Variation in Acquisition: An Optimal Approach

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1.0 Introduction

Researchers have long noted that children's early words are frequently characterized by multiple surface forms for a given target word. Typical examples from English and Dutch are presented in (1).

(1)

a.	[ka:] ~ [ka]	/kla:r/	'ready'	Dutch - Fikkert (1994)
b.	[bɑ] ~ [bɑf]	/bɑl/	'ball'	Dutch - Fikkert (1994)
c.	[mɔ] ~ [mɔmɔ]	/mɑmɑ/	'mama'	English - Matthei (1989)

Many researchers have shown that certain types of variation are not random, but result from a phonological system that lacks certain featural contrasts (e.g., Ingram, 1976, 1996; Rice, 1996a,b; Rice & Avery, 1995; Vihman, Macken, Miller, Simmons, & Miller, 1985). Others observe that early segmental variation is partially due to interactions with higher-level prosodic structures such as the syllable (e.g., Dinnsen, 1992, 1996a,b; Fudge, 1969; Levelt, 1994, 1996; Macken, 1980; Stemberger, 1992; Stoel-Gammon, 1983, 1996). Some of this work begins to invoke the term *constraints* in trying to capture the types of segmental/syllabic interactions that seem to be operating in children's early phonological development. Still other analyses have recently been taken a step further to the level of the *phonological word* (Demuth, 1995, 1996a,b,c; Demuth & Fee, 1995; Fee, 1992, 1994, 1995, 1996). This work has begun to identify interactions between constraints at the level of segments, syllables, and phonological words, all of which compete with each other to yield well-formed prosodic words whose segmental and/or syllabic structure may vary as in (1) above.

A *constraint-based* approach to acquisition issues has, therefore, been emerging slowly over the past ten years - a phenomenon in search of a theory. Rule-based systems such as the one employed by Smith (1973) seemed to be missing some major generalizations about the nature of children's developing phonologies. Spencer's (1986) autosegmental analysis of the same data was a vast improvement, yet certain higher-level generalizations were still missing. Since the development of Optimality Theory (OT) (Prince & Smolensky, 1993, in press), the field of language acquisition has begun to explode, as evidenced by the large number of recent publications in this area (e.g., Bernhardt & Stemberger, in press; Demuth, 1995, 1996b,c; Gnanadesikan, 1995; Goad, 1996; Levelt, 1996; Lleó, 1996; Paradis, 1995; Pater & Paradis, 1996; Velleman, 1996). One of the problems, however, with applying an optimality theoretic analysis to the area of language acquisition involves the issue of variation. At the very heart of OT is the notion that there is only one output (surface form) for a given input (underlying representation). Does OT then have anything to offer the study of phonological development? If so, it must allow for the presence of partially-ranked constraints (Demuth, 1995). This has recently been formalized in learnability terms as in Tesar and Smolensky (1996).

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This paper demonstrates that children's early words are generally prosodically well-formed, yet variation can arise through needs to satisfy competing constraints at different levels of phonological structure. That is, children's early words are not ill-formed, randomly generated articulatory objects, but word-like units that are prosodically constrained even if various segmental and featural faithfulness constraints are not met. The purpose of this paper is to demonstrate how OT provides a framework for understanding the nature of these constraint interactions, and specifically how *multiple optional outputs* are permitted in a system of *stratified domination hierarchies*.

The paper is organized as follows. Section 2 reviews some of the recent findings regarding the prosodic structure of children's early words, showing that different "stages" of development can be identified despite variation in form. Section 3 explores how this variation can be handled with an OT framework in terms of partial constraint ranking, or stratified domination hierarchies. Section 4 concludes with a discussion of how this approach to problems of variation in acquisition might be extended to handle variation problems in other domains.

2.0 Prosodic Structure of Early Words

Fudge (1969) was one of the first to recognize the importance of prosodic structure in determining the shape of children's early words. More recently, Fee (1992, 1994, 1995), Demuth (1995, 1996a,b, in press), Demuth and Fee (1995), Gennari and Demuth (1997) have found the existence of prosodic constraints in languages as different as English, Dutch, Spanish, and Sesotho. Although the specific nature of these prosodic constraints differs somewhat from language to language, there are common developmental trends toward increasing prosodic complexity in phonological word structure over time. An illustration from Dutch is instructive: Fikkert (1994) identifies several stages of early word structure in her study of several Dutch-speaking children's acquisition of stress. The earliest of these stages are outlined below. Note the presence of variation at each of these stages. Although vowel length is not contrastive at Stages I and II, it becomes contrastive at Stage III, showing properties of compensatory lengthening.

(2) Word shapes in early Dutch (Fikkert, 1994)

Stage I	Core Syllables (vowel length not distinctive) CV ~ CVV
Stage II	Obstruent Codas (vowel length not distinctive) (C)VC ~ (C)VVC
Stage III	Sonorant Codas, Vowel length distinctive (C)VV ~ $(C)VC_{son}$
Stage IV	Sonorant Codas, Vowel length distinctive $(C)VC_{son}$

But Fikkert (1994) also notes that these stages of word (and syllable) development are not discrete. That is, words from Stage I are sometimes found even at Stage II, and words of Stage II may also be found at Stage III. A few examples will serve to illustrate these phenomena.

(3)

Stage	Child	Adult Target (Dutch)		Age of Child (years;months)
I	[ka:], [kɑ]	/kla:r/	'ready'	J (1;4-1;5)
II	[a:p], [ɑp] [bɑf], [bɑ]	/a:p/ /bɑl/	'monkey' 'ball'	J (1;6-1;7)
III	[bo:], [bɑu] [pɑv], [bɑl]	/bɑl]	'ball'	J (1;10-2;0)
IV	[bɑl]	/bɑl/	'ball'	J (2;0)

The Dutch phenomena illustrated in (3) are typical of developmental patterns found in other languages as well. Similar types of variation have been documented for early English (Fee, 1992). Thus, despite obvious milestones in development, the path of acquisition is often a continuous one, where stages can be identified but where the boundaries are not discrete. That is, a parameter-setting approach to these issues is incompatible with the data. Rather, a much weaker "interaction of small parameters or constraints" is needed to capture the actual developmental nature of the language acquisition process (cf. Demuth, 1996c).

One of the key issues in understanding the nature of stages in the acquisition of phonology has been the realization that early units of production are not simply segments or even syllables, but actually *phonological words*. Once this higher level of structure is recognized, it can be shown that children learning either English or Dutch pass through a stage of prosodic word development where their early words can be characterized as *minimal words* or binary feet, even though they may show some (restricted) amount of variation in the segmental and syllabic realization of those feet (Demuth & Fee, 1995). This is illustrated in the word shapes seen in Stages II and III above. That is, syllabic and segmental constraints "compete" with requirements of well-formed prosodic words, resulting in a restricted set of multiple optimal outputs (Demuth, 1995). We turn now to an examination of how these types of variation can be understood from the perspective of constraint-interactions. Critical to this enterprise will be the necessity of invoking partial constraint ranking, or stratified domination hierarchies (Demuth, 1995; Tesar & Smolensky, 1996).

3.0 A Constraint-based Theory of Phonological Development

Over the past few years, several researchers have begun to explore issues of phonological development from the perspective of OT (Bernhardt & Stemberger, in press; Demuth, 1995, 1996b,c; Gnanadesikan, 1995; Goad, 1996; Levelt, 1996; Lleó, 1996; Paradis, 1995; Pater & Paradis, 1996; Velleman, 1996). Central to much of this work is the notion that initial constraint-rankings are not random as assumed in much of the learnability work (e.g., Tesar & Smolensky, 1995), but rather begin with the high ranking of constraints that yield *unmarked* phonological structures. This is not new in the field of acquisition studies. Jakobson (1941/68) proposed that the first segments children would use would be unmarked consonants (e.g., voiceless stops such as /p/) and unmarked vowels (such as low central /a/). What *is* new about more recent acquisition studies is the notion that early unmarked aspects of phonology apply to higher level *prosodic* structures as well. Phonologists have proposed that Core Syllables, or CV structures, are the unmarked form of syllable structure (e.g., Clements & Keyser, 1983), and that Minimal Words (or binary feet) are the unmarked form of Prosodic Words (McCarthy & Prince, 1990, 1994). From this perspective, the stages of acquisition outlined above can be characterized by a set of phonological constraints where unmarked values (e.g., Core Syllables, Minimal Words) are initially highly ranked, and where language development involves the demotion of these constraints (if needed) over time.

OT identifies two types of constraints: Structural Constraints govern the well-formedness of output form, and Faithfulness Constraints govern the mapping between input and output form. Some of the Structural Constraints needed to address the shape of children's early words are the following, where NO-CODA is shorthand for the two constraints NO-CODA$_{SON}$, NO-CODA$_{OBS}$.

(4) Structural Constraints

AlignR	Align (Ft,R,PrWd,R): Align the right edge of every Foot with the right edge of the Prosodic Word.
AlignL	Align (Ft,L,PrWd,L): Align the left edge of every Foot with the left edge of the Prosodic Word.
FTBIN	Feet are binary at some level of analysis (σ, μ; where σ denotes a syllable, and μ denotes a mora).
NO-CODA	Syllables may not have codas. NOCODA$_{SON}$, NO-CODA$_{OBS}$
*VV	No long vowels/dipththongs
*COMPLEX	No consonant clusters.

The faithfulness constraints involved are the following, where the constraints named in parentheses are simply notational variants of the same constraint in Correspondence Theory (McCarthy, 1995), and where IDENT[F] is shorthand for various IDENT constraints, such as that identifying laterals ([lat]), voicing ([voice]), and the quality of vowels([V]).

(5) Faithfulness Constraints

PARSE-SEG	Every segment in the Input has a Correspondent in the Output. (No Deletion (MAX-IO))
FILL	Every segment in the Output has a Correspondent in the Input. (No Epenthesis (DEP-IO))
IDENT[F]	Every feature in the Input has a Correspondent in the Output IDENT[V], IDENT[lat], IDENT[voice]

We assume that constraint reranking is achieved through the demotion of unmarked constraints, and that this takes place in the context of both positive evidence and implicit negative evidence. This is the notion of Constraint Demotion outlined in Tesar and Smolensky (1996). We also keep open the possibility that Constraint Promotion may also take place; that is, there may be equal pressures exerted in the developing phonology to make the output more faithful to the input (underlying form) in terms of the number of segments and syllables, or the featural content of segments. This is an empirical issue which will require further investigation.

Using a constraint-based framework, it is now possible to examine the structure of children's early words. Recall that at Stage I (the Core Syllable Stage) there was variation in vowel length. This is repeated below in (6). Recall also that Fikkert (1994) maintains that vowel length is noncontrastive at this point; that is, it exhibits free variation, and does not contribute to the prosodic structure of the word. These words, then, are not only monosyllabic, but also phonologically monomoraic, or Sub-Minimal Words.

(6) Stage I Core Syllables [ka:], [kɑ] /kla:r/ 'ready' (cf. Example (3))

The variation in shape of these earliest words is captured Tableau 1, where constraints that are hierarchically ranked with respect to one another are separated by a heavy line (and ≫); others are equally ranked (or are those for which there is no evidence of hierarchical ranking). IDENT[V] is shorthand for identification of vowel features. "*" means there is a violation for the constraint, and "!" indicates that the violation is fatal. Irrelevant areas are shaded.

Tableau 1. Unmarked prosodic constraints ranked high, faithfulness constraints ranked low
AlignL, AlignR,*VV,NO-CODA,FILL≫FTBIN,IDENT[V],PARSE-SEG

	/kla:r/ 'ready'	AlignL	AlignR	*VV	NO-CODA SON,OBS	FILL	FTBIN	PARSE-SEG	IDENT [V]
i. ☞	[kɑ]						*	***	*
ii. ☞	[ka:]μ						*	**	
iii.	[ka:]μμ			*!					
iv.	[ka:rɑ]					*!			
v.	[ka:r]				*!			*	

Here we see that the unmarked structural well-formedness constraints mediate against long vowels, codas, and epenthetic segments, permitting only a monomoraic phonological word. It appears that these constraints must all dominate the faithfulness constraints as well as FTBIN. Demuth and Fee (1995) capture this in terms of the prosodic hierarchy (Nespor & Vogel, 1986; Selkirk, 1984), where the only structure allowed is that in (7). That is, a Phonological Word may or may not consist of a Foot, but if it does, that Foot consists of only a monomoraic syllable.

(7) Stage I - Sub-Minimal Words

Pw
|
(FT)
|
σ

Given the high ranking of constraints prohibiting long vowels, coda consonants, and the use of epenthetic material, the resulting optimal surface forms are CV or CVV. That is, both (i) and (ii) in Tableau 1 are "optimal" precisely because they both have the phonological value of a monomoraic monosyllabic form. Note that these two forms do not actually compete with each other in a meaningful way. Both forms are permitted based on the fact that vowel length is not contrastive within the child's phonology at this point. This is a case of noncontrastive variation as described by Rice (1996a,b) and Rice and Avery (1995). Only once vowel length becomes contrastive will these forms have a different phonological status, one becoming more highly preferred. Therefore, this is a case of *multiple optimal outputs*, but one where faithfulness constraints must be extremely low-ranked such as to have little effect on the grammar. Some might even propose that this type of variation might be best captured in terms of articulatory factors. Further research will be needed to investigate this possibility more fully.

Critically, however, the variation in Tableau 1 differs from the types of variation found elsewhere in early acquisition. Consider the Minimal Word Stage (Stage II), where vowel length is still not contrastive, but where obstruent codas begin to appear. Examples are presented again in (8) (cf. Example (3)).

(8) Stage II [bɑf], [bɑ] /bɑl/ 'ball'

As noted in Tableau 2, at this point, sonorant codas are still not permitted, providing evidence that there must be two coda constraints which operate separately. Long vowels are still not permitted, nor are epenthetic vowels.

Tableau 2. Bimoraic (C)VC$_{son}$ Minimal Words appear - Demotion of NO-CODA$_{OBS}$
AlignL/R, *VV,NO-CODA$_{SON}$,FILL ≫ FTBIN,IDENT[lat],[v],PARSE-SEG ≫ NO-CODA$_{OBS}$

	/bɑl/ 'ball'	Align L/R	*VV	NO-CODA SON	FILL	FTBIN	PARSE-SEG	IDENT [lat], [v]	NO-CODA OBS
i. ☞	[bɑ]					*	*		
ii.	[bo:]		*!						
iii.	[bɑfə]				*!				
iv. ☞	[bɑf]							*	*
v.	[bɑl]			*!					

Once NO-CODA$_{OBS}$ has been demoted, monosyllabic phonological words can take the shape of binary feet by having a coda consonant, but only if it is not a sonorant. This means that the child has two choices for attempting to meet the target form. Either the features of the coda consonant can be changed (i.e., an obstruent can be used), thereby violating IDENT[lat], or the offending coda can be omitted altogether, thereby violating both FTBIN and PARSE-SEG. Both forms are possible only if both FTBIN and IDENT[lat] are equally ranked with respect to one another. If either is more highly ranked, then either [bɑ] or [bɑf] will be preferred, but not both. That is, this is a true case of multiple optimal outputs, where two phonologically different surface forms are equally valued by the grammar. But this can only occur if FTBIN, PARSE-SEG, and IDENT[lat] are all equally ranked with respect to one another.

We now turn to Stage III, where multiple optimal outputs are found again. These are repeated in (9) (cf. Example (3)).

(9) Stage III [bo:], [bɑu] /bɑl/ 'ball'
[pɑv], [bɑl]

The constraint ranking needed to account for these forms is shown in Tableau 3, where *VV and NO-CODA$_{SON}$ have been demoted. FTBIN now plays a more active role in the grammar. There is no evidence as to the relative ranking of FTBIN with respect to FILL and the Align constraints; therefore, it is left unranked with respect to these. NO-CODA$_{SON}$, however, still seems to play some role. It must be equally ranked with respect to PARSE-SEG and the IDENT constraints; thereby allowing not only for the target form to be optimal, but several other candidates as well.

Tableau 3. Bimoraic (C)VC$_{son}$Minimal Words appear - Demotion of *VV and NO-CODA$_{SON}$
AlignL/R,FILL,FTBIN ≫ PARSE-SEG,IDENT[lat],[voice],[V],NO-CODA$_{SON}$ ≫ *VV,NO-CODA$_{OBS}$

	/bɑl/ 'ball'	Align L/R	FILL	FTBIN	PARSE-SEG	IDENT [lat], [voice], [V]	NO-CODA SON	*VV	NO-CODA OBS
i.	[bɑ]			*!	*				
ii. ☞	[bo:]					*		*	
iii. ☞	[bɑu]					*			
iv. ☞	[pɑv]					**			*
v. ☞	[bɑl]						*		

All the optimal outputs are bimoraic Minimal Words, where vowel length is now contrastive, used as a means of compensatory lengthening - presumably to meet the prosodic requirements of FTBIN which have now become more highly ranked. That it is FTBIN and not PARSE-SEG that is active here is evidenced by other word shapes found at this time, such as [pɔm] < /bɑ'lɔn/ 'ballon' (Fikkert, 1994). Thus, PARSE-SEG is still ranked lower than FTBIN, as are the IDENT constraints. Note critically, however, that the IDENT constraints are all ranked equally with respect to one another, allowing for four different optimal output forms. Here again we see the need for a stratified domination hierarchy where groups of contraints are hierarchically ranked with respect to one another, but where the individual constraints within a group have equal status within the grammar. This gives rise to multiple optimal outputs at this stage in grammar learning - a stage which will eventually pass. This is shown at the next stage of acquisition, as noted in (10), where the target constitutes the unique optimal output.

(10) Stage IV [bɑl] /bɑl/ 'ball'

This can be accounted for if NO-CODA$_{SON}$ has been demoted to a position where it is now ranked lower than the IDENT constraints. This is shown in Tableau 4.

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