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Preserving synchronic parallelism: Diachrony and opacity in Polish

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Certain types of phonological opacity have proven to be problematic for strictly parallel versions of Optimality Theory (OT; Prince and Smolensky 1993). In this paper, I discuss one such case from Polish, an alternation between [ɔ] and [u], that is opaquely obscured by word-final obstruent devoicing. In §1, I present the relevant data and generalizations, and I provide a skeletal OT analysis which demonstrates why these data cannot be analyzed in strictly parallel OT if both governing generalizations are synchronically productive. In §2, I bring to light lexical and experimental data which suggests that the [ɔ]~[u] alternation is not in fact synchronically productive, clearing the way for a strictly parallel synchronic phonology. In order to account for the existence of opacity in the lexicon, I construct a diachronic analysis of these data in §3 within a system of serially ordered parallel phonologies. I propose that a strong version of Prince and Smolensky's (1993) Lexicon Optimization encodes the results of each historical sound change directly into the evolving lexicon. Finally, in §4, I summarize the major claims of this paper and pose questions for further study.

1 Data

All data are from Jastrzębska-okoń and Billip (1993) and have been confirmed by a native speaker of Polish. Broad IPA transcription is used throughout, with [ɕ] and [ʑ] used for orthographic ⟨*ś*⟩ and ⟨*ź*⟩, [ʲ] for other palatalized sounds, and [ʂ], [ʐ], and [tʂ] for ⟨*sz*⟩, ⟨*rz*⟩, and ⟨*cz*⟩. I use the somewhat inaccurate [ɨ] for orthographic ⟨*y*⟩ to avoid discussion of the historical evolution of modern Polish [ɪ] from Proto-Slavic [ɨ].

Polish generally has a voicing contrast in obstruents, but word-final obstruents must always be voiceless (1):

(1)

klu**p**	klu**b**ɨ	'club (SG/PL)'
ɕla**t**	ɕla**d**ɨ	'remnant (SG/PL)'
bzɛ̨**k**	bzɛ̨**gʲ**i	'edge (SG/PL)'

In addition, the back mid vowel [ɔ] is banned before word-final voiced oral consonants; the high vowel [u] appears instead (only word-final sonorants are given in (2), since Polish has no word-final voiced obstruents (1)):

(2)

st**u**w	st**ɔ**wɨ	'table'
sw**u**j	sw**ɔ**jɛ	'pot'
m**u**l	m**ɔ**lɛ	'moth'
dv**u**r	dv**ɔ**rɨ	'mansion'

The generalizations in (1) and (2) interact opaquely in the data in (3), with the [ɔ]~[u] alternation overapplying where it should not, before voiceless obstruents:[1]

(3)

gr**up**	gr**ɔbɨ**	'grave'
r**ut**	r**ɔdɨ**	'family'
st**uk**	st**ɔg^{j}**i	'stack'

As is well known, this type of opacity cannot be analyzed in strictly parallel OT. Consider the following constraints:

(4)

***d#**	voiced obstruents cannot appear word-finally
***ɔd#**	[ɔ] cannot appear before word-final voiced oral consonants
ID-hi	do not change vowel height from input to output
ID-voi	do not change voicing from input to output

Regardless of how these constraints are ranked (the tableau in (5) shows one possible ranking), the violations incurred by the relevant candidates do not change. These crucial candidates are the opaque [rut] (5a) and the transparent [rɔt] (5b) (candidates (5c) and (5d) are shown for completeness and do not change the issues at hand):

(5)

		/rɔd/	*d#	ID-voi	*ɔd#	ID-hi
⊗	a.	rut		*		*
⇐	b.	rɔt		*		
	c.	rud	*			*
	d.	rɔd	*		*	

The opaque candidate, marked by ⊗, violates both of the faithfulness constraints ID-voi and ID-hi. In comparison, the transparent candidate, marked by ⇐, only violates one faithfulness constraint, ID-voi. Since all other constraint violations are equal between these two candidates, (5b) with a proper subset of (5a)'s violations is said to harmonically bound (5a). This means that no ranking of these constraints can ever result in (5a) being selected as the optimal candidate.

To allow opaque candidates such as (5a) to be selected over their transparent competitors, various modifications to OT have been proposed, including such theories as sympathetic correspondence (McCarthy 1999), turbidity (Goldrick and Smolensky 1998, Goldrick 2000), and multiple levels (Goldsmith 1993, Inkelas and Orgun 1995, Kiparsky to appear, etc.). The common assumption behind these analyses is that this type of opacity is synchronically productive (pre-OT analyses of Polish with this same assumption include Gussman 1980, Rubach 1984, and Kenstowicz 1994). Very often, however, the drive to account for synchronically productive opacity is the sole (or at least, primary) motivating factor behind these modifications to OT.

Under the assumption that synchronic phonology is strictly parallel,[2] and adopting only those modifications to OT that are independently motivated, we must conclude that, contrary to previous analyses, the opacity seen in the data in (3) cannot be synchronically productive. In the next section, I discuss two sets of data which support this conclusion.

2 Productivity

In both the native and loanword vocabulary of Polish, there are many lexical exceptions to the ban on [ɔ] before underlying voiced oral consonants. Those with word-final sonorants are given in (6), while those with word-final obstruents are given in (7):[3]

(6)	ɔɕɔw	*ɔɕ**u**w	'donkey'		
	anʲɔw	*anʲ**u**w	'angel'		
	kɔvbɔj	*kɔvb**u**j	'cowboy'		
	xɔl	*x**u**l	'lobby'		
	parasɔl	*paras**u**l	'umbrella'		
	pɔr	*p**u**r	'leek'		
	kɔlɔr	*kɔl**u**r	'card suit'		
(7)	glɔp	*gl**u**p	'globe'	*cf.* glɔbɨ	'globes'
	snɔp	*sn**u**p	'snob'	*cf.* snɔbɨ	'snobs'
	ɛpʲizɔt	*ɛpʲiz**u**t	'episode'	*cf.* ɛpʲizɔdɨ	'episodes'
	kɔt	*k**u**t	'code'	*cf.* kɔdɨ	'codes'
	nɛkrɔlɔk	*nɛkrɔl**u**k	'obituary'	*cf.* nɛkrɔlɔgʲi	'obituaries'
	prɔlɔk	*prɔl**u**k	'prologue'	*cf.* prɔlɔgʲi	'prologues'
	rɛkɔrt	*rɛk**u**rt	'record'	*cf.* rɛkɔrdɨ	'records'
	fʲɔrt	*fʲ**u**rt	'fjord'	*cf.* fʲɔrdɨ	'fjords'
	xɔwt	*x**u**wt	'homage'	*cf.* xɔwdɨ	'homages'
	tʂɔwk	*tʂ**u**wk	'tank'	*cf.* tʂɔwgʲi	'tanks'

In addition to the lexical search, I conducted an experiment (described in more detail in the Appendix) in which native speakers were asked to produce singulars from nonsense plurals. The singulars should be opaque if the [ɔ]~[u] alternation is productive. However, the results of the experiment, given in (8), are similar to the lexical data above, with no [ɔ]~[u] alternation:

(8)	ʑnabɔt	*ʑnab**u**t	*from* ʑnabɔdɨ
	pʂakɔt	*pʂak**u**t	*from* pʂakɔdɨ
	ʂtapɔt	*ʂtap**u**t	*from* ʂtapɔdɨ
	ʂlapɔk	*ʂlap**u**k	*from* ʂlapɔgʲi
	ɕrabɔk	*ɕrab**u**k	*from* ɕrabɔgʲi
	smatɔk	*smat**u**k	*from* smatɔgʲi

This lexical and experimental evidence suggest that the [ɔ]~[u] alternation is not synchronically productive and only applies to a fixed subset of the lexicon. This subset must still be accounted for systematically rather than treated as an arbitrary anomaly. The opacity seen in this lexical subset arises from multiple historical sound changes, so I propose that this data should be analyzed diachronically. I construct such an analysis in the following section.

3 Diachronic analysis

In this section, I discuss the five most recent sound changes which have contributed to the opaque [ɔ]~[u] alternation in modern Polish (based on Stieber 1968, de Bray 1969, Carlton 1990, and Gotteri 1998). Sometime after the loss of word-final Proto-Slavic (PSl) jers, prehistoric Polish (pre-P) required long vowels to cue voicing in word-final consonants. Within a few centuries, in Old Polish (OP), word-final obstruents lost their voicing and long mid vowels raised slightly (or perhaps tensed). In Middle Polish (MP), all older length contrasts in vowels were completely lost. Finally, in modern Polish (P), the OP raised mid vowel [o̯] raised further, merging with the high vowel [u]. These sound changes are summarized below in (9), demonstrated with the PSl word *rɔdʊ* 'family', which became early pre-P *rɔd* after the fall of the jers:

(9)	pre-P	12th c.	V: before final voiced C	rɔd	>	rɔːd
	OP	14th c.	final obstruents devoice,	rɔːd	>	rɔːt
			and *ɔˑ*, *ɛˑ* > *o̯ˑ*, *e̯ˑ*	rɔːt	>	ro̯ːt[4]
	MP	16th c.	V: > V everywhere	ro̯ːt	>	ro̯t
	P	18th c.	*o̯* > *u* (but note *e̯* > *ɛ*)	ro̯t	>	rut

Before building the framework for my OT-based analysis, I define the necessary markedness (10) and faithfulness (11) constraints below:

(10)	**CUE-voi**	voicing must be adequately cued: (i) contemporaneous with or followed by a sonorant, and (ii) preceded by a long vowel if word-final (perceptually motivated; cf. Steriade 1997)
	***Vː**	long vowels are marked (articulatory effort)
	***ɔː**	[ɔː] is marked (presumably, articulatory effort against long, lax vowels; whatever the functional motivation, this constraint should apply to [ɛː] as well, since both [ɔː] and [ɛː] raise in OP)
	***o̯**	[o̯] is marked (universal markedness, with *o̯ ≫ *ɔ ≫ *u; cf. Archangeli and Pulleyblank 1994, where [o̯] = [o])
(11)	**ID-hi**	do not change vowel height
	ID-voi	do not change voicing
	ID-μ	do not change vowel length

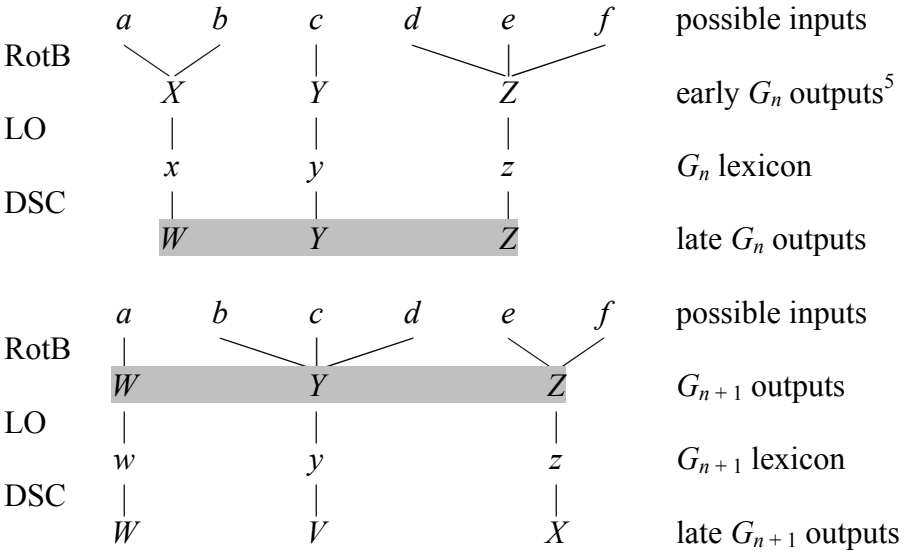
3.1 L1 acquisition and diachronic sound change

For each historical stage, I assume a three-phase framework which combines acquisition and diachronic sound change. Prince and Smolensky's (1993) *Richness of the Base* (RotB) hypothesis claims that multiple possible inputs are posited for the same desired output and that the grammar should produce a well-formed output of the language regardless of the input. I adopt RotB as the first phase of my framework, though it should be noted that this choice is not crucial, as long as some mechanism is assumed which will result in a fully functional constraint hierarchy that creates grammatical outputs from arbitrary inputs.

The second phase in this framework is *Lexicon Optimization* (LO) (Prince and Smolensky 1993; see also Kiparsky 1968 for a prescient version of LO), which requires that, in the case of multiple inputs mapping to the same output, the input which is most faithful to the output is selected as the underlying representation (UR). I assume a strong version of LO, which essentially results in URs being phonologically identical to their surface form, regardless of morphological complexity. The weaker version of LO in Prince and Smolensky 1993 imposes a restriction against multiple storage for morphemes; each morpheme is allowed only one UR. This difference will be explored in §3.3.

Finally, *diachronic sound change* (DSC) can occur. DSCs are represented in this framework by reranking constraints in the hierarchy. The outputs of a DSC become the set of forms that the next generation will use for the RotB phase. This next generation then in turn lexicalizes these new forms via LO, encoding the previous generation's DSCs directly into the current lexicon. The diagram below graphically represents this framework for arbitrary *n*th and (*n* + 1)th generations, G_n and G_{n+1} (note the highlighted forms *W*, *Y*, and *Z*, which show that the late outputs of the previous generation are identical to the early outputs of the following generation):

(12)



3.2 Pre-Polish vowel lengthening (12th century)

Early pre-P allowed voiced codas, so ID-voi outranks CUE-voi to prevent final devoicing (13c) as a possible strategy to circumvent inadequate voicing cues (13a). In addition, vowels did not lengthen in pre-P in order to cue voicing (13b), so *V: outranks CUE-voi as well:

(13)

	/rɔd/	ID-voi	*V:	CUE-voi
⇒	a. rɔd			**
	b. rɔ:d		*!	*
	c. rɔt	*!		

Previous historical stages created long vowels for prosodic reasons (specifically, the neo-acute accent, which was a shift in accent from a weak jer to a preceding syllable), so input vowel length was preserved in early pre-P outputs (14a). This is achieved by ranking ID-μ over *V: and *ɔ: to prevent shortening (14b). Additionally, the marked [ɔ:] did not raise (14c), so *ɔ: is outranked by ID-hi:

(14)

	/stɔ:p/ 'foot (GEN PL)'	ID-hi	ID-μ	*V:	*ɔ:
⇒	a. stɔ:p			*	*
	b. stɔp		*!		
	c. stᵩ:p	*!		*	

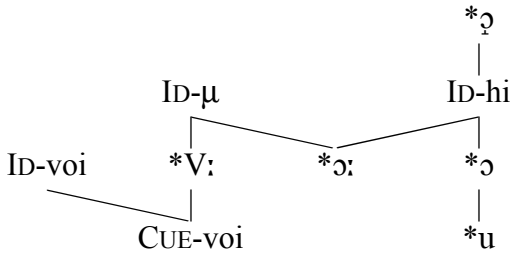
Indeed, [ᵩ] does not appear at all in pre-P, so *ᵩ ≫ ID-hi. Since both [ɔ] and [u] did appear, *ɔ and *u must be ranked below ID-hi. The result is that an underlying /ᵩ/ (as in the possible input /stᵩk/ for [stuk] 'knock') raises to [u] (15a), rather than lowering to [ɔ] (15b) or surfacing faithfully (15c):

(15)

	/stᵩk/	*ᵩ	ID-hi	*ɔ	*u
⇒	a. stuk		*		*
	b. stɔk		*	*!	
	c. stᵩk	*!			

The final combined constraint ranking for early pre-Polish is schematized below:

(16)



The hierarchy in (16) is generated in the acquisition process, assumed here to be primarily based upon RotB. In the next phase of acquisition, the lexicon is fixed through LO, which stores a UR for each output that is identical to the output. Thus, the UR for pre-P [rɔd] is /rɔd/. This UR will be the input for the DSC that occurs in late pre-P.

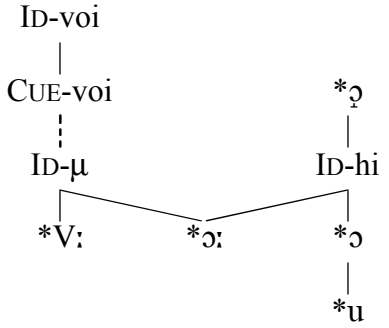
As in many languages, including English, late pre-P required long vowels as a cue to word-final voicing (17a); short vowels were no longer allowed in this position (17b). This DSC requires reranking CUE-voi over ID-μ (and transitively, over *Vː and *ɔː). Note that devoicing was not yet active (17c):

(17)

	/rɔd/	ID-voi	CUE-voi	ID-μ	*Vː	*ɔː
⇒	a. rɔːd		*	*	*	*
	b. rɔd		**!			
	c. rɔt	*!				

The new constraint hierarchy for late pre-P is given below, with DSC-related rerankings shown with dotted lines. As a general rule, I assume that other rankings from the early period of a historical stage hold in the late period:

(18)



Note that the plural form /rɔdɨ/ surfaces faithfully with a short vowel (19a) because the voiced consonant is not word-final and thus does not need to be cued by a preceding long vowel (19b):

(19)

	/rɔdɨ/	ID-voi	CUE-voi	ID-μ	*Vː	*ɔː
⇒	a. rɔdɨ					
	b. rɔːdɨ			*!	*	*

3.3 Old Polish devoicing and 1st vowel raising (14th century)

The early OP RotB phase operates on late pre-P outputs and derives the same hierarchy as in (18). Both inputs /rɔːd/ and /rɔd/ surface as [rɔːd], but since /rɔːd/ is more identical to [rɔːd], strong LO selects /rɔːd/ as the UR for [rɔːd]. The plural UR is /rɔdɨ/, without underlying length. In comparison, weak LO would store this pair as /rɔd/ and /rɔd/+/ɨ/, with one UR for the morpheme /rɔd/. My analysis relies crucially on strong LO, as I show below.

Two DSCs occurred in OP: devoicing of word-final obstruents and raising of long mid vowels. For the sake of clarity, I consider them one at a time, devoicing first; it is not necessary to the analysis to order them this way.

In order to force devoicing, CUE-voi must be reranked over ID-voi. This ensures that word-final voicing in obstruents is abandoned (20a), since any attempt to maintain it is lacking at least one voicing cue (20b,c):

(20)

	/rɔːd/	CUE-voi	ID-voi
⇒ a.	rɔːt		*
b.	rɔːd	*!	
c.	rɔd	**!	

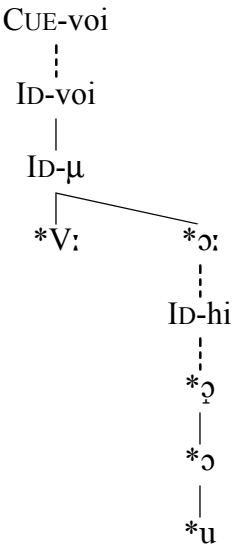
Raising of long mid vowels resulted in underlying /rɔːd/ emerging as [rɔ̝ːt] (21a), with devoicing coming from the ranking in (20). In order for [ɔ̝] to surface at all, ID-hi must be reranked over *ɔ̝. Because of the gradient nature of ID-hi, [ɔː] cannot raise all the way to [uː] (21b). In addition, *ɔː must be ranked over ID-hi (and transitively, over *ɔ̝) to prevent /ɔː/ from surfacing without raising (21c). Note that shortening is not a viable option because underlying length is preserved via the early OP ranking of ID-μ over *Vː and *ɔː):

(21)

	/rɔːd/	*ɔː	ID-hi	*ɔ̝	*ɔ	*u
⇒ a.	rɔ̝ːt		*	*		
b.	ruːt		**!			*
c.	rɔːt	*!			*	

The final constraint hierarchy for late OP is given in (22):

(22)



The crucial difference between strong and weak LO becomes apparent in late OP. If the UR was /rɔd/, as expected by weak LO, then it would be impossible to derive the opaque [rɔ̨ːt] with a strictly parallel grammar for the same reasons as discussed in §1 (it is harmonically bounded by the transparent candidate [rɔt], which has no evidence of the formerly predictable historical length):

(23)

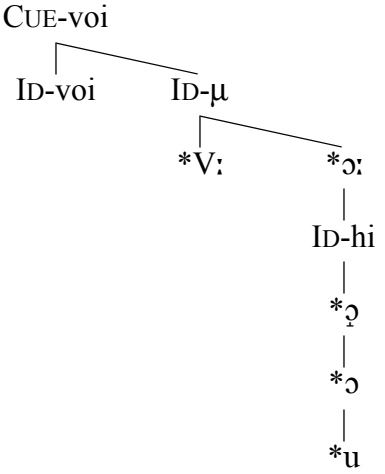
	/rɔd/	ID-voi	ID-μ	*Vː	*ɔː	ID-hi	*ɔ̨
⊗	a. rɔ̨ːt	*	*	*	*	*	*
⇐	b. rɔt	*					

The inherent serial nature of this opacity puts it in conflict with strict parallelism, requiring some sort of intermediate form to act as a placeholder. Strong LO directly encodes this intermediate form into the evolving lexicon (early OP /rɔːd/ in this case), preserving strict parallelism in the synchronic grammar.

3.4 Middle Polish vowel shortening (16th century)

The early MP grammar is slightly different from the late OP grammar because some constraint rankings in late OP are holdovers from early OP by assumption. Since it is assumed that constraint hierarchies are not passed along genetically, when constructing the early MP grammar, we can dispense with non-crucial relics of the early OP grammar that remained in late OP. What is crucial for early MP is a vowel length contrast (ID-μ ≫ *Vː, *ɔː), maximal voicing cues to force final devoicing and long vowels before final sonorants (CUE-voi ≫ ID-voi, ID-μ), an absence of long lax mid vowels (ID-μ ≫ *ɔː ≫ ID-hi), and the existence of the vowel [ɔ̨] (ID-hi ≫ *ɔ̨). The resulting early MP grammar is given in (24):

(24)



LO operates just as before, with the stored UR being identical to the output. Thus, /rɔ̨ːt/ is stored as the UR for 'family'. In late MP, vowel length was no longer allowed (25b), with underlying long vowels forced to shorten (25a). This DSC requires *Vː to rerank over ID-μ:

(25)

	/rɔ̟ːt/	*Vː	ID-μ
⇒ a.	rɔ̟t		*
b.	rɔ̟ːt	*!	

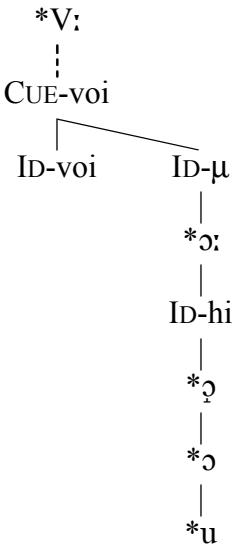
In addition, *Vː must rerank even higher, over CUE-voi, to shorten underlying long vowels before word-final sonorants (26a), despite the role preceding long vowels play in cueing word-final voicing (26b):

(26)

	/dvɔ̟ːr/	*Vː	CUE-voi
⇒ a.	dvɔ̟r		*
b.	dvɔ̟ːr	*!	

This yields the following constraint hierarchy for late MP:

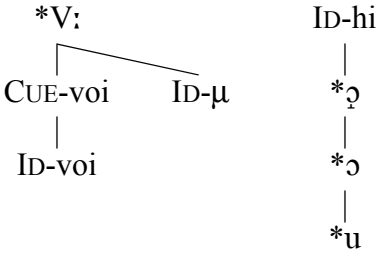
(27)



3.5 Modern Polish 2nd vowel raising (18th century)

In early P, there were no long vowels, even to satisfy voicing cues for word-final sonorants (*Vː ≫ CUE-voi, ID-μ); word-final obstruent devoicing due to insufficient voicing cues was active (CUE-voi ≫ ID-voi); and the vowel [ɔ̟] existed (ID-hi ≫ *ɔ). Since *Vː is undominated, the more specific constraint *ɔː cannot play a role, so it is unrankable. The constraint hierarchy for early P is:

(28)



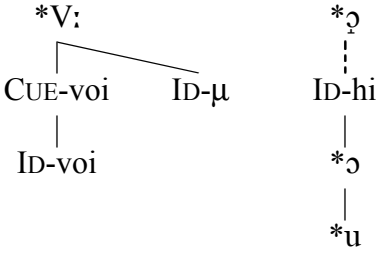
By LO, the UR for [rɤt] 'family' will be /rɤt/. Late P introduced further vowel raising as a DSC, changing /ɤ/ into [u] (in some dialects, this DSC has not occurred, and /ɤ/ is still surfaces distinctly from [ɔ] and [u]). This DSC requires reranking ID-hi over *ɔː, with the universal ranking of *ɔ over *u ensuring that raising, not lowering, will satisfy *ɤ:

(29)

	/rɤt/	*ɤ	ID-hi	*ɔ	*u
⇒	a. rut		*		*
	b. rɔt		*	*!	
	c. rɤt	*!			

The final constraint ranking for late P is:

(30)



As expected, under this constraint ranking, underlying /rɔd/ does not emerge with devoicing and full raising as the opaque [rut] (31b). Rather, it surfaces as the transparent [rɔt] (31a). The opacity rampant in the lexicon (which exists because it has been preserved through recurrent strong LO) is not synchronically productive, matching the lexical and experimental data in §2:

(31)

	/rɔd/	*Vː	ID-μ	CUE-voi	ID-voi	*ɤ	ID-hi
⇒	a. rɔt				*		
	b. rut				*		**!
	c. rɤt				*	*!	*
	d. rɔːd	*!	*	*			

4 Summary and issues for further study

In this paper, I have supplied data from both lexical exceptions and experiments on the phonology of nonsense words which suggest that the [ɔ]~[u] alternation in modern Polish is not synchronically productive. Thus, its opaque interaction with word-final obstruent devoicing is not a problem for strictly parallel models of synchronic phonology such as OT.

Since the [ɔ]~[u] alternation is still pervasive in the extant Polish lexicon, I have constructed an analysis of the alternation based on its historical origins. The novel piece of my analysis is strong Lexicon Optimization, which selects underlying representations that are phonologically identical to their outputs. By

having strong Lexicon Optimization interspersed between serially ordered diachronic sound changes, the analysis maintains the serialism required to account for opacity without sacrificing strict parallelism in the synchronic grammar. The trade-off is an increased burden on lexical storage. It remains to be seen whether this burden is less desirable than a non-parallel synchronic grammar.

There are number of interesting ways to expand this research. The [ɔ]~[u] alternation is notorious for not applying before nasals, as in *dɔm* 'house'. If this alternation were synchronic, there would be no explanation for the lack of **dum* in Polish. One would simply have to build further ad hoc embellishments to the synchronic grammar. However, under my analysis, a natural explanation can easily be found. Nasal codas very often nasalize a preceding vowel, so it is likely that late pre-Polish *dɔ:m* was actually something like *dɔ̃:m*. Nasality can affect vowel height (Wright 1986, Beddor 1993, Padgett 1997), and this effect probably circumvented the Old Polish raising that applied to oral mid vowels.

There is an alternation, similar to the [ɔ]~[u] alternation, between orthographic ⟨*ą*⟩ and ⟨*ę*⟩ (which have various phonological realizations in modern Polish) seen in words such as *ząb~zęby* 'tooth (SG/PL)'. Proto-Slavic had two nasal vowels, but they eventually merged into one vowel, often written as ⟨*ǫ*⟩. Like all vowels in pre-Polish, ⟨*ǫ*⟩ lengthened before word-final voiced consonants. This long ⟨*ǫǫ*⟩ eventually became a back nasal vowel (Modern Polish ⟨*ą*⟩) while short ⟨*ǫ*⟩ fronted to Modern Polish ⟨*ę*⟩. This alternation is opaque, like the [ɔ]~[u] alternation, and could be analyzed within the framework developed in this paper.

A final question arises from raising in late modern Polish. Why did the front vowel lower (*ɛ̨* > *ɛ*) rather than raise, like the back vowel did? This could be related to the migration of Proto-Slavic [ɨ] to Modern Polish [ɪ], which crowded the front vowel space and may have forced [ɛ̨] to lower in order to be more perceptually distinct from [ɪ]. Further study is required to answer this question.

Appendix

The two subjects who have taken part in this experiment so far are: MJ, a male in his thirties, who has been in the United States for over 10 years; and KN, a female teenager from Warsaw, who had been in the United States for approximately three months at the time of the experiment. The subjects were given 3 repetitions each of the following types of sentences (spoken by a female native speaker in her twenties, recorded on a Sony Professional Walkman and converted to WAV format for presentation to the subjects), in which the underlined word, a nonsense noun in the masculine nominative plural, was the only variable. The subjects were told in advance that the nonsense words were to be thought of as imaginary creatures who were helping John:

(32) Bardzo ładne <u>cztapody</u> dały Jankowi kawę, nie herbatę.
Bardzo ładne <u>smatogi</u> dały Jankowi kawę, nie herbatę. (etc.)
'The very pretty cztapuds (smatogs, ...) gave John coffee, not tea.'

The subjects were asked to say the following sentence three times after the third repetition of a sentence from (32), with the appropriate form of the nonsense word in the blank. Responses were recorded on the Sony Professional Walkman and converted to WAV format for later analysis.

(33) Jeden bardzo ładny _____ pożyczył Jankowi i pieniądze, i koszulę.
'One very pretty _____ lent John both money and a shirt.'

The valid form to go in the blank is the masculine nominative singular, which drops the vowel ending of the plural and creates the environment for both raising of [ɔ] to [u] and for devoicing. Thus, these forms should be opaque if the [ɔ]~[u] alternation is productive.

F1, the phonetic correlate of vowel height, was measured for the final vowel for all of MJ's tokens of the relevant nonsense words, using Boersma and Weenink's (1992/2000) Praat program. These measurements were grouped into four rime families and had the means listed below:

(34)

ɔtks	/ɔ/ followed by a voiceless obstruent	514.8 Hz
ɔgdz	/ɔ/ followed by a voiced obstruent	511.4 Hz
utks	/u/ followed by a voiceless obstruent	404.9 Hz
udgz	/u/ followed by a voiced obstruent	418.4 Hz

The data from the four families were subjected to the Tukey method of multiple comparison to test whether the differences between the means are statistically significant. The relevant statistic, the Studentized range statistic q, for each pairwise comparison of families is:

(35)

	ɔtks	ɔdgz	udgz	utks
ɔtks	0.000	0.367	10.278	11.717
ɔdgz	0.367	0.000	9.910	11.350
udgz	10.278	9.910	0.000	1.439
utks	11.717	11.350	1.439	0.000

The critical value for q is approximately 5.6, based on 72 data points, 4 families, and a confidence interval of $\alpha = 0.001$ (Glass and Hopkins 1996 give the critical value to be 5.05, but I believe this to be a misprint; regardless, the results are the same with $q_{crit} = 5.05$ or 5.6). If the value of q is greater than the critical value, as in the shaded boxes, the families are statistically different (that is, we can reject H_0 = 'the two families in the pair are identical') with 99.9% confidence. It is clear that the ɔtks family and (crucially) the would-be opaque ɔdgz family are both statistically different from the utks and udgz families (and statistically similar to each other). Thus, for nonsense words, [ɔ] does not alternate with [u] in the expected environment, so the alternation is not synchronically productive for MJ.

Measurements for KN are incomplete. Impressionistically, the results for KN are the same as for MJ, and preliminary computations support the ɔdgz family being statistically different from the utks and udgz families for KN as well.

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Notes

[1] I am only concerned here with the [ɔ]~[u] alternation in masculine nominative nouns. The same alternation exists in the feminine and neuter genitive, in which the plural is opaque. I have been informed that the genitive alternation is fully productive (Anna Łubowicz and Jerzy Rubach, p.c.), though I have not yet verified this claim through experimentation. Since these forms are clearly morphologically complex (i.e. morphosyntactically genitive and plural), it seems reasonable that they could pattern differently than the nominative singular. The genitive plural might have access to some morphological or underlying phonological feature which could trigger the alternation productively. Further work in this area is required.

[2] In fact, this assumption needs to be modified somewhat, as morphologically derived words can show patterns of opacity that rely on morphologically simpler forms to facilitate an opaque interaction (cf. Benua's (1997) model of output-output correspondence). However, the crucial difference between such cases and the data discussed here is that for these data, there are no morphologically simpler forms. In other words, the serial nature of output-output correspondence is not sufficient to account for opaque patterns in monomorphemic words such as those in (3).

[3] It is interesting to note that both native and loanword data of the type in (6) is relatively easy to find (except for word-final [ɔj], which seems to occur only in loanwords). In comparison, data of the type in (7) is almost exclusively foreign (except for cluster-final words, which can be either native or foreign). I have no explanation for these splits in the data. Statistical analysis is required to determine how significant the split might be.

[4] The exact quality of MP [ọ] is debatable (similarly for [ẹ]). It is thought to have been intermediate between [ɔ] and [u]. For the purposes of this analysis, I assume that [ɔ], [u], and [ọ] all differ from each other in vowel height, and thus a change from one to another incurs a violation of ID-hi.

[5] I use the term 'early' to indicate the period of time in a historical stage of a language prior to the relevant DSCs in that stage (i.e. the grammar created by the RotB phase). Analogously, the term 'late' is used to indicate the period of time after any DSCs have occurred.

References

Archangeli, Diana, and Douglas Pulleyblank. 1994. *Grounded Phonology*. Cambridge, MA: MIT Press.

Beddor, Patrice Speeter. 1993. The perception of nasal vowels. *Nasals, Nasalization, and the Velum*. Phonetics and Phonology 5, ed. by Marie K. Huffman and Rena A. Krakow, 171–196. San Diego, CA: Academic Press.

Benua, Laura. 1997. *Transderivational identity: Phonological relations between words*. Doctoral dissertation, University of Massachusetts, Amherst.

Boersma, Paul, and Weenink, David. 1992/2000. *Praat 3.9: A System for Doing Phonetics by Computer*. <http://www.praat.org>

Carlton, Terence R. 1990. *Introduction to the Phonological History of the Slavic Languages.* Columbus, OH: Slavica.
de Bray, R. G. A. 1969. *Guide to the Slavonic Languages*. London: J. M. Dent and Sons.
Glass, Gene V., and Kenneth D. Hopkins. 1996. *Statistical Methods in Education and Psychology.* 3rd ed. Boston: Allyn and Bacon.
Goldrick, Matthew. 2000. Turbid output representations and the unity of opacity. *Proceedings of the North East Linguistic Society 30*. Amherst, MA: GLSA.
Goldrick, Matthew, and Paul Smolensky. 1998. Turbidity: Opacity and phonetic functionalism in optimality theory. Paper presented at University of California, Santa Cruz.
Goldsmith, John. 1993. Harmonic phonology. *The Last Phonological Rule: Reflections on Constraints and Derivations*, ed. by John Goldsmith, 21–60. University of Chicago Press.
Gotteri, Nigel. 1998. Polish. *Encyclopedia of the Languages of Europe*, ed. by Glanville Price, 360–364. Oxford: Blackwell.
Gussmann, Edmund. 1980. *Studies in Abstract Phonology*. Cambridge, MA: MIT Press.
Inkelas, Sharon, and C. Orhan Orgun. 1995. Level ordering and economy in the lexical phonology of Turkish. *Language* 71/4:763–793.
Jastrzębska-okoń, I., and K. Billip, eds. 1993. *Wiedza Powszechna Compact Polish and English Dictionary*. Lincolnwood, IL: NTC Publishing Group.
Kenstowicz, Michael. 1994. *Phonology in Generative Grammar*. Cambridge, MA: MIT Press.
Kiparsky, Paul. 1968. Linguistic universals and linguistic change. *Universals in Linguistic Theory*, ed. by E. Bach and R. T. Harms, 171–202. New York: Holt, Rinehart, and Winston.
Kiparsky, Paul. To appear. *Paradigm Effects and Opacity*. Stanford University: CSLI Publications.
McCarthy, John. 1999. Sympathy and phonological opacity. *Phonology* 16/2:331–399.
Padgett, Jaye. 1997. Perceptual distance of contrast: Vowel height and nasality. *Phonology at Santa Cruz 5*, ed. by Rachel Walker, Motoko Katayama, and Daniel Karvonen, 63–78.
Prince, Alan, and Paul Smolensky. 1993. Optimality Theory: Constraint interaction in generative grammar. Ms., Rutgers University and University of Colorado at Boulder.
Rubach, Jerzy. 1984. *Cyclic and Lexical Phonology: The Structure of Polish*. Dordrecht: Foris.
Steriade, Donca. 1997. Phonetics in phonology: The case of laryngeal neutralization. Ms., UCLA.
Stieber, Zdzisław. 1968. The phonological development of Polish. Michigan Slavic Materials 8, trans. by E. Schwartz. Ann Arbor: Department of Slavic Languages and Literature, University of Michigan.
Wright, J. T. 1986. The behavior of vowels in the perceptual vowel space. *Experimental Phonology*, ed. by J. J. Ohala and J. J. Jaeger, 45–67. Orlando, FL: Academic Press.