English Voicing Assimilation: Input-to-Output [±voice] and Output-to-Input [±voice]

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1. Introduction

This study is an attempt to model variation in a constraint-based theory. It is not the first one of its kind. Ever since an optimality-theoretic analysis of English t/d deletion was proposed by Kiparsky (1993), the systematic treatment of variation in Optimality Theory literature has been growing. There are various ways to approach variation in Optimality Theory (henceforth OT) (Prince and Smolensky 1993/2000, McCarthy and Prince 1993a&b). Anttila (2002) provides a useful discussion of various possibilities. Especially interesting are Hammond's (1994) account of variable stress in Walmatjari by means of *tied violations*: two or more candidates incur exactly the same violations with respect to all the constraints in the grammar; Müller's (1999) *pseudo-optionality* approach in which variation is attributed to free choice between alternative inputs; and Boersma and Hayes' (2001) *continuous ranking scale* in which each constraint has a fixed ranking value along a real-number scale.

A new way of explaining the distribution of variant pronunciations in English is added to the existing optimality-theoretic approaches to variation mentioned above. It accounts for variation in terms of a single invariant ranking. Formally, we propose to specify the levels of representation with respect to which identity constraints are evaluated. We characterize the specific requirement for a constraint to refer either to an input, or to an output as I-to-O [±voice] and O-to-I [±voice]. Our proposal is compatible with OT, and with Correspondence Theory in particular. Correspondence Theory allows constraints on the output, on input-output relations, and on output-input relations.

In this paper we propose an analysis within OT to account for obstruent voicing alternations in English when onset-specific faithfulness is irrelevant. We will argue that we must break the identity constraint that specifically targets obstruent [voice] into [+voice] and [-voice] constraints and elaborate these identity constraints somewhat, so that we have a way of stating that in regular voicing assimilation an input obstruent maps to an output one, while in case of variation in voicing alternation in output an output obstruent maps to an input one. We begin in section 2 with some facts about English obstruent clusters. We follow this in section 3 with different OT analyses of tautosyllabic obstruent clusters in English. In section 4 we present more facts about obstruent voicing and devoicing. Section 5 describes our alternative account of the variation in English voicing alternations. The most significant conclusions are summarized in section 6.

2. Some facts from English

English stem-final obstruent clusters have a single value for the voicing feature. With the exception of the word *adze* in which the final obstruent clusters are voiced [dz], stem-final obstruent clusters are invariably voiceless. Consider the items in (1) which are given in their orthographic representations except for the obstruents in question.

(1) Stem-final obstruent clusters in English

a.	grasp	[sp]
b.	opt	[pt]
	act	[kt]
	shift	[ft]
	list	[st]
c.	mask	[sk]
d.	corpse	[ps]
	spitz	[ts]
	ax	[ks]

Obstruents displaying voicing alternation show up elsewhere in English. One noteworthy place is in the regular verbal and nominal inflections where the suffixal obstruent assimilates the voicing of the final segment of the stem.

(2) Suffixal voicing pattern

a.	Plurals			
	ropes	[ps]	robes	[bz]
	cats	[ts]	roads	[dz]
	lakes	[ks]	rugs	[gz]
	giraffes	[fs]	gloves	[vz]
b.	Possessive			
	Hope's	[ps]	Bob's	[bz]
	Robert's	[ts]	Ted's	[dz]
	Dick's	[ks]	Greg's	[gz]
	Ralph's	[fs]	Steve's	[vz]
c.	Third person singular, present tense			
	sleeps	[ps]	rubs	[bz]
	waits	[ts]	needs	[dz]
	talks	[ks]	brags	[gz]
	laughs	[fs]	behaves	[vz]
d.	Past tense			
	stopped	[pt]	robbed	[bd]
	walked	[kt]	dragged	[gd]
	coughed	[ft]	shaved	[vd]

In addition to the suffixal voicing pattern above, all voiced obstruents become voiceless before a voiceless obstruent within the same foot.

(3) Word-final voiced obstruents alternating with voiceless ones

a.	b ~ p			
	scribe	[b]	scripture	[pt]
	inscribe	[b]	inscription	[pʃ]
	describe	[b]	description	[pʃ]
	absorb	[b]	absorption	[pʃ]

b. v ~ f

give	[v]	gift	[ft]
five	[v]	fifth	[fθ]
five	[v]	fifteen	[ft]
five	[v]	fifty	[ft]
twelve	[v]	twelfth	[fθ]
sieve	[v]	sift	[ft]
bereave	[v]	bereft	[ft]
leave	[v]	left	[ft]
cleave	[v]	cleft	[ft]

c. z ~ s

lose	[z]	lost	[st]

To account for the distribution of the allomorphs in (2) the strategy in traditional generative phonology has been to posit a single underlying form /d/ for the past tense and /z/ for the plural and its exact parallels and to provide a progressive assimilation rule that devoices /d/ and /z/ after voiceless obstruents. The voicing assimilation seen in (3) is viewed as a separate phonological process and is accounted for by a different rule of regressive assimilation that devoices the end of the stem.

In OT these two rules are seen as having one surface effect: enforcing agreement in voicing in clusters of obstruent consonants. Assimilation then is motivated by representational wellformedness and regulated by a set of constraints on phonological structure. We turn now to details of constraint-based analyses of English voicing assimilation.

3. OT accounts of voicing assimilation

3.1 Lombardi (1999)

Lombardi (1999) recasts her (1991, 1995) typology of voicing assimilation and neutralization in terms of Optimality Theory. Assuming that voice is privative, she proposes a faithfulness constraint and a markedness constraint. The constraints and their definitions, as proposed by Lombardi (1999), are given in (4) and (5).

(4) Faithfulness constraint
IDENT (Laryngeal) (IDENTLar)
Consonants must have identical laryngeal specification.

The constraint IDENTLar prefers output forms of underlying obstruents that are identical to their underlying representation in their laryngeal specification.

(5) Markedness constraint
***LAR**
Obstruents do not have laryngeal features.

The constraint *LAR militates against the surface occurrence of voiced obstruents in general.

In addition, she adopts a constraint HARMS' GENERALIZATION, which requires voiced obstruents to be closer to the syllable nucleus.

(6) **HARMS' GENERALIZATION**
Voiced obstruents must be closer than voiceless to the syllable nucleus.

On Lombardi's account, the pattern of voicing assimilation in English falls out of the ranking HARMS' GENERALIZATION » IDENTLar » *LAR. This ranking is demonstrated by the tableaux in (7) and (8).

(7) Input: ca/t/ + /z/	HARMS' GENL.	IDENTLAR	*LAR
a. ca[tz]	*!		*
b. ca[dz]		*	*!*
c. ☞ ca[ts]		*	

The input in (7) has a voiceless plus voiced obstruent cluster. Any faithful rendering of the obstruent cluster, as in (7a), runs afoul of HARMS' GENL., which is undominated. Any attempt to remedy this disagreement either by voicing the stem member of the cluster as in (7b) or by devoicing the suffix member of the cluster as in (7c) violates the constraint IDENTLar. The decision thus comes down to (7b) and (7c), and a general markedness constraint against voiced obstruents, *LAR, rules in favor of the one of these candidates that has a devoiced suffixal obstruent.

(8) Input: roa/d/ + /z/	HARMS' GENL.	IDENTLAR	*LAR
a. ☞ roa[dz]			**
b. roa[ts]		*!*	
c. roa[ds]		*!	*

The input now has a voiced obstruent cluster. A faithful rendition of the cluster in (8a) is optimal since it does not violate faithfulness to voicing. Its competitors all violate IDENTLAR. Because IDENTLAR is higher than *LAR, the faithfulness violations in (8b) and (8c) are fatal.

The analysis presented thus far works correctly if the suffix in question is underlyingly voiced, but apparently not for this example of underlyingly voiceless suffix, as shown in (9) below. The competition includes not only the suffix-faithful candidates in (9a) and (9b) but also the voice-agreeing candidate in (9c). As shown in the tableau, the incorrect output (9a) is selected due to the actual optimal candidate's failure on IDENTLAR (candidates which are erroneously chosen as optimal are indicated by 💣).

(9) Input: fi/v/ + /θ/	HARMS' GENL.	IDENTLAR	LAR
a. 💣 fi[vθ]			*
b. ☞ fi[fθ]		*!	
c. fi[vð]		*!	**

3.2 Borowsky (2000)

The OT account of English presented in Borowsky (2000) has the constraints in (10) and (11). The first sets of constraints (10) are identity constraints: one is the general constraint IDLar, which requires that output consonants should have the same specification for voicing as their corresponding input forms. The other two are restricted to a specified morphological domain: IDWD to word domain and IDMS to the affix. The second sets of constraints are two markedness constraints: *LAR, which is violated by any voiced obstruent segment and AGREE which penalizes obstruent clusters, which disagree in terms of voicing.

(10) Faithfulness constraints (Borowsky 2000)

a. **IDENT (Laryngeal) (IDLar)**
Consonants must have identical laryngeal specification.

b. **IDWD**
Do not change laryngeal features of the word.

c. **IDMS**
Do not change laryngeal features of a morpheme, which consists of only one segment.

(11) Markedness constraints (Borowsky 2000)

a. ***LAR**
Obstruents do not have laryngeal features.

b. **AGREE**
Obstruent clusters agree in voicing.

Borowsky claims that in English, the constraints are ranked IDWD, AGREE » IDMS » IDLar » *LAR. This constraint ranking seems to choose the correct output as the most optimal as demonstrated by the tableaux (12-14).

On Borowsky's account, the optimal output for an input such as in (12), with a voiceless stop followed by a voiced fricative has a voiceless cluster:

(12) Input: ca/t/ + /z/	IDWD	AGREE	IDMS	IDLar
a. ca[tz]		*!		
b. ca[dz]	*!			*
c. ☞ ca[ts]			*	*

The optimal candidate for an input cluster as in (13) with a voiced stop followed by a voiced fricative has an identical voiced-voiced cluster.

(13) Input: roa/d/ + /z/	IDWD	AGREE	IDMS	IDLar
a. roa[ds]		*!		
b. roa[ts]	*!		*	**
c. ☞ roa[dz]				

An underlying voiced obstruent loses its voice feature when it is in root-final position before a voiceless suffix, as indicated in (14):

(14) Input: fi/v/e + /θ/	AGREE	IDMS	IDLar	*LAR
a. fi[vθ]	*!			*
b. fi[vð]		*!	*	**
c. ☞ fi[fθ]			*	

This analysis doesn't yet adequately explain the difference between the input *lea/f/ + /z/* and the input *belie/f/ + /z/*, as shown in the following tableaux. In fact, when we try to derive the optimal output for the latter, we end up with the wrong result:

(15) Input: lea/f/ + /z/	AGREE	IDMS	IDLar	*LAR
a. lea[fz]	*!			*
b. lea[fs]		*!	*	
c. ☞ lea[vz]			*	**

(16) Input: belie/f/ + /z/	AGREE	IDMS	IDLar	*LAR
a. beli[fz]	*!			*
b. ☞ belie[fs]		*!	*	
c. 💣 belie[vz]			*	**

The correct output is (16b), but it was ruled out because it violated the constraint against changing laryngeal features of the monoconsonantal plural morpheme.

3.3 Grijzenhout (2000)

Grijzenhout (2000) presents an analysis of voice assimilation in obstruent clusters, which is intended to account for voicing assimilation patterns in English, German, and Dutch. She adopts two faithfulness constraints: one is a domain-specific identity constraint, IDENT$^{\text{STEM}}$ (Voice), which requires that segments in a stem retain their underlying specifications for voice. The other is the general constraint IDENT (Voice), which requires that corresponding input and output obstruents have the same laryngeal specification. In addition, she adopts two markedness constraints that prohibit voiced obstruents: DEVOICING and FINAL DEVOICING and a constraint AGREE, which requires that obstruents in a cluster agree in voicing.

(17) Faithfulness constraints (Grijzenhout 2000)

a. **IDENT$^{\text{STEM}}$ (Voice)**
Voicing specifications of segments in the stem must not change.

b. **IDENT (Voice)**
Obstruents in the output have the same value for the feature [voice] as in the input.

(18) Markedness constraints (Grijzenhout 2000)

a. **DEVOICING**
*[+VOICE] (“Obstruents are voiceless”)

b. **AGREE**
Obstruent clusters agree in voicing.

c. **FINAL DEVOICING**
$*C_{[\text{-son}]}\ ]_\sigma$ (“syllable-final obstruents are voiceless”)
|
[+voice]

Grijzenhout claims that in English, the constraints are ranked IDENT^{STEM} (Voice) » AGREE » IDENT (Voice) » FINALDEV , *[+VOICE]. This ranking is illustrated by the tableaux (19-21). The first tableau evaluates candidates for the input ca/t/$_{stem}$ + /z/. The candidate (19a) fatally violates AGREE. Its two main competitors all violate IDENT (Voice) to the same extent, but IDENT^{STEM} (Voice) rules the regressively assimilated candidate out.

(19) Input: ca/t/$_{stem}$ + /z/	IDENT^{STEM} (Voice)	AGREE	IDENT (Voice)	FINALDEV
a. ca[tz]		*!		*
b. ca[dz]	*!		*	*
c. ☞ ca[ts]			*	

The second tableau evaluates candidates for the input roa/d/$_{stem}$ + /z/. Candidate (20c) is optimal since it does not violate top-ranked IDENT^{STEM} (Voice).

(20) Input: roa/d/$_{stem}$ + /z/	IDENT^{STEM} (Voice)	AGREE	IDENT (Voice)	FINALDEV
a. roa[tz]	*!	*	*	*
b. roa[ts]	*!		**	
c. ☞ roa[dz]				*

The third tableau evaluates candidates for the input fi/v/$_{Root}$ + /θ/ where IDENT^{STEM} (Voice) is not violated because we are dealing with a combination of a root and a suffix. The faithful candidate (21a) is eliminated by undominated AGREE. Both remaining candidates violate the faithfulness constraint IDENT (Voice). FINALDEV serves as a tie-breaker between the two voice-agreeing candidates (21b) and (21c) choosing the latter as the optimal output.

(21) Input: fi/v/$_{Root}$ + /θ/	AGREE	IDENT (Voice)	FINALDEV	*[+VOICE]
a. fi[vθ]	*!			*
b. fi[vð]		*	*!	**
c. ☞ fi[fθ]		*		

4. Some more facts

In case a stem-final voiceless obstruent is followed by the plural morpheme /-z/, the obstruent in question surfaces either as voiced (22) or as voiceless with the change in voicing in the suffix (23)[All forms in this subsection are culled from Kenyon and Knott (1954) *A Pronouncing Dictionary of American English*]:

(22) Regressive voicing assimilation

a.	calf	[f]	calves	[vz]
	elf	[f]	elves	[vz]
	half	[f]	halves	[vz]
	knife	[f]	knives	[vz]
	leaf	[f]	leaves	[vz]
	life	[f]	lives	[vz]
	loaf	[f]	loaves	[vz]
	self	[f]	selves	[vz]

	sheaf	[f]	sheaves	[vz]
	shelf	[f]	shelves	[vz]
	thief	[f]	thieves	[vz]
	wife	[f]	wives	[vz]
	wolf	[f]	wolves	[vz]
b.	bath	[θ]	baths	[ðz]
	mouth	[θ]	mouths	[ðz]
	oath	[θ]	oaths	[ðz]
	path	[θ]	paths	[ðz]
	sheath	[θ]	sheaths	[ðz]

(23) Progressive voicing assimilation

a.	belief	[f]	beliefs	[fs]
	chief	[f]	chiefs	[fs]
	cliff	[f]	cliffs	[fs]
	cough	[f]	coughs	[fs]
	cuff	[f]	cuffs	[fs]
b.	berth	[θ]	berths	[θs]
	birth	[θ]	births	[θs]
	breath	[θ]	breaths	[θs]
	broth	[θ]	broths	[θs]
	dearth	[θ]	dearths	[θs]
	death	[θ]	deaths	[θs]
	faith	[θ]	faiths	[θs]
	froth	[θ]	froths	[θs]
	girth	[θ]	girths	[θs]
	growth	[θ]	growths	[θs]
	hearth	[θ]	hearths	[θs]
	heath	[θ]	heaths	[θs]
	mammoth	[θ]	mammoths	[θs]
	month	[θ]	months	[θs]
	myth	[θ]	myths	[θs]
	pith	[θ]	piths	[θs]
	psychopath	[θ]	psychopaths	[θs]
	wraith	[θ]	wraiths	[θs]

The English plural pattern illustrated in (22) and (23) is made more interesting by obstruent clusters that exhibit both regressive and progressive voicing assimilation. Consider the data in (24).

(24) Varied realization of voice

a.	cloth	[θ]	cloths	[θs] ~ [ðz]
	moth	[θ]	moths	[ðz] ~ [θs]

	truth	[θ]	truths	[ðz] ~ [θs]
	wreath	[θ]	wreaths	[ðz] ~ [θs]
	youth	[θ]	youths	[ðz] ~ [θs]
b.	hoof	[f]	hoofs ~ hooves	[fs] ~ [vz]
	scarf	[f]	scarves ~ scarfs	[vz] ~ [fs]
	wharf	[f]	wharves ~ wharfs	[vz] ~ [fs]

These data are like those found in (22) and (23) where the stems end in voiceless obstruents, yet the data in (24) form their plurals by progressively assimilated voiceless clusters as well as by regressively assimilated clusters giving rise to variation in the output. These examples especially those that have two variant pronunciations pose a challenge to OT models discussed in section 3 and render them incapable of accounting for English language data.

5. An optimal alternative to voicing assimilation

To account for voicing assimilation of obstruent clusters in English when onset-specific faithfulness is not at stake, we will adopt two domain-specific identity constraints, one is restricted to stems and the other to root affixes. The definitions of these constraints are given in (25) and (26).

(25) **IDENT(Voice)$_{\text{Stem}}$**
Correspondent input and output segments in a stem have the same specification for the feature [voice].

(26) **IDENT(Voice)$_{\text{Affix}}$**
Correspondent input and output segments in a root affix have the same specification for the feature [voice].

These constraints belong to the IDENT (F) family of Correspondence constraints proposed by McCarthy and Prince (1995). IDENT(Voice)$_{\text{Stem}}$ and IDENT(Voice)$_{\text{Affix}}$ require that output segments should have the same featural specification for [voice] as their corresponding input forms.

The data in (2) suggest that stem-final obstruents retain their underlying specifications for voice. The data in (3b,c) suggest that the feature [voice] specification of an affix that selects a root as its host is not altered due to high-ranked IDENT(Voice)$_{\text{Affix}}$. The feature specification of the root-final obstruent may differ from its input specification to ensure that adjacent obstruents agree in voicing in the optimal output form. This implies that English voicing assimilation involves a grammar in which the constraint AGREE is subordinated to these domain-specific identity constraints.

(27) **AGREE**
Obstruent clusters agree in voicing.

This constraint demands identity in voicing specifications of adjacent obstruents.

In addition to the above constraints motivated for English, we also need a general constraint IDENT(Voice), which requires that corresponding input and output segments have the same laryngeal specification. Following Pater (1999), Butska (1998) and Baković (1999), we assume that the universal set of constraints contains both Ident(+F) and Ident(-F) constraints. This means that IDENT(Voice) must be differentiated into IDENT [+voice] and IDENT [-voice].

(28) **IDENT[+Voice]**
Output correspondent of an input obstruent specified as [+voice] must be [+voice].

(29) **IDENT[-Voice]**
Output correspondent of an input obstruent specified as [-voice] must be [-voice].

The data in (2) and (3b,c) suggest that in the grammar of English, the aforementioned constraints are ranked as follows:

(30) IDENT(Voice)$_{Stem}$, IDENT(Voice)$_{Affix}$ » AGREE » IDENT [+voice] » IDENT [-voice]

The correctness of this ranking is demonstrated by the tableaux (31-33). The first tableau evaluates candidates for the input ca/t/$_{stem}$ + /z/. Under IDENT(Voice)$_{Stem}$ dominance, candidate (31b) is ruled out. The non-optimal candidate (31a) loses because it violates the higher-ranked AGREE constraint. The optimal candidate (31c) respects both constraints.

(31) Input: ca/t/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [+VOICE]	IDENT [-VOICE]
a. ca[tz]		*!		
b. ca[dz]	*!			*
c. ☞ ca[ts]			*	

Next consider tableau (32) of the input do/g/$_{stem}$ + /z/. Candidate (32b) loses the competition early in violating high-ranking IDENT(Voice)$_{Stem}$. The top candidate (32a) fatally violates AGREE. The optimal candidate (32c) incurs no violations

(32) Input: do/g/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [+VOICE]	IDENT [-VOICE]
a. do[gs]		*!	*	
b. do[ks]	*!		**	
c. ☞ do[gz]				

The following tableau (33) shows why competitors lose to the candidate with regressive voicing assimilation: the faithful candidate (33a) violates AGREE; candidate (33b) with progressive assimilation violates IDENT(Voice)$_{Affix}$. Candidate (33c) incurs a violation on IDENT [+voice], but passes on other constraints, and therefore is optimal.

(33) Input: fi/v/$_{Root}$ + /θ/	IDENT(Voice)$_{Affix}$	AGREE	IDENT [+VOICE]	IDENT [-VOICE]
a. fi[vθ]		*!		
b. fi[vð]	*!			*
c. ☞ fi[fθ]			*	

As shown by the pattern of alternations catalogued so far, some obstruents in English never alter their voicing specifications (34a) while others assimilate in voicing to neighboring obstruents (34b,c).

(34)	a. glove	[v]	gloves	[vz]
	wave	[v]	waves	[vz]
	b. calf	[f]	calves	[vz]
	bath	[θ]	baths	[ðz]
	c. belief	[f]	beliefs	[fs]
	berth	[θ]	berths	[θs]

As might be expected, the OT grammar developed above also derives the correct result for these forms by assuming that the stem-final voiceless obstruents which surface as voiced as the first member of a cluster must be underspecified for [±voice] underlyingly.

To account for the data by means of underspecification, we assume underlying representations like the following:

(35)	a. glove	/v/	[+voice]
	wave	/v/	[+voice]
	b. calf	/F/	[Øvoice]
	bath	/TH/	[Øvoice]
	c. belief	/f/	[-voice]
	berth	[θ]	[-voice]

This approach has been used by Inkelas (1994) for Turkish, by Grijzenhout (2000) for English and by Krämer (2000) for Breton. The stem-final obstruents in (35b) have no underlying specification for the feature [±voice] (with F and TH symbolizing the underspecified obstruents), while the final obstruents in (35a) and (35c) are prespecified as voiced and voiceless, respectively. Since there is no specification for voicing in the input of stem-final obstruents in (35b) there is nothing to compare the output with; this means that surface forms of undrspecified obstruents never violate identity constraints. An illustration of this contrastive use of underspecification is provided by tableaux (36-38).

(36) Input: glo/v/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [+VOICE]	IDENT [-VOICE]
a. glo[vs]		*!	*	
b. glo[fs]	*!		**	
c. ☞ glo[vz]				

(37) Input: cal/F/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [+VOICE]	IDENT [-VOICE]
a. cal[fz]		*!		
b. cal[fs]			*!	
c. ☞ cal[vz]				

(38) Input: belie/f/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [+VOICE]	IDENT [-VOICE]
a. belie[fz]		*!		
b. belie[vz]	*!			*
c. ☞ belie[fs]			*	

In the first tableau, candidate (36b) is immediately eliminated, failing IDENT(Voice)$_{Stem}$. Candidate (36a) violates AGREE. Candidate (36c) is correctly picked by satisfying both constraints. In the second tableau, since the stem-final obstruent is unspecified for voicing in the input, the corresponding obstruents in the output do not have a voicing specification to be identical to and thus never violate IDENT(Voice)$_{Stem}$ and IDENT[+VOICE] decides between the candidates which do not violate AGREE. In the third tableau, candidate (38b) loses out by violating IDENT(Voice)$_{Stem}$, since the underlying specification of the stem-final obstruent is [-voice]. The most faithful candidate (38a) is ruled out for violating AGREE, because it has a cluster that does not agree in voicing. The optimal candidate (38c) avoids this with progressive assimilation, thus incurring a violation of IDENT[+VOICE].

The basic idea to capture regressive voicing in this account is that if an underspecified obstruent is followed by another obstruent, the former (the underspecified one) acquires the positive voice specification in satisfaction of AGREE, because it has no underlying voice specification to be maintained to satisfy IDENT(Voice)$_{Stem}$, the constraint responsible for selecting forms which are faithful to voice specifications of the stem. Under the analysis developed so far, one still cannot account for the data in (24) in which a single input is being mapped onto two outputs, each of which is grammatical.

OT allows free variation to result from partial ordering of constraints (for OT analyses of phonological variation see Antilla 1997; Borowsky and Horvath 1997; Itô and Mester 1997). In this free ranking approach, strict domination holds within each competition. Tableaux for the illustrative input hoo/F/$_{stem}$ + /z/, where the selection of the winning candidate crucially involves the two different–ranking scenarios, IDENT [+VOICE] » IDENT[-VOICE] and IDENT [-VOICE] » IDENT[+VOICE] are given in (39) and (40) respectively.

(39) Input: hoo/F/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [+VOICE]	IDENT [-VOICE]
a. hoo[fz]		*!		
b. hoo[fs]			*!	
c. ☞ hoo[vz]				

(40) Input: hoo/F/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [-VOICE]	IDENT [+VOICE]
a. hoo[fz]		*!		
b. hoo[fs]				*!
c. ☞ hoo[vz]				

The central result is that in this case ranking variation does not translate into variation in the output. With either ranking, the same candidate is selected, namely, *hoo[vz]*. This is so because the ranking of two constraints makes a difference only when the two competing candidates each pass, and fail, one of the constraints. But if the candidates both satisfy one of the constraints, then the constraint in question (here, IDENT[-VOICE]) has no deciding power. When IDENT[-VOICE] is in this way irrelevant, then its ranking with respect to IDENT[+VOICE] will also be irrelevant; hence different rankings have no effect and lead to the same winner.

As an alternative where strict domination does not hold for individual competitions, there is tied violations: these two constraints are true equals, in the sense that a violation of neither constraint ever counts as dominating a violation of the other. In other words, violations of the two constraints IDENT [+VOICE] and IDENT[-VOICE] count as equivalent: It is just as bad to violate IDENT [+VOICE] as it is to violate IDENT[-VOICE]. In (41), following Itô and Mester (1997), this is indicated by assigning the two relevant constraints to the same column in the tableau, without a separating vertical line.

(41) Input: hoo/F/$_{stem}$ + /z/	IDENT(Voice)$_{Stem}$	AGREE	IDENT [+VOICE] IDENT[-VOICE]
a. hoo[fz]		*!	
b. hoo[fs]			*
c. ☞ hoo[vz]			

But the two competing variants do not have identical violation profiles and thus variation is blocked. It is immediately obvious that these cases of free variation cannot be modeled in current OT practice.

It turns out that our analysis already contains the basic ingredients for the solution, once we recognize the need to specify the constraints as applying from I-to-O or O-to-I:

(42) **IDENT O→I [+Voice]**
Input correspondent of an output obstruent specified as [+voice] must be [+voice].

(43) **IDENT O→I [-Voice]**
Input correspondent of an output obstruent specified as [-voice] must be [-voice].

The first constraint IDENT O→I [+Voice] (42) penalizes voiceless input obstruents corresponding to output voiced obstruents. The second constraint IDENT O→I [-Voice] (43) ensures that output voiceless obstruents are voiceless in the input. The I-to-O counterparts of these constraints, IDENT I→O [+Voice] and IDENT I→O [-Voice] are given for convenience in (44).

(44) a. **IDENT I→O [+Voice]**
Output correspondent of an input obstruent specified as [+voice] must be [+voice].

b. **IDENT I→O [-Voice]**
Output correspondent of an input obstruent specified as [-voice] must be [-voice].

The question now arises whether in evaluating IDENT O→I [±Voice] the input forms of the underspecified segments incur IDENT [±Voice] violations or not. The concept of featural identity demands faithfulness of underlying segments to surface segments. For the case in question IDENT [±Voice] is satisfied if both obstruents are [αvoice]. It is violated if one of them is [αvoice] and the other is [βvoice]. Assessment of violations in I-to-O is different from its assessment in O-to-I because in I-to-O there is no voice feature in the input, and thus there is nothing to compare the output with. In case of IDENT O→I [±Voice] underspecified obstruents incur violations, because all output forms of an underspecified input obstruent have a voice specification. From this point of view, all inputs of underspecified obstruents violate [±Voice] because there are voice features in the output, which should be identical to the input voice feature specifications.

Addition of IDENT O→I [±Voice] as further constraints has the necessary effect: reducing variation to differences in the specific requirement for a constraint to apply from I-to-O or O-to-I. The proposed faithfulness constraints correctly pick a winner. Tableaux for the illustrative input *you/TH/$_{stem}$ + /z/*, where the selection of the winning candidate crucially involves a difference between "input-output" faithfulness and "output-input" faithfulness, are given in (45) and (46) for the two different scenarios of these constraints as applying from I-to-O or O-to-I:

(45) Input: you/TH/$_{stem}$ + /z/	IDENT (Voice) $_{Stem}$	AGREE	IDENT I→O [+Voice]	IDENT I→O [-Voice]
a. you[θz]		*!		
b. you[θs]			*!	
c. ☞ you[ðz]				

(46) Input: you/TH/$_{stem}$ + /z/	IDENT (Voice) $_{Stem}$	AGREE	IDENT O→I [+Voice]	IDENT O→I [-Voice]
a. you[θz]		*!		*
b. ☞ you[θs]				**
c. you[ðz]			*!	

In (46) *IDENT O→I [-Voice]* gets one mark in (a) and two in (b); nevertheless (b) is the optimal candidate since it fares better with respect to *IDENT O→I [+Voice]* and *AGREE*, the higher-ranked constraints. The reason for free variation is that both optimal forms in (45) and (46) satisfy or violate the same IDENT [Voice] constraints differently, once the familiar *IDENT O→I [Voice]* and *IDENT I→O [Voice]* requirement is incorporated into the constraint system, and emerge as co-winners in a single invariant ranking.

The upshot of the analysis is that free variation that has defied a classical OT solution turns out to have at its core a fairly simple and unified OT constraint-ranking analysis. We have, then, succeeded in constructing a viable account of voicing alternations in English within an OT model, crucially relying on archephonemic underspecification and on the assumption that the identity constraint that specifically targets obstruent [voice] need to be specified as applying from I-to-O or O-to-I.

6. Conclusion

We have discussed English voicing alternations from the perspective of Optimality Theory. Our account exploits the use of archisegments (i.e. segments underspecified for the feature voice) and a constraint system in which faithfulness to voicing is distinguished from faithfulness to voicelessness. The variation that occurs is seen to be a function of identity constraints targeting obstruent voice that apply from I-to-O and O-to-I.

We have argued that in English the feature voice is subject to alternations such that certain forms may end in variable obstruent voicing. This fact cannot emerge naturally from any reasonable account in classical OT. We have shown how OT can account for both the categorical voice choice, which occurs with most stems and the variation that occurs with other stems. Our analysis shows that variation data can be modeled by a grammar with constraints on output-input relations. OT's usual alternatives to variation, free ranking and tied violations, have proved inadequate to handle the English facts. It seems fair to conclude that OT has opened up a new perspective for the study of phonological variation.

Finally, the alternations in obstruent voicing in English provide evidence against the claim that [voice] is a privative feature. The English voicing phenomena show that [voice] is a binary valued feature and underspecification is a third option in English. This underlying ternary distinction between [+voice], [-voice], and [Øvoice], which is necessary to account for regressive as well as progressive voicing assimilation in obstruent clusters is inherently incompatible with the privativity hypothesis. English has homogeneous voice clusters, which are created by spreading both values of the [±voice] feature over the entire cluster, in a regressive pattern {wolf [f]/wolves [vz], sheath [θ]/sheaths [ðz]} and a progressive pattern {cuff [f]/cuffs [fs], wraith [θ]/wraiths [θs]}.

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