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Variation in acquisition: An optimal approach

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Abstract

The presence of intra-speaker variation in early acquisition has long presented an intriguing problem for researchers of phonological development. This paper demonstrates how Optimality Theory is useful in identifying three different types of variation in acquisition, only one of which is a true case of 'multiple optimal outputs. It then illustrates how *multiple optimal outputs* can be handled from an Optimality theoretic perspective if 'partial constraint rankings', or *stratified domination hierarchies*, are allowed (Demuth 1995, 1997, Tesar & Smokensly 1996). The paper concludes with a discussion of what Optimality Theory can contribute to the understanding of intra-speaker variation in other domains, including second language learning, 'optional' structures in adult language, and processes of historical change.

1. Introduction

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

xx other ex

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

Some researchers have shown that early variation is not random, but results from a phonological system that lacks certain featural contrasts (e.g. Ingram 1976, 1996, Vihman, Macken, Miller, Simmons, & Miller 1985, Rice 1996a,b, Rice & Avery 1995). In contrast, other researches observe that early segmental variation is partially due to interactions with higher-level prosodic structures such as the syllable (e.g. Fudge 1969, Macken 1980, Stoel-Gammon 1983, 1996, Stemberger 1992, Dinnsen 1992, 1996a,b, Levelt 1994, 1996). Still others find interactions between segments, syllables, and higher-level phonological words (Fee 1992, 1994, 1995, 1996, Demuth 1995, 1996a,b,c, Demuth & Fee 1995). 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. Finally, other types of apparent surface variation result from different underlying inputs (Matheir 1989, Grimshaw 1995). This paper shows how Optimality Theory is especially useful in exploring the second type of variation, where *multiple optimal outputs* result from partial constraint ranking, or *stratifed domination hierarchies* (Tesar & Smolenksy 1996). However, Optimality Theory also provides a framework for identifying the other two types of variation as well.

Since the development of Optimality Theory (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. Demuth 1995, 1996b,c, Gnanadesikan 1995, Paradis 1995, Pater & Paradis 1996, Goad 1996, Levelt 1996, Lleó 1996, Velleman 1996, Bernhardt & Stemberger (in press)). 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 Optimality Theory has been the notion that there is only one output (surface form) for a given input (underlying representation). The question has then been, does Optimality Theory 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 in Tesar & Smolensky (1996) in terms of *stratified domination hierarchies.*

This paper demonstrates that children's early words are generally prosodically wellformed, 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 Optimality Theory 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 within an Optimality-theoretic framework in terms of partial constraint ranking, or *stratified domination hierarchie*s. Section 4. concludes with a discussion of how this this approach to problems of variation in acquisition might be extended to handle variation problems in other domains.

2. The 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 & Fee (1995), Gennari & 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, where vowel length is not contrastive at Stages I and II, yet 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 descrete. 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		
I	[ka:], [kɑ]	/kla:r/	‘ready’	J (1;4-1;5)
II	[a:p], [ɑp]	/a:p/	‘monkey’	J (1;6-1;7)
	[bɑf], [bɑ]	/bɑl/	‘ball’	
III	[bo:], [bɑu]	/bɑl/	‘ball’	J (1;10-2;0)
	[pɑv], [bɑl]			
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 mile-stones in development, the path of acquisition is often a continuous one, where ‘stages’ can be identified, but where the boundaries are not descrete. 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 both English and 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 wellformed 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. 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 Optimality Theory (Demuth 1995, 1996b,c, Gnanadesikan 1995, Paradis 1995, Pater & Paradis 1996, Goad 1996, Levelt 1996, Lleó 1996, Velleman 1996, Bernhardt & Stemberger (in press)). 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 begins 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/back /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.

Optimality Theory identifies two types of constraints: Structural Constraints govern the wellformedness 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*

ALIGN-R	Align (Ft, R, PrWd, R) Align the right edge of every Foot with the right edge of the Prosodic Word
ALIGN-L	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 (□, □)
NO-CODA	Syllables may not have codas NO-CODA$_{SON}$, NO-CODA$_{OBS}$
*VV	No long vowels/diphthongs
*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, voicing, and the quality of vowels.

(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 demontion 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 & 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 non-contrastive at this point. That is, it exhibits free variation, and does not contribute to the prosodic structure of the word. These words are then not only monosyllabic, but also phonologically monomoraic, or Sub-Minimal words.

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

The variation in shape of these earliest words is captured in the tableau in (7), where constraints that are hierarchically ranked with respect to one another are indicated with the solid line (and >>), whereas those that are equally ranked (or for which there is no evidence of hierarchical ranking) are separated by a dotted line (and ','). IDENT[V] is shorthand for identification of vowel features.

(7) Unmarked prosodic constraints ranked high, faithfulness constraints ranked low

ALIGN-L, ALIGN-R, *VV, NO-CODA, FILL >> FTBIN, IDENT[V], PARSE-SEG

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

Here we see that the unmarked structural wellformedness 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 & Fee (1995) capture this in terms of the prosodic hierarchy (Selkirk 1984, Nespor & Vogel 1986), where the only structure allowed is that in (8). That is, a Phonological Word many or many not consist of a Foot, but if it does that Foot consists of only a monomoraic syllable.

(8) Stage I - Sub-Minimal Words

Pw
|
(FT)
|
□

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 (7i) and (7ii) 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 any 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 non-contrastive variation as described by Rice (1996a,b) and Rice & Avery (1995). Only once vowel length becomes contrastive will these forms have a different phonological status, one becoming more highly preferred. This is therefore a case of *multiple optimal outputs*, but one where constraints faithfulness constraints must be extremely lowly 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 (7) 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 (9=3).

(9) Stage II [bɑf], [bɑ] /bɑl/ ‘ball’

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.

(10) Bimoraic (C)VC$_{son}$ Minimal Words appear - demotion of NO-CODA$_{OBS}$

ALIGN-L/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 (11=3).

(11) Stage III [bo:], [bɑu] /bɑl/ ‘ball’
[pɑv], [bɑl]

The constraint ranking needed to account for these forms is shown in the tableau in (12) 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: It is therefore 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. This is shown in (12).

(12) Bimoraic (C)VC$_{son}$ Minimal Words appear - demotion of *VV and NO-CODA$_{SON}$

ALIGN-L/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 [pòm] < /bɑˈlòn/ '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 constraints 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, where the target constitutes the unique optimal output.

(13) 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 the tableau in (14).

(14) Bimoraic (C)VC Minimal Words - demotion of NO-CODA$_{SON}$

ALIGN-L/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 of those forms which violate IDENT constraints are now ruled out, and the grammar permits only the target form.

In sum, the empirical data on phonological development points to the fact that children's early grammars permit multiple surface forms for the same underlying target, and that this is especially prevalent at early stages of acquisition, often prior to the age of 2. The above discussion has illustrated how these forms can be handled from a constraint-based perspective if partially ordered constraints, or *stratified domination hierarchies*, are permitted along the lines implemented in Demuth (1995, 1996c) and formalized in Tesar & Smolensky (1996).

4. Discussion

This paper has examined the variation in the shape of children's early words, focusing specifically on the problem of *multiple optimal outputs*. It first showed that certain types of variation may be due to the lack of featural contrasts. This is illustrated by the lack of contrastive vowel length found in examples such as (1a) [kɑ:] ~ [kɑ] < /klɑ:r/ 'ready', where both forms have equal status within the grammar. This can be captured by a given constraint ranking where constraints are hierarchically ranked with respect to one another, and where certain featural faithfulness constraints are ranked relatively low. Other types of variation, however, involve actual competition between different types of phonological structures, where the equal ranking of prosodic, segmental and featural constraints gives rise to *multiple optimal outputs*. This is illustrated by examples such as (1b) [bɑ] ~ [bɑf] < /bɑl/ 'ball', where either prosodic or featural constraints are violated, depending on the form. These constraints must therefore be *equally ranked*. Thus, even if the child begins the learning process with unmarked constraints ranked highest in the grammar, as assumed in most of the Optimality-theoretic work on language acquisition, there is a certain indeterminacy with respect to how certain structural and faithfulness constraints are ranked with respect to one another, and at certain points they may be equally ranked. We expect this to be particularly true at the earliest stages of acquisition such as those examined here. Over time we expect constraints be become increasingly hierarchically ranked, gradually converging on the target adult grammar.

Other types of variation appear to require a slightly different explanation. Grimshaw (in press) notes that different *outputs* may actually have different *inputs*, exploring these issues with respect to wh-in situ versus wh-movement constructions in English. Demuth (1996b, in press) addresses the implications of this approach for acquisition, where a target word may surface differently depending on whether it is produced in isolation (e.g. in a one-word utterance) or as part of a larger phonological phrase (e.g. in a two-word utterance). Many of the examples of variation in Matthei (1989) are of this sort, as illustrated in (1c) [mɔ] ~ [mɔmɔ] < /mɑmɑ/ 'mama', where the form [mɔ] occurred in two-word utterance, and was therefore reduced, and Gennari & Demuth (1997) and Demuth (1997) explore similar types of variation in the acquisition of Spanish. Thus, some types of so-called 'variation' may actually have different 'inputs', resulting in apparent surface variation in the shape of a given phonological word.

Other proposals regarding the nature of variation have also been made. Grimshaw (1994) suggests that some types of variation in acquisition might actually represent fluctuation between two different grammars. We can understand this in terms of bilingual children who presumably have two separate grammars, and may switch between them as needed (cf. Paradis 1995, Pater & Paradis 1996). In theory, then, there should be nothing cognitively or linguistically unacceptable about such a proposal. It is not clear, however, how two grammars for a given language would eventually be collapsed into one.

In conclusion, this paper has shown how an Optimality-theoretic approach to *multiple optimal outputs* in acquisition can be handled in terms of partially ordered constraint rankings, or *stratified domination hierarchies*. From this perspective children's grammars are similar to adult grammars in that constraints are available as part of UG, yet learning a target grammar involves a period of indeterminacy, where some constraints may be equally ranked with respect to one another. Thus, children's grammars are similar to adult grammars in kind, yet different in detail, exhibiting aspects of 'weak-continuity'. Further research will be needed to determine whether variation in other domains, such as second language learning, reports of adult variation (such as Dutch /mèlk/ ~ /mèlək/ 'milk'), and/or problems of aphasic speech, are truly cases of *multiple optimal outputs*, or are better treated as instances of different inputs or different grammars. This paper has attempted to illustrate how Optimality Theory can provide a framework for exploring these issues in greater depth.

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