacritics above or below the consonants. Lebanese schoolchildren learn to read and write fully voweled texts in the standard and classical registers, which differ considerably from the colloquial phonologically and in other ways. These texts represent underlying /i/ with the symbol *kasra*, a short line below the consonant (ِ). In the environments where colloquial Lebanese has epenthetic [i], standard texts have the symbol *sukuun*, a circle above the consonant (ْ), indicating absence of a vowel. If subjects mentally drew up these fully voweled standard forms when doing the study, the *kasra* vs. *sukuun* distinction could bias them towards non-neutralization. We cannot be sure whether this happened. We should note that fully voweled texts have a very limited place in the Lebanese written corpus, being confined to special genres such as religious scripture, poetry, and books for beginning readers. The vast majority of everyday written materials, such as newspapers, novels, and textbooks, do not include short vowels, which suggests that speakers are not likely to automatically visualize the vowel diacritics when looking at a consonantal text. On the other hand, since writing is associated with the standard register more than the colloquial register, the very use of written stimuli might be a factor biasing speakers towards formality and hence non-neutralization.

As mentioned above, one speaker, W2, made notes on her stimulus sheet to remind herself to use colloquial pronunciations. She went through the Arabic orthographic forms and systematically marked colloquial consonants, and also wrote in the epenthetic vowels using the symbol *kasra*. This speaker is one of the group who strongly differentiated epenthetic and underlying vowels in F2. Evidently, seeing the epenthetic vowels written like lexical /i/ in her word list did not cause her to produce them as [i].

In short, we cannot conclusively say how orthography may have affected our results, but would like to point out that expanding incomplete neutralization studies to languages with a different relation between orthography and phonology, including languages with non-Latin orthographic systems, may help elucidate the relation between orthography and phonetic realization.

3.3.2   Is Lebanese stress-epenthesis interaction opaque?

The standard view of stress-epenthesis interaction in Lebanese is that it is completely opaque: epenthetic [i] behaves differently than lexical [i] for stress, but there are no surface clues (in an isolated word, without morphological analysis) as to which vowel is the epenthetic one (Alderete & Tesar 2002 make this assumption explicit).

While this might describe the speech of some individuals considered in isolation, we believe that in the non-idealized setting of the Lebanese speech community, learners do have some clear clues available as to which vowels are epenthetic. The variability of epenthesis is one clue: the stressed lexical vowel in /fihimna/ [fhím.na] 'he understood us' always has a correspondent in the unsuffixed [fi.him] 'he understood,' but the unstressed vowel in /dist-na/ [dí.sit.na] 'our boiler' only has a correspondent in [dís(i̱)t] 'boiler' some of the time.

Moreover, we have shown that information about the epenthetic vowels being different is sometimes present in the acoustic signal. Whether listeners can take advantage of this information to identify lexical items is not known; the question needs to be answered in a perception study. We expect that listeners could tell the difference between lexical and epenthetic vowels in at least some people's speech (but recall that some speakers do appear to neutralize completely). The JND (just noticeable difference) for F2 in consonantal context is about 50 Hz (Kewley-Port 1995), and our differentiators produced an average difference of 166

Hz, far greater than the JND. A conservatively estimated JND for duration is about 20 ms (Klatt 1976), which some of our speakers approximate (W3 produced a difference of 25 ms). (Of course, the raw magnitude of durational differences depends on prosodic position, and we looked only at words in a clause-internal position. Charles-Luce (1985) found that incomplete neutralization effects for final devoicing were stronger for words in clause-final position. Hence, a different frame sentence might produce larger durational differences.) Durational differences found in incomplete neutralization studies are typically smaller than ours—in fact, they often barely reach 5 ms. Since some of these studies have found that speakers could use these subphonemic differences for word disambiguation (Port & O'Dell 1985, Port & Crawford 1989, Warner et al. 2004), we expect that our speakers could also do this with the relatively large differences found in some Lebanese speech.

4 Incomplete neutralization and phonology

Incomplete neutralization is a phonetic fact. The question is, is it a problem for phonology, and does phonology need to say anything about it? Some argue that it puts the very concept of neutralization in question (Dinnsen & Charles-Luce 1984), but we believe that it is a powerful argument for the reality of phonological processes and underlying representations (Blumstein 1991 articulates this argument very well). In order for a difference to exist, speakers have to think of lexical and epenthetic vowels as different, and they have to apply a (possibly gradient) process to reduce or eliminate the difference.

In the remainder of the paper, we discuss a way to relate incomplete neutralization to an OT grammar, and also the implications of incomplete neutralization for the problem of learning stress-epenthesis interactions.

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4.1 Incomplete neutralization as accessing an intermediate representation

One way of thinking about incomplete neutralization is as access to an intermediate stage of a derivation. Instead of pronouncing the fully neutralizing surface phonological representation, the speaker is pronouncing something between the underlying and the surface representation. This may be a partially devoiced consonant, a partially nasalized vowel, or, in the case of epenthesis, something that is between zero and [i].

We will assume here that at the phonological level, all epenthesizing speakers share the same fully neutralized surface representation for the outputs, i.e., with an epenthetic [i]. At the level of phonetic implementation, however, speakers optionally access the intermediate stage (this notion will be made precise below). This assumption of phonological sameness and phonetic optionality allows us to explain why not all speakers differentiate the vowels phonetically. It is also consistent with the observation that incomplete neutralization is variable and highly sensitive to experimental design: pragmatics, orthography, and other non-phonological factors may increase or decrease the magnitude of the effects (sociolinguistic work on near-mergers is also relevant; see Labov (1994)). This might mean that the explanation for the "why" of incomplete neutralization lies outside of phonology proper. Incomplete neutralization meshes with assumptions about phonological mappings, however, and ideally phonological theory should be able to model it.

Until recently, the notion of intermediate stages of derivation has been inimical to almost all versions of Optimality Theory. However, one way to formalize our intuition is offered by the Optimality Theory with Candidate Chains (OT-CC, McCarthy to appear, Becker 2006), a theory that has been proposed precisely to capture opaque interactions like that of Levantine stress and epenthesis.

In OT with Candidate Chains, a candidate consists of a derivational chain from the input to the output, which includes the starting point (the input) and the endpoint (the phonological surface form with all of the necessary structure fully assigned). The mapping from the input to the output is gradual: it proceeds in incremental steps rather than in a simple "quantum leap" characteristic of classic, parallel OT (Prince & Smolensky 1993/2004, McCarthy & Prince 1995). Each derivational step corresponds to a single violation of a faithfulness constraint. It is impossible, for example, to map /tat/ to [tade] in one step, since it involves both the insertion of [e] and the voicing of /d/. Instead, /tat/ maps to *tate*, which then maps to *tade*. A chain starts with the fully faithful parse, and each successful step inherits all of the faithfulness violations of the previous one.

McCarthy (to appear) analyzes Levantine stress similarly: the optimal mapping of /ʔibn-na/ to [ʔíbin.na] must involve intermediate stages. Stress is assigned first (ʔíbn.na), and the cluster is broken up by epenthesis afterwards. This chain <ʔibn.na, (ʔíbn).na, (ʔí.bin)na> beats the transparent alternative chain <ʔibn.na, ʔi.bin.na, (ʔibín)na> because a special PRECEDENCE constraint requires that epenthesis precede insertion of stress. (See McCarthy to appear for a detailed exposition.)

We propose a small refinement to this analysis. In the case of epenthesis, the shape of a chain depends on the theory of epenthesis. We believe, following a body of work on epenthesis, that zero would not map directly to [i]; rather, [ɨ] and [ə] have to be intermediate stages. Steriade 1995, Howe & Pulleyblank 2004, Gouskova 2003 and others have argued that epenthetic vowels are subject to faithfulness constraints that limit their prominence (sonority). An ideal epenthetic vowel is one that is least noticeable, i.e., one that is shortest and least sonorous. The more

sonorous the epenthetic vowel, the greater the disparity between the input and the output. The sonority hierarchy for vowels (see Parker (2002) and the references therein) is the basis for the following faithfulness hierarchy of DEP constraints on vowel epenthesis:

(7)   DEP/ɨ >> DEP /ə >> DEP /i,u >> DEP /e,o >> DEP/a

If sonority is understood to be a cumulative property, where [a] has all of the sonority of schwa and then some (see de Lacy (2002) for one formalization), then a mapping from zero to [a] entails the most faithfulness violations, a mapping to [e]—somewhat fewer, to [i]—still fewer, and so on. Thus, we propose that in order to epenthesize [i], the candidate chain must contain a mapping from zero to [ɨ] to [ə] to [i], as in the following:

(8)   Candidate chain for epenthesis of [i]:

/CC/   <CC,   CɨC,   CəC,   CiC>
               DEP/ɨ,   DEP/ə,   DEP/i,u

The winning candidate is not just the last link in the chain, CiC, but the entire chain. This chain contains considerably more information than just the surface representation CiC: it encodes what CiC came from (that is, CC) and the intermediate steps of this mapping.

Furthermore, we suggest that phonetics can access this entire chain rather than just the last link. This explains why the epenthetic vowel for some of our speakers is sometimes closer in quality to [ɨ] or even [ə]. Thus, the speakers are phonetically implementing an intermediate stage of the derivation:

(9)

Phonetic interpretation of /CC/:

phonological output:	<CC,	CɨC,	CəC,	CiC>
phonetic realization:		[CɨC] or	[CəC] or	[CiC]

Phonetic interpretation of /CiC/:

phonological output:	<CiC,	CiC>
phonetic realization:		[CiC]

We leave open the possibility that perhaps even the first member of the chain, the fully faithful CC, can optionally surface. This is one way of looking at the fact that a single speaker may be inconsistent as to whether he or she pronounces an epenthetic vowel in a particular word.

Even though speakers varied in the phonetic quality of their epenthetic vowels and also in whether they epenthesized in the first place, they all shared the same opaque stress grammar. This is consistent with our theory: we claim that our speakers use different phonetic implementations of the same candidate chain. Since in this chain, stress is assigned before epenthesis, we may expect to see something less than a full epenthetic [i], but we do not expect to see differences in how stress is assigned.

Our theory of incomplete neutralization makes several predictions. First, it predicts that an incompletely neutralized variant should always be between the underlying and the surface representation. Lebanese phonology categorically rules out epenthesis of anything more prominent than [i] (i.e., CeC and CaC). Epenthesis of a more prominent vowel requires a longer candidate chain and therefore would not be expected to emerge in this grammar.

Our theory also predicts that incomplete neutralization should in principle be an option for any phonological processes that involve a truly synchronic derivation, but not for alternations that involve, for example, multiple listed allomorphs. In English *a/an* allomorphy, the allomorphs are not derived from a common underlying representation, so we would not

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expect speakers to produce anything in-between *a* and *an*. Incomplete neutralization is expected

to exist only when the phonetic form is phonologically derived. The choice of which specific

derivations give rise to incomplete neutralization lies outside of phonology proper, but our model

can accommodate any gradual mapping.

This theory is not meant to be a complete account of near-neutralization, which often

involves partial devoicing and other not-quite-phonemic distinctions. A phonological candidate

chain for devoicing does not involve an intermediate "half-voiced" stage, since "half-voiced" has

no status phonologically. We speculate that perhaps the phonetics may interpolate phonetic

continua between members of a chain for mappings such as devoicing.

Candidate chains do two jobs. First, they are crucial to the analysis of opaque stress in

Lebanese (see McCarthy to appear)—an account that works without relying on the phonetic

distinction or indeed any representational distinction. The phonological analysis explains how

stress is assigned both by speakers who do and who do not distinguish the vowels phonetically.

Second, candidate chains provide information for the phonetics about the derivational history of

the epenthetic form, so speakers have the option to neutralize partially as opposed to fully.

Speakers have the same phonology but may differ as to which epenthetic vowel along the

available continuum they access in the phonetic implementation.

4.2   Incomplete neutralization and learning

Our phonetic findings are also relevant to the question of how learners acquire correct underlying

forms. Learning an OT grammar involves finding a constraint ranking that generates outputs that

match those of the target grammar (Tesar & Smolensky 1998 et seq.). Learning starts

with phonotactics and is complicated by tasks such as resolving structural ambiguity and

deciding between several grammars of differing restrictiveness. Most relevant to our concerns is

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the assumption, shared by much of the work in learnability theory, that early non-morphological learning proceeds under the Identity Map Hypothesis (IM): every output is mapped to an identical input.

Alderete and Tesar (2002) note that opaque stress-epenthesis interactions present the learner with a type of subset problem (Prince & Tesar (2004) and others). The learner can account for all the surface forms of a stress-epenthesis grammar (such as Levantine) by positing a less restrictive grammar in which stress is lexical. In such a grammar, faith to stress is ranked above the markedness constraints that determine default stress placement. Stress is indicated in the underlying forms, so that 'our son' [ʔíbɪnna] is underlyingly /ʔíbin-na/, not /ʔibn-na/, and the presence of underlying stress would account for surface stress differences between [ʔíbɪnna] and regular words like [darábna]. This superset grammar can accommodate stress in just about any position—unlike its subset, the correct grammar in which only epenthetic vowels are unstressable but stress is otherwise predictable. If the learner settles on a superset grammar, there is a danger of producing ungrammatical forms. Alderete and Tesar suggest that at least part of the solution is to modify IM. To learn the correct subset grammar, the learner must first consider unfaithful origin as the explanation for deviant stress and move on to the lexical stress grammar only if that doesn't work. This modification is necessary if one adopts the view that the learner only ever encounters idealized, phonetically invariant data.

The finding that Lebanese learners are exposed to phonetic differences between epenthetic and underlying vowels (not necessarily from all speakers, but from some), opens the possibility of a different solution to this particular learning problem. We propose here that the learner can use phonetic variation of the kind we found as additional motivation to posit distinct underlying representations, and, crucially, correct candidate chains to go with these URs.[9]

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Learning Lebanese stress requires positing a vowel-zero contrast for [ʔíbɨnna] and

[darábna] and selecting the correct candidate chain for each output. Recall that in the analysis of

Levantine (McCarthy to appear), the correct candidate chain for the opaque [ʔíbɨnna] is <ʔibn.na,

(ʔíbn)na, (ʔí.bɨn)na, (ʔí.bən)na, (ʔí.bin)na>. This chain and associated input must be

distinguished from the wrong chain /ʔíbinna/, [ʔíbinna], which contains no interesting derivations

at all. We have shown that in the Lebanese speech community, /ʔibn/ 'son' can be pronounced as

either [ʔibɨn] or [ʔibɨn]; we conjecture that similar variability characterizes suffixed forms in

which stress is opaque, as well. Under our theory that phonetic realizations can optionally

represent different parts of the candidate chain, the existence of these variant outputs is

consistent with the longer candidate chain and epenthesis but not with the lexical stress

analysis, since under such an analysis, there would be no account for the variant pronunciation

with the backer vowel. We propose that the learner can use such information from incomplete

neutralization as an additional clue that there is a multi-step derivation. The Identity Map

Hypothesis is modified as follows:

(10)   Modified Identity Map Hypothesis (MIM): The phonological content of surface forms is

        mapped directly into candidate chain representations: every observed output must be

        identical to some member of the word's candidate chain.

We assume that the learner is able to distinguish ordinary, low-level phonetic variation (such as

occurs in all vowels due to normal variability in the magnitude or overlap of articulatory

gestures) from the type of exceptional phonetic variation that we found in epenthetic vowels

only. When the learner realizes that a given word can be pronounced with an unusual degree of

phonetic variation, MIM requires him or her to construct a longer candidate chain that includes additional derivational steps accommodating the various observed forms. A longer candidate chain of this sort entails an unfaithful mapping: generally, a faithful mapping only requires the assignment of prosodic structure, which can be done in two steps (syllabification, footing). Therefore, the learner can use phonetic variability that is the product of incomplete neutralization to diagnose unfaithful input-output mappings and to construct a grammar that can account for opaque consequences of derivation.

Our proposal is not meant to be a complete theory of candidate chain construction. The learner cannot rely exclusively on phonetic variation for the purpose of constructing candidate chains; in some cases, as for some Lebanese speakers, it may be absent or barely discernible, so there needs to be a mechanism in place for generating candidate chains that is independent of variation. Furthermore, not all phonetic variation is due to incomplete neutralization—some results from optional low-level phonetic processes. This kind of variation is probably not problematic for our point. For example, the learner might encounter variable partial nasalization of vowels in syllables with nasal codas, i.e., both [ãn] and [an]. Under our proposal, the learner would automatically posit the chain /an/, [ãn] <an, ãn>. This is not necessarily problematic, though, because presumably, the variation in nasalization is general and does not correlate with underlying distinctions. If, on the other hand, only *derived* outputs are variable in the way we documented, the learner has additional evidence that the salient and robust surface differences produced by opacity are due to underlying distinctions.

5   Conclusion

Our phonetic study of epenthetic and lexical [i] in Lebanese Arabic falsifies the null hypothesis that these vowels are identical on the surface, which is assumed in most phonological work on

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Arabic stress-epenthesis interactions. The vowels are reliably different for some (though not all) speakers. We see this as a positive result for phonology rather than a challenge to it. First, the presence of phonetic differences between epenthetic and lexical vowels simplifies the task of learning opaque stress-epenthesis interactions, offering another line of attack on a thorny learnability problem. Second, the results support the existence of abstract underlying representations and processes that change them. Third, because the vowels are identical for some speakers but different for others, phonological accounts of stress-epenthesis interactions must work independently of phonetics, i.e., they must work even if no phonetic differences existed. At the same time, if phonology is to say anything about incomplete neutralization, it needs to provide certain information to phonetics. We discussed one possibility for implementing this in Optimality Theory with Candidate Chains. Because a candidate in this theory contains the entire derivational history of the phonological output, phonetics can optionally access forms other than the fully neutralizing one, which provides a way to model incomplete neutralization.

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1. Glides vocalize in the environment C_#; glide-initial final clusters remain intact. We did not include such clusters in our experiment.

2. However, even where epenthesis is basically obligatory, another factor can interfere: educated Lebanese learn in school to speak Standard Arabic, which lacks epenthesis in final CC clusters. One speaker we consulted, a former teacher of Standard Arabic, occasionally lacked epenthesis in environments where Haddad describes it as obligatory. She was probably drifting into a non-colloquial register.

3. It is controversial whether Lebanese has secondary stress (Nasr, 1959), but this is irrelevant to our study.

4. Mitleb (1984) shows that voicing does not affect vowel duration in another Levantine dialect, Jordanian.

5. Thanks to Ghada Khattab for extensive help in locating near-minimal pairs—a difficult task due to the lack of colloquial Lebanese dictionaries.

6. Even subjects recruited in Lebanon, from a small area, would likely be linguistically heterogeneous. We have conducted a similar study on Palestinian Arabic in Haifa, Israel, with speakers who live in a single neighborhood and are connected through bonds of family or friendship. Nevertheless, they showed considerable linguistic variation in terms of lexical items, consonant inventory, and quality of the epenthetic vowel. Haddad (1984) found similar microvariation in his study of Lebanese syncope, observing, "no matter to what extent the variables (in a sociolinguistic sense) have been restricted or narrowed down, such as interviewing male peers of the same dialectal area, or even brothers or sisters, no less variability has been observed."

7. We performed t-tests for the other measures as well; W3 had a significant difference in vowel duration, but no other results were significant for any subject.

8. A reviewer commented that the F2 values are somewhat low for both lexical and epenthetic [i]; as noted above, the three short vowels of Lebanese are fairly centralized, particularly in unstressed position as here, so [i] should be understood as only a broad transcription. The fact that /i/ and /u/ are only marginally contrastive (Haddad 1984) may also contribute to /i/ being realized as rather back.

9. For additional discussion of learning underlying representations and candidate chains, see Tesar (2005), McCarthy (to appear).

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