ACQUISITION OF FINAL VOICING: AN ACOUSTIC AND THEORETICAL ACCOUNT*

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This study evaluates an opacity effect in the productions of an English-speaking child (male, aged 2;5). Specifically, the child exhibited the adult pattern of vowel lengthening before voiced obstruents plus the developmental pattern of final-obstruent devoicing, both of which were verified with acoustic analyses. The vowel-lengthening pattern, plus evidence from morphophonemic alternations ([dɔːk] 'dog', [dɔːgi] 'doggie'), attest to Child 1's knowledge of the voice contrast in final position. We adopt optimality theory with candidate chains (OT-CC) to account for the child's productions. High-ranking markedness constraints (*V̆C̬, prohibiting short vowels before voiced obstruents, and *C̬#, prohibiting final voiced obstruents) are assumed to account for the child's surface forms at Point 1. The emergence of final voiced obstruents at Point 2 is due to the simple demotion of *C̬#. We consider the implications of this account as they relate to phonological acquisition generally.

1. Introduction

A common cross-linguistic phonological pattern is that of final devoicing (Dinnsen and Eckman 1978; Lombardi 1995; Wetzels and Mascaró 2001), whereby obstruents that are contrastive for voicing in certain contexts are noncontrastive in syllable- and word-final contexts. Probably one of the most widely studied cases of final devoicing is that of German; in fact, it is a common problem set that many students in introductory phonology classes must tackle. Students successfully identify this problem set as a case of neutralization (rather than allophony) by observing the following (Dinnsen 1984): a) presence of a voicing contrast in certain contexts (e.g., intervocalically, as in *Grade* [grɑdə] 'degrees' vs. *Grate* [grɑtə] 'edges'), b) lack of a contrast in other contexts (e.g., voiced obstruents are absent syllable-finally), and c) occurrence of morphophonemic alternations for some morphemes (e.g., final [d] and [t] in *Grade* [grɑdə] 'degrees' vs. *Grad* [grɑt] 'degree'; cf. *Grate* [grɑtə] 'edges' vs. *Grat* [grɑt] 'edge'). The keen student will note that *Grad* [grɑt] is underlyingly /grɑd/, but is subjected to a rule of final devoicing which neutralizes the underlying voicing contrast in surface forms (Dinnsen and Garcia-Zamor 1971; King 1969).

Only with time and experience do students learn that there is a little more to the problem—that there is a vowel length difference whereby vowels preceding underlying voiced obstruents are lengthened. In fact, *Grad* and *Grat* are not true homonyms; rather, they form a near minimal pair ([grɑːt] and [grɑt], respectively). That is, while the voice contrast may be neutralized in final position, there remains a surface contrast between the forms due to vowel length differences (thus, it is a case of incomplete neutralization; for discussion, see Dinnsen 1985; Dinnsen and Charles-Luce 1984; Port and Crawford 1989; Port et al. 1984; Port and

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O'Dell 1985). This is when phonology students then learn about the different rule ordering relationships that occur in languages of the world, and they are first exposed to the (perhaps dreaded) terms *feeding, counterfeeding, bleeding*, and *counterbleeding*. The German case is a classic counterbleeding case: Specifically, the vowel lengthening rule must apply before the devoicing rule. The surface form is rendered *opaque* because it appears that the rule of vowel lengthening has applied when it should not have (before a voiceless obstruent), as with *Grad* [grɑːt]. Thus, it is an instance of *overapplication* (Baković 2007). Applied in the reverse order, devoicing would *bleed* lengthening; that is, application of the devoicing rule would prevent application of the lengthening rule, yielding identical transparent forms that would be true homonyms: *Grad* *[grɑt] and *Grat* [grɑt].

Final devoicing, though associated with certain phonetic variation (see, for more recent discussion, Blevins 2006), is also phonologically productive, and is observed in many languages of the world, as well as in phonological acquisition by first- and second-language learners, independent of the facts of the language being acquired (Catts and Jensen 1983; Clark and Bowerman 1986; de Boysson-Bardies et al. 1981; Eckman 1981a; Eilers et al. 1989; Haelsig and Madison 1986; Hodson and Paden 1981; Ingram 1989a, 1989b; Krause 1982; Lehman and Sharf 1989; Leonard et al. 1985; Snow 1997; Stampe 1973; Yavaş 1997). Its widespread occurrence across developing and fully-developed systems is often taken as evidence that it is a universal pattern of language, whereby voiceless obstruents are assumed to be unmarked relative to voiced obstruents (at least in final position). Thus, it should be no surprise that final devoicing would be apparent in developing systems because, under most frameworks of generative grammar, that would be a property of language for which the child is 'pre-wired' (Chomsky and Halle 1968; Lenneberg 1967). In acquiring a language such as German, the child need not overcome the devoicing pattern. On the other hand, in acquiring a language such as English, the child must eventually recognize, based on the available input, that final obstruents may be voiced; at some point, the constraint, process, or rule (depending on the particular instantiation of generative phonology that one adopts) must be demoted, suppressed, or lost, respectively.

Similarly, vowel lengthening before voiced consonants is also widely-observed cross-linguistically (Chen 1970). There is some debate over whether this is phonetically motivated (de Jong 1991; Löfqvist and Gracco 1997), or truly universal in nature (see Keating 1985 for discussion); nevertheless, there is evidence to suggest that young children show a tendency to lengthen vowels before voiced obstruents, regardless of the (phonemic) status of vowel length in the language being acquired (Buder and Stoel-Gammon 2002).

Phonological alternations, whether allophonic or neutralizing, have also been observed in first- and second-language acquisition, and are taken as evidence in support of claims that developing systems have grammars that are different from (that is, independent of) the target system (Archibald 1992; Dinnsen 1993, 1996b, 1999, 2002; Dinnsen and McGarrity 2004; Eckman 1981b, 1984; Eckman and Iverson 1997; Gierut 1986b; Gierut and Champion 2000; Ingram 1974; Jesney 2005; Macken 1980, 1987; Pater and Tessier 2006; Peng and Setter 2000). In some cases, phonological alternations may be revealing of knowledge that is altogether different from the target system. Take the case of AJ, described by Gierut (1986b, 1989), who, at one stage of acquiring the English language, appears to treat [f] and [s] as allophones of the same phoneme that occur in complementary distribution. The child produced some forms target appropriately (e.g., [fes] 'face'), suggesting of adult-like knowledge of the sound system; yet, other forms were produced inappropriately (e.g., [fit] 'seat' and [kɔs] 'cough'). Taking all the child's productions together, it was evident that [f] and [s] were in complementary distribution. Thus, the child did not have both [f] and [s] in his phonemic inventory; further, it was assumed that his grammar (e.g., a rule or constraint) was responsible for the distribution of the two sounds.

In other cases, alternations may illustrate differential knowledge for surface-identical forms. For instance, Dinnsen (1999) describes a child (Subject 27) who produces both word-final /t/ and /θ/ as [t]. At first glance, it might seem that the child has no knowledge of the contrast between the two sounds of the adult system. Yet, further evaluation of the child's productions reveals that target /t/ surfaces as [ʔ] intervocalically, while target /θ/ continues to surface as [t], with additional evidence of alternations: [bæt] 'fat' and [bæʔi] 'fatty' versus [tit] 'teeth' and [titi] 'teethy'. Thus, the differential behavior of the two sounds are revealing of the child's differential knowledge of the two target sounds.

Alternations can also reveal differences in knowledge between two children with seemingly identical error patterns. For instance, Weismer, Dinnsen, and Elbert (1981) describe three children, all of whom show omission of final stops. On the surface, these children present with perhaps identical final consonant deletion patterns. Children A and B, however, show evidence of knowledge of the underlying stops via presence of vowel lengthening before the omitted stop (e.g., /dɔː/ 'dog', but /dʌ/ 'duck'), consistent with the patterning of vowels in the adult system (House and Fairbanks 1953), and via the occurrence of morphophonemic alternations (e.g., /dɔː/ 'dog' and /dɔgi/ 'doggie'). Child C, on the other hand, showed no such knowledge. Vowel lengths were no different before omitted voiced versus voiceless stops, and no morphophonemic alternations were apparent. In fact, few stops ever occurred intervocalically (e.g., /dɔ/ 'dog' and /dai/ 'doggie'). Thus, while all three children omitted final stops, Child C appeared to do so for a reason that was altogether different from that of Children A and B.

Another interesting observation can be made about Children A and B. Assuming a derivational account of their productions, it would be necessary to assume that the rule of vowel lengthening had to apply prior to final consonant deletion. Thus, we have a case of a rule-ordering relationship very much like the counterbleeding relationship that occurs with German final obstruents. Cases of opacity, including counterbleeding effects, have been noted to occur in developing systems, and more recently are drawing a great deal of attention (Barlow 2007; Dinnsen 2004, 2008b; Dinnsen and Farris-Trimble 2008, in press). This is likely due in large part to the challenge that opacity generally poses for the nonderivational framework of optimality theory (McCarthy and Prince 1999; Prince and Smolensky 1993/2004). In its classical form, optimality theory cannot achieve the effects of rule-ordering relationships that so easily account for counterbleeding (and counterfeeding) phenomena. A recent modification to the framework, referred to as *optimality theory with candidate chains* (OT-CC; McCarthy 2007), has been proposed to handle these and similar such phenomena that are problematic for the original theory.

In the current paper, we present a case study of an English-learning child with a sound system not unlike that of German, with vowel lengthening before target voiced obstruents and devoicing of final obstruents, yielding opaque surface forms. The paper is organized as follows. In section 2, we present longitudinal data from the child in the form of perceptually-based (transcribed) data, as well as from the results of acoustic analyses of his productions. In section 3, we present an optimality theoretic account of his productions, longitudinally, by appealing to OT-CC. The longitudinal change is accounted for via demotion of a single constraint, which is triggered, it is assumed, by positive evidence. The paper then concludes in section 4 with a discussion of implications of the account and of opacity in phonological acquisition more generally.

2. The data

The data to be described come from productions of a typically-developing English-speaking child, Child 1 (male, aged 2;5 at the start of the study). This child was part of a larger ongoing cross-sectional and longitudinal study evaluating the typological properties of developing sound systems. Child 1's single-word productions are drawn from the *Assessment of English Phonology* (AEP; Barlow 2003). This picture-naming probe targets the consonants and vowels of the English language a minimum of 5 times each. The child's productions were transcribed by a judge trained in narrow transcription using the IPA. A second judge retranscribed 20% of the words for reliability purposes. Mean point-to-point reliability for consonants and vowels was 88%.

One design of the AEP is to sample potential morphophonemic alternations (after Gierut 1986a) by targeting monomorphemic forms (e.g., *dog)* and their inflected counterparts (e.g., diminutive *doggie*). Child 1 showed evidence of such alternations in his productions, and we focus on these alternations in the current study. Two separate points in time will be presented.

2.1 Point 1

At Point 1, Child 1 exhibited two phonological patterns that resulted in opaque surface forms. Specifically, Child 1 exhibited the target-appropriate pattern of vowel lengthening before voiced obstruents, but also exhibited the developmental pattern of final-obstruent devoicing in the very same forms, as illustrated in (1) below.

(1) Point 1: Distribution of voiced and voiceless obstruents

a. Voiced and voiceless obstruents occur word-initially and intervocalically

[dɔːk]	'dog'	[tʰʌːp]	'tub'
[væ̃ːn]	'van'	[fɪs]	'fish'
[bɪːts]	'bridge'	[pʰeɪːts]	'page'
[wɛːbi]	'web (dim.)'	[soʊpi]	'soap (dim.)'
[ʧiːzi]	'cheese (dim.)'	[fɪsi]	'fish (dim.)'
[bɑːʤi]	'badge (dim.)'	[wɪʧi]	'witch (dim.)'

b. Voice contrast is neutralized word-finally

[woʊːp]	'robe'	[soʊp]	'soap'
[dɔːk]	'dog'	[dʌk]	'duck'
[dʌːf]	'glove'	[wif]	'leaf'
[ʧiːs]	'cheese'	[ʤus]	'juice'
[bɪːts]	'bridge'	[wɑts]	'watch'

It has been recognized for many decades that children master this vowel length alternation, just as Child 1 did, at a very young age (Smith 1973; Velten 1943). Nevertheless, to verify the accuracy of the transcribed data as regards vowel-lengthening and final devoicing, we subjected Child 1's productions to acoustic analyses with Praat software (Boersma and Weenink 2005). Specifically, we evaluated spectrographic displays of all of Child 1's productions for target word-final voiced and voiceless obstruents for presence of vocal fold vibration as evidenced by vertical striations during the consonant articulation. Consistent with the transcriptions, Child 1 showed no voicing on any obstruent in final position (target-appropriate or otherwise).

We also measured the durations of vowels preceding target voiced and voiceless obstruents in consonant-vowel-consonant (C_1VC_2) forms. To do this, we defined the vowel portion of each utterance as follows. The onset of the vowel was defined as the start of periodicity on the waveform and the start of vertical striations for the first formant on the spectrogram. In cases where C_1 was a sonorant segment, thus already presenting with periodicity and formants, the vowel onset was defined as the point at which the formants of the vowel were steady. In some of these cases, particularly with the approximants, auditory cues also were necessary (e.g., to determine the point at which lip rounding no longer was audible in the case of the transition from [w] to [ɛː] in the word 'web'). The offset of the vowel was defined as the point at which vertical striations on the first formant ceased. Independent samples *t*-tests revealed that the mean duration for vowels before target voiced obstruents was significantly longer than the mean duration of vowels before target voiceless obstruents at Point 1 ($t(66)=3.07$, $p<0.05$).

The vowel-length difference attests to Child 1's knowledge of final voicing at Point 1, despite the devoicing pattern, as does additional evidence from morphophonemic alternations between monomorphemic and diminutive forms, as shown in (2).

(2) Point 1: Morphophonemic alternations for target morpheme-final voiced obstruents

[mʌːt]	'mud'	[mʌːdi]	'mud (dim.)'
[dɔːk]	'dog'	[dɔːgi]	'dog (dim.)'
[dʌːf]	'glove'	[gʌːvi]	'glove (dim.)'
[ʧiːs]	'cheese'	[ʧiːzi]	'cheese (dim.)'
[bɑːts]	'badge'	[bɑːʤi]	'badge (dim.)'
[bɪːts]	'bridge'	[bɪːʤi]	'bridge (dim.)'

Because Child 1 shows productive knowledge of voicing on final obstruents, it is assumed that his lexical representations of target forms with final obstruents are adult-like; surface forms are therefore attributed to effects of his grammar, which we illustrate in section 3.

2.2 Point 2

At Point 2, at age 2;11, voiced obstruents emerge in word-final position in Child 1's productions. The vowel-lengthening pattern continues as before, such that vowels are significantly longer before target voiced versus voiceless obstruents ($t(30)=2.19$, $p<0.05$). Refer to the data in (3).

(3) Point 2: Voicing contrast emerges word-finally

[oʊːb]	'robe'	[woʊːbi]	'robe (dim.)'
[bɛːd]	'bed'	[bɛːdi]	'bed (dim.)'
[dʌk]	'duck'	[dʌki]	'duck (dim.)'
[dɑːg]	'dog'	[dɑːgi]	'dog (dim.)'
[mɑθ]	'moth'	[mɑfi]	'moth (dim.)'
[gʌːv]	'glove'	[gʌːvi]	'glove (dim.)'
[ʤus]	'juice'	[ʤusi]	'juice (dim.)'
[noʊːz]	'nose'	[noʊːzi]	'nose (dim.)'
[wɑts]	'watch'	[wɑtsi]	'watch (dim.)'
[bɪːdz]	'bridge'	[bɪːʤi]	'bridge (dim.)'

Thus, Child 1 still shows evidence of the target-appropriate vowel-lengthening pattern in his productions, which continues to occur only before target voiced obstruents. Vowels remain short before voiceless obstruents. The change that occurred in Child 1's productions is attributed to changes in his grammar (section 3); thus, it is assumed that his lexical representations for these forms remained unchanged over time. That is, he showed knowledge of the voicing contrast across both points in time.

We turn now to a theoretical account of Child 1's grammar and the change that occurs across time.

3. The account

3.1 Point 1

Child 1's productions are easily accounted for within a derivational framework that appeals to rule ordering, such that vowel lengthening and final devoicing apply in a counterbleeding order, as illustrated in (4).

(4) Derivational account: Counterbleeding application of two rules

/dɔg/ 'dog'	/dɔg+i/ 'doggie'	/dʌk/ 'duck'	underlying form
dɔːg	dɔːgi	---	vowel lengthening
dɔːk	---	---	final devoicing
[dɔːk]	[dɔːgi]	[dʌk]	surface form

If the rules were applied in the reverse order, the devoicing rule would bleed the lengthening rule, thereby preventing its application, as shown in (5).

(5) Opposite rule order: Devoicing bleeds lengthening

/dɔg/ 'dog'	/dɔg+i/ 'doggie'	/dʌk/ 'duck'	underlying form
dɔk	---	---	final devoicing
---	dɔːgi	---	vowel lengthening
*[dɔk]	[dɔːgi]	[dʌk]	surface form

The success of the derivational account lies in its assumptions about intermediate representations and serial application of rules. A nonderivational account framed within classic optimality theory (McCarthy and Prince 1999; Prince and Smolensky 1993/2004) does not fare so well, however, because intermediate representations play no role in the mapping between input and output forms. Assume a markedness constraint that prohibits short vowels before voiced obstruents (*V̆C̬) is in conflict with a faithfulness constraint (ID[length]), and another markedness constraint that prohibits voiced coda obstruents (*C̬#) conflicts with a faithfulness constraint (ID[voice]). Though these are standard assumptions for independent accounts of such patterns, there is no way to achieve the attested form whereby the two patterns interact. In other words, no matter how the constraints rank, a more transparent form will always be selected by the grammar as most harmonic (as in the sample tableau in (6), where '☟' indicates the candidate that would be incorrectly selected by the grammar).

(6) Tableau: Classic OT fails to derive opaque form

/dɔg/ 'dog'	*V̆C̬	*C̬#	ID[length]	ID[voice]
a. dɔg	*!	*		
b. dɔːg		*!	*	
c. dɔːk			*!	*
d. ☟ dɔk				*

Despite classic OT's failure to account for cases of opacity such as the present one, of course there is no need to abandon the theory altogether. In fact, a recent revision to optimality theory, known as optimality theory with candidate chains (OT-CC; McCarthy 2007), has emerged as superior to classic optimality theory in its ability to account for this type of opacity, among other phenomena. In the current study, an account of Child 1's productions are offered within OT-CC, in order to illustrate the application of this newly proposed framework to a child's sound system.

The novelty of OT-CC is its assumptions about enriched candidates, or *candidate chains*. Specifically, each candidate chain begins with the fully-faithful candidate (e.g., dɔg) which is followed by zero or more minimally different candidates that harmonically improve according to the constraint ranking of the grammar. Thus, one chain for input /dɔg/ is <dɔg>, while another is <dɔg, dɔk>, another is <dɔg, dɔːg>, and so on. Also new to the framework is a family of PREC(EDENCE) constraints which evaluate the order in which unfaithful mappings occur within a candidate chain. These constraints, assumed to be a part of the universal set of constraints of all grammars, stipulate a preferred order for violations of constraints within the hierarchy. The PREC constraint relevant to the current account is defined in (7):

(7) PREC(ID[length], ID[voice]): Every violation of ID[voice] must be preceded by a violation of ID[length] and must not be followed by a violation of ID[length].

Thus, PREC is violated if ID[voice] is violated in the absence of a (preceding) violation of ID[length]. Following the metaconstraint on the ranking of PREC constraints

(McCarthy 2007), ID[voice] must outrank PREC. For the current account, ID[voice] must rank below the two markedness constraints and above the two faithfulness constraints. The ranking for Point 1 in Child 1's grammar is thus illustrated in (8), and a representative tableau is shown in (9).

(8) Ranking for Point 1: *V̆C̬, *C̬# >> ID[voice] >> PREC >> ID[length]

(9) Point 1: Opaque forms show voicing and vowel length changes

/dɔg/	'dog'	*V̆C̬	*C̬#	ID[voice]	PREC	ID[length]
a.	<dɔg> faithful candidate	*!	*			
b.	<dɔg, dɔːg> ID[length]		*!			*
c. ☞	<dɔg, dɔːg, dɔːk> ID[length], ID[voice]			*		*
d.	<dɔg, dɔk> ID[voice]			*	*!	

In this example, candidate (c) is selected as the optimal candidate, despite its two faithfulness violations, because the candidate chain satisfies PREC by incurring faithfulness violations in the prescribed order (ID[length] before ID[voice]). Candidate (d), a transparent form, incurs a fatal violation of PREC because it violates ID[voice] in the absence of any preceding ID[length] violation in the chain.

Note that we assume that MAX and DEP are ranked high in the grammar, thereby preventing deletion or insertion (respectively) of segments as a means for satisfying the markedness constraints *V̆C̬ and *C̬#. These are not illustrated in the tableau for space considerations. Nevertheless, with MAX and DEP ranked high, candidate chains of the type <dɔg, dɔ> or <dɔg, dɔgi> for input /dɔg/ would be ruled out by the grammar due to violations of these respective higher-ranking faithfulness constraints.

The proposed ranking can also account for more transparent forms, such as [dɔːgi] for target 'doggie', which only show changes in vowel length. These forms are particularly interesting, given that they violate one of the constraints that are relevant to the PREC constraint, namely ID[length]. However, since violation of PREC is dependent only on whether ID[voice] is violated, such forms do not pose a problem for PREC; rather, PREC is vacuously satisfied. Refer to the tableau in (10) for an illustration.

(10) Point 1: Transparent forms that show vowel length changes only

/dɔg+i/	'dog (dim.)'	*V̆C̬	*C̬#	ID[voice]	PREC	ID[length]
a.	<dɔgi> faithful candidate	*!				
b. ☞	<dɔgi, dɔːgi> ID[length]					*

As shown, faithful candidate (a) loses out due to its violation of high-ranking *V̌C̬. Candidate (b) is selected as optimal because it satisfies the higher-ranked *V̌C̬ in exchange for a violation of lower-ranked ID[length]. Again, PREC is vacuously satisfied, as there is no ID[voice] violation incurred by candidate (b).

Similarly, the proposed ranking can also account for transparent forms that do not show any changes in the mapping between input and output forms (as far as voicing and vowel length are concerned), such as [dʌk] ‘duck’. Important to this point (as well as the case of ‘doggie’ above) is the stipulation of OT-CC that chains must *improve harmonically* in an incremental fashion with respect to the constraint ranking. Thus, a candidate chain such as **<dɔg, dɔːk> for input /dɔg/ ‘dog’ is not valid, given that the second member of the candidate chain differs from the first in more than one way (voicing and vowel length). Nor is **<dʌk, dʌg> a valid candidate chain for input /dʌk/ ‘duck’, given that the second member is more marked than the first. In fact, as far as V̌C̬ and *C̬# are concerned, the only valid candidate chain for input /dʌk/ ‘duck’ would be the fully faithful <dʌk>, since both markedness constraints are already satisfied by that form.

3.2 Point 2

At Point 2, recall, voiced obstruents now occur in final position in Child 1’s productions. The vowel-lengthening pattern persists, as expected, given its continuity with the target grammar. This change in Child 1’s productions, which has now yielded transparency with respect to the forms in question, is attributed to a simple demotion of *C̬# to just below ID[voice] in the ranking, following assumptions of minimal demotion in phonological acquisition (Tesar and Smolensky 2000). The new ranking for Point 2 is shown in (11) below. A tableau illustrating this new ranking follows in (12).

(11) Ranking for Point 2: *V̌C̬ >> ID[voice] >> *C̬#, PREC >> ID[length]

(12) Point 2: Absence of voicing changes renders all relevant forms transparent

/dɑg/	‘dog’	*V̌C̬	ID[voice]	*C̬#	PREC	ID[length]
a.	<dɑg> faithful candidate	*!		*		
b. ☞	<dɑg, dɑːg> ID[length]			*		*
c.	<dɑg, dɑːg, dɑːk> ID[length], ID[voice]		*!			*
d.	<dɑg, dɑk> ID[voice]		*!		*	

This new ranking also easily accounts for the other forms that continue to be more transparent from Point 1, namely [dɑːgi] for ‘doggie’ forms, given that *C̬# is vacuously satisfied by the attested (winning) form. Refer to the tableau in (13). (Of course, /dʌk/ ‘duck’ forms also continue to be realized as their fully-faithful outputs as with Point 1.)

(13) Point 2: Transparent forms that show vowel length changes only

/dɑg+i/	‘doggie’	*V̆C̬	ID[voice]	*C̬#	PREC	ID[length]
a.	<dɑgi> faithful candidate	*!				
b. ☞	<dɑgi, dɑːgi> ID[length]					*

4. Discussion

To summarize the foregoing, we presented a longitudinal account of a child’s acquisition of the voice contrast in word-final position and its relationship to an independent, though interacting, pattern of vowel lengthening. The final devoicing pattern observed at Point 1 was attributed to a high-ranking markedness constraint against final voiced obstruents (*C̬#), while the vowel lengthening pattern (at both Points 1 and 2) was attributed to a high-ranking markedness constraint against short vowels before voiced obstruents (*V̆C̬). This is consistent with general assumptions about the ranking of markedness over faithfulness constraints early on in acquisition. The occurrence of final voiced obstruents at Point 2 was attributed to the demotion of *C̬# to below the faithfulness constraint ID[voice], which is likewise consistent with assumptions about the process of developmental change in optimality theoretic grammars (Tesar and Smolensky 2000). Along with these fairly straightforward patterns of devoicing and vowel lengthening was an interaction between the two that is, in derivational terms, viewed as overapplication of a process. That is, vowels lengthened even before certain surface voiceless obstruents. The presence of an alternation between voiced and voiceless obstruents motivated the assumption that those very same voiceless obstruents were underlyingly voiced. The nonderivational framework of optimality theory, revised to include candidate chains, was adopted to account for the overapplication pattern in the child’s system.

It is generally assumed that morphophonemic alternations must be relatively difficult to learn (Chomsky and Halle 1968; though see Fikkert and Freitas 2006). A number of learning algorithms have been proposed to account for how children do this (e.g., Albright and Hayes 2003, in press; Alderete et al. 2005; Hayes 2004; McCarthy 2005), and there are a growing number of studies that specifically address children’s learning of allomorphy of a target system based on productive data (see, e.g., Berko 1958; Bernhardt and Stemberger 1998; Jarmulowicz 2006; Kerkhoff 2004; Marshall and van der Lely 2007; Nakipoglu and Ketrez 2006; Seva et al. 2007; Thomas and Gathercole 2007; Zamuner et al. 2006a, 2006b). Of course, Berko’s (1958) famous Wug Test provided evidence of children’s productive knowledge of English plural allomorphy ([-s], [-z], or [-əz]). Yet, children do make errors in the process of learning the underlying representations for such alternating forms. For instance, Dinnsen and Chin (1993) describe an English-learning child who incorrectly internalizes the plural morpheme as an invariant /-s/ suffix, lacking the target appropriate morphophonemic alternations, despite the occurrence of [z] in the child’s productions elsewhere ([dɪps] ‘chips’, [taʊs] ‘toes’, and [g̊aʊms] ‘combs’, but [waʊz] ‘rose’ and [tiz] ‘cheese’).

In evaluating the acquisition of allomorphy in Dutch with a similar Wug-type test (Kerkhoff 2004; Zamuner et al. 2006a, 2006b), researchers found that Dutch-speaking children had difficulty in both production and comprehension in the learning of novel words that showed allomorphy with respect to voicing of final obstruents (e.g., *slad* [slɑt] vs. *sladden* [slɑdən]). Numerous other studies have evaluated children's acquisition of allomorphy with artificial languages, and have found, for instance, differences between typically developing and phonologically delayed children (e.g., Dunn and Till 1982; Jones 1991; Tessier 2006).

Opacity and morphophonemic alternations themselves do not appear to be especially problematic or 'unnatural' in developing systems, as they are common, and reported widely in the literature (Barlow 2007; Bernhardt and Stemberger 1998; Chin 2002; Dinnsen 1993, 1996a, 1996c, 1997, 1999, 2002, 2004, 2008b; Dinnsen and Chin 1993; Dinnsen and Farris 2006; Dinnsen and Farris-Trimble 2008, in press; Dinnsen and McGarrity 2004; Dinnsen et al. 1997, 2000, 2001; Fey and Stalker 1986; Gierut 1986a; Gierut and Champion 2000). Opacity effects may in fact be unavoidable in certain paths of phonological acquisition. Consider that, following assumptions about the initial state, markedness constraints must outrank faithfulness constraints (Smolensky 1996). This was the case for Child 1 in the current study, where *V̌C̬ and *C̬# outranked the relevant ID constraints. It is assumed that, prior to learning the phonemes, lexical representations, and allophonic/allomorphic variation in a sound system, a child first determines the phonotactics of the language based on the input (Hayes 2004; Sommerstein 1974; Tesar and Prince 2007). With exposure to marked structure in the sound system, such as the presence of final voiced obstruents, the relevant markedness constraint, in this case *C̬#, is demoted below its relevant faithfulness constraint, such as ID[voice]. This could happen in the absence of any knowledge about lexical representations, morphology, or alternations. In the case of Child 1, however, the change appears to have occurred *following* the emergence of voiced obstruents in the final position of morphemes. That is, the presence of allomorphy for forms such as *dog* and *doggie* in his productions indicates that the voicing contrast was phonemic in his sound system. The consequence of having a phonemic voicing contrast, but also high-ranking *V̌C̬ and *C̬# in his sound system (along with the ranking of Prec) led to the observed opacity effects in his sound system.

Thus, the very natures of opacity and allomorphy may not necessarily be problematic for the learner, though there is some evidence that non-ambient opacity effects in the sound systems of children with phonological delay may be relatively difficult to overcome (Barlow 2007; Dinnsen 2008a, 2008b; Gierut and Champion 1999). Nevertheless, acquiring an opaque property of a sound system, that is, determining the underlying representations of morphemes that show several surface allomorphs, is assumed to be particularly challenging to the learner (Kiparsky 1971, 1973). Thus far, there is little published information about how children do this, and it is a direction that phonological acquisition research should follow.

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