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## Multiple Optimal Outputs in Acquisition\*

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The presence of intra-speaker variation in early acquisition has long presented an intriguing problem for researchers of phonological development. It would also appear to present difficulties for Optimality Theory, a theory which by its very nature states that one and only one surface output form is 'optimal'. This raises fundamental questions about the nature of children's emerging grammars with respect to the issue of 'Discontinuity' versus Strong or Weak 'Continuity'. That is, are children's grammars qualitatively different from those of adults, or are they basically the same? It also poses interesting questions for Optimality Theory regarding its ability to generalize to problems of language learning: Is Optimality Theory useful in exploring issues of early language acquisition? If so, what does it have to say about variation - or Multiple Optimal Outputs for a given target? Must some of the original assumptions about Optimality-theoretic grammars be challenged or changed to account for variation in child language?

The purpose of this paper is to explore these issues more fully. First, the 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 this type of variation can be handled from an Optimality-theoretic perspective if 'partial constraint rankings', or *stratified domination hierarchies*, are allowed (Demuth 1995, 1997, Tesar & Smolensky 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, language in disordered populations, 'optional' structures in adult language, and processes of historical change.

### 1 Variation in Early Words

Since the development of Optimality Theory (Prince & Smolensky 1993/in press) research on the acquisition of phonology has begun to expand, 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 1997). One of the problems, however, with applying an Optimality-theoretic analysis to the area of language acquisition involves the issue of variation, or 'multiple outputs' for a given target form. At the very heart of Optimality Theory is the notion that there is only one 'optimal' output (surface form) for a given input (underlying representation). The question has then been, does Optimality Theory have

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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 Tesar & Smolensky (1996) in terms of *stratified domination hierarchies*, or sets of 'strata', where several constraints (unranked with respect to one another in a given stratum) dominate another stratum of constraints (also unranked with respect to one another), and so on, as shown in (1).

- (1)  $\{C_1, C_2, \dots, C_3\} \gg \{C_4, C_5, \dots, C_6\} \gg \dots \gg \{C_7, C_8, \dots, C_9\}$

This paper provides empirical support for *stratified domination hierarchies*, and explores the conditions under which these are found. It also discusses the implications of *stratified domination hierarchies* for the notion of 'stages' of development, a concept researchers find convenient to use, yet one which often defies quantification.

What, then, are the different types of variation that occur in children's early utterances? Some researchers have shown that early variation, especially at the level of segments, is not random, but result from a phonological system that lacks certain featural contrasts (e.g. Ingram 1976, 1996, Vihman, Macken, Miller, Simmons, & Miller 1985, Rice & Avery 1995, Rice 1996a,b, Dinnsen 1992, 1996a). This type of variation I call No Contrast. On the other hand, other researchers 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 1996b, 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, in press, Demuth & Fee 1995). Some of this work begins to invoke the term 'constraints' in trying to capture the types of segmental/syllabic/prosodic word interactions operating in children's early phonological development. It is this type of variation, which I call Multiple Optimal Outputs, that presents a challenge for a theory that permits only a unique output form. It is constructions such as these that are the focus of this paper. The third type of variation is qualitatively different, where surface variation results from different target forms, or Different Inputs (Grimshaw (in press)). Such variation is also found in adult language (e.g. I saw 'im vs. I saw HIM), and can be handled within a constraint ranking which is completely hierarchical. These three types of variation are summarized in (2), with illustrative examples given in (3).

- (2) Different Types of Variation in Language Acquisition
- a. No Contrast
  - b. Multiple Optimal Outputs
  - c. Different Inputs

No Contrast means that the child does not have a contrastive feature. This could be due to perceptual, articulatory, or phonological factors (e.g. not having posited an appropriate phoneme). For example, in early Dutch, Fikkert (1994) reports that children have no contrastive vowel length. Thus, though the surface forms in (3a) differ, they have the same underlying representation and are generated by the same hierarchically ordered ranking of constraints. This is

qualitatively different from cases like those in (3b), where a coda consonant 'optionally' appears. This is a case of Multiple Optimal Outputs, where the constraints PARSE-SEG(MENT) and IDENTIFY-F(EATURE) must be equally ranked with respect to one another, yielding two equally valued forms. This differs again from the forms in (3c), where 'mama' surfaces as two syllables in one case, and as one syllable in the next. Note, however, that the targets are different: This is a case of Different Inputs, where surface variation results from a difference in underlying (input) form.

- (3)
- |    | Child        | Adult Target            |                          |
|----|--------------|-------------------------|--------------------------|
| a. | [ka:] ~ [ka] | /kla:r/ 'ready'         | Dutch - Fikkert (1994)   |
| b. | [ba] ~ [baf] | /bal/ 'ball'            | Dutch - Fikkert (1994)   |
| c. | [mɔmɔ]       | /mama/ 'mama'           | English - Marthei (1989) |
|    | [mɔki]       | /mamɔkiz/ 'mama's keys' |                          |

The purpose of this paper is to demonstrate that 1) these three types of variation are qualitatively different, and 2) Optimality Theory can provide a framework for understanding Multiple Optimal Outputs if 'partial constraint ranking', or *stratified domination hierarchies*, are permitted. 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 identifies the three different types of 'variation' in acquisition, and demonstrates how Multiple Optimal Outputs can be handled within an Optimality-theoretic framework in terms of 'partial constraint ranking', or *stratified domination hierarchies*. Section 4 concludes with a discussion of how these findings can be extended to handle problems of variation in other domains.

## 2 The Prosodic Structure of Early Words

Fudge (1969) was one of the first to recognize the importance of the prosodic structure of syllables 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 early existence of prosodic constraints in languages as prosodically different as English, Dutch, Spanish, and Sesotho. Although the specific nature of these 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 eight 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.

(4) 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 <sub>son</sub>
Stage IV	Codas, Vowel length distinctive (C)VC

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

(5) Stage	Child	Adult Target	
I	[ka:], [ka]	/kla:r/ 'ready'	J (1;4-1;5)
II	[a:p], [ap]	/a:p/ 'monkey'	J (1;6-1;7)
	[baf], [ba]	/bal/ 'ball'	
III	[bo:], [bau]	/bal/ 'ball'	J (1;10-2;0)
	[pav], [bal]		
IV	[bal]	/bal/ 'ball'	J (2;0)

The Dutch examples in (3) are similar to developmental patterns found in English as well (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 between 'stages' are not categorical. 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 these words may show some (restricted) amount of segmental and syllabic variation (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 amount of 'variation' at a certain point in the acquisition process (Demuth 1995). The next section provides examples of these different types of variation, and how they can be handled from an Optimality-theoretic perspective.

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 1997). Central to much of this work is the notion that initial constraint-rankings are not random or unordered, as assumed in much of the learnability work (e.g. Tesar & Smolensky 1995), but rather begins with the high ranking of certain structural constraints (e.g. NO-CODA) and low ranking of certain faithfulness constraints, thereby yielding early '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 unmarked aspects of early phonology apply at 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.

(6) Structural Constraints

ALIGN-R	Align (Ft, R, PW, R) Align the right edge of every Foot with the right edge of the Prosodic Word
ALIGN-L	Align (Ft, L, PW, 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 ( $\sigma, \mu$ )
NO-CODA	Syllables may not have codas NO-CODASON, NO-CODAOBS
*VV	No long vowels/diphthongs
*COMPLEX	No Consonant clusters

The Faithfulness Constraints involved are given below, where the constraints named in parentheses are 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.

(7) *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[lat], IDENT[voice], IDENT[V]

Constraint reranking is achieved through the demotion of 'unmarked' constraints, and 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). Each of the types of surface 'variation' will now be considered.

3.1 No Contrast

Recall that at Stage I there was no underlying contrast in vowel length, with surface forms alternating between long and short vowels.

- (8) Stage I [ka:] ~ [ka] /kla:r/ 'ready'

Fikkert (1994) maintains that vowel length is non-contrastive at this point. That is, short and long vowels exhibit free variation, and do not contribute to the prosodic structure of the word.<sup>1</sup> These words are then not only monosyllabic, but also monomoraic. This is indicated in the tableau by one mora [ka:]μ. The variation in shape of these earliest words is captured in the tableau below, where constraints that are hierarchically ranked with respect to one another are indicated with the solid line (and >>), and those for which there is no evidence of hierarchical ranking (for this particular candidate set) are separated by a dotted line (and ','). Critically, however, it is assumed that all these constraints are hierarchically ranked with respect to one another.

<sup>1</sup> Note that these vowels also appear to differ in vowel quality. It is possible, however, that issues of vowel quality and vowel length (or tense/lax distinctions) are intricately connected, with the former being resolved once the latter distinctions have been made. Further research will have to explore these issues more fully. For the purposes of this example vowel length (not vowel quality features) is considered to be the relevant factor.

- (9) Unmarked prosodic constraints ranked high,  
faithfulness constraints ranked low  
\*VV, NO-CODA, FILL >> FTBIN, PARSE-SEG

(10)	/kla:r/	*COMPLEX	*VV	NO-CODA	FILL	FTBIN	PARSE-SEG
i.	[ka]					*	**
ii.	[ka:]μ					*	**
iii.	[ka:]μμ		*!				
iv.	[ka:ra]				*!		
v.	[ka:r]			*!			

The tableau shows that the unmarked structural wellformedness constraints are highly ranked, mediating against long vowels, codas, and epenthetic segments. These constraints dominate FTBIN and PARSE-SEG. Both of the winning candidates violate these constraints, but they do so equally. That is, these two forms do not '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 & Avery (1995) and Rice (1996a,b). 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 variation, but one where 'partial constraint ranking', or *stratified domination hierarchies*, are not required. Variation due to No Contrast seems to be typical not only of normally developing children, but also of some children with phonological disorders (Dimmsen 1993). It is highly likely that No Contrast characterizes much of the variation found in speech productions of adult second language learners as well (cf. Davidson 1997).

3.2 Multiple Optimal Outputs

Now consider the Minimal Word Stage (Stage II), where obstruent codas begin to appear (11).

- (11) Stage II [baf] ~ [ba] /ba/ 'ball'

Sonorant codas, however, do not yet occur, indicating that NO-CODA must consist of two different constraints (NO-CODASON and NO-CODAOBS) which are separately ranked. The resultant constraint ranking is given in (12) and in the tableau in (13), where the constraints *in italics* (and between curly brackets {...}) belong to the same strata, i.e. they are unranked with respect to one another, as part of a *stratified domination hierarchy*.

- (12) Demotion of NO-CODAOBS  
\*VV, NO-CODASON, FILL >> {FTBIN, IDENT[lat], PARSE-SEG},  
>>...>> NO-CODAOBS

(13)	/ba/	*VV	NO-CODASON	FILL	FTBIN	PARSE-SEG	IDENT [lat]	NO-CODAOBS
i.	[ba]				*	*		
ii.	[bafə]			*!				
iii.	[baf]						*	*
iv.	[bal]		*!					

Once NO-CODAOBS 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 /ba/ 'ball': Either the features of the coda consonant can be changed (13iii), thereby violating IDENT[lat], or the offending coda can be omitted altogether (13i), thereby violating both FTBIN and PARSE-SEG. Both forms are possible only if FTBIN, PARSE-SEG, and IDENT[lat] are equally ranked with respect to one another. If one is more highly ranked, either [ba] or [baf] will be optimal, but not both.

This is a case of Multiple Optimal Outputs, where two different surface forms are equally valued by the grammar because certain constraints are not hierarchically ranked with respect to one another. That is, several constraints occur as part of the same stratified domination hierarchy. This is illustrated in (14).

$$(14) \{C_1, C_2, \dots, C_3\} \gg \{FTBIN, PARSE-SEG, IDENT [lat]\} \\ \gg \dots \gg \{C_7, C_8, \dots, C_9\}$$

Note, however, that two other tenants of Optimality Theory (Prince & Smolensky 1993/in press) appear to be violated by proposing that [ba] and [baf] are equally ranked. The first is the notion of *gradient constraint violation*, where a constraint may be violated more than once. In such cases the candidate which has the fewest number of violations is the 'optimal' one. If *stratified domination hierarchies* are treated in a gradient manner, [baf] would be the 'optimal' candidate since it violates only one constraint within the stratum, whereas [ba] violates two. Alternatively, it could be that constraint violations within a given stratum are treated categorically. The empirical evidence in (13) would appear to give support for such a position.

A subsequent issue raised by the tableau in (13) is the notion that if two candidate forms equally violate a highly ranked constraint (or set of constraints within a stratum), the 'optimal' form will be determined by constraints which are violated further down the hierarchy. That is, given that [baf] violates NO-CODAOBS and [ba] does not, [ba] should be the optimal candidate. This raises several issues: First, it is possible that other constraints might be equally ranked with NO-CODAOBS in another stratum, or that NO-CODAOBS is actually ranked in the same stratum as {FTBIN, PARSE-SEG, IDENT [lat]}. Either would result in

exhaustively paired constraint violations for both candidates, thereby yielding no unique winner.

Alternatively, it could be that NO-CODAOBS has been demoted so low that it ceases to have an effect on the child's grammar. Although lowly ranked constraints are assumed to be 'active' in adult grammars (McCarthy & Prince 1994), the status of lowly ranked constraints in the grammar of young language learners has not been addressed. It is possible, however, that one of the differences between child and adult grammars may actually be due to non-linguistic factors such as short-term memory and processing limitations, and these limitations in children may influence the learning process (cf. Elman 1991, 1993). In Optimality-theoretic terms this might be realized as an upper bound on the number of constraints that can play an active role in the grammar. It is therefore possible that once young language learners demote a constraint far enough, it will no longer play an active role in evaluating candidate forms. Larry Leonard (p.c.) suggests that such a scenario might account for some of the persistent intraspeaker variation found in children with Specific Language Impairment.

Many of these issues arise at the next stage of acquisition as well. Consider Stage III, where \*VV and NO-CODASON have been demoted, but where Multiple Optimal Outputs still occur. In fact, four different forms are now attested - a situation some might think would represent 'regression'.

$$(15) \text{ Stage III } [bo:] \sim [bau] \sim [pav] \sim [bal] \quad /ba/ \text{ 'ball'}$$

The constraint ranking needed to account for these forms is given (16) and in the tableau in (17). Even though NO-CODASON has been demoted, however, it 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 an optimal output, but several other candidates as well. FTBIN is now more highly ranked and plays a more active role in the grammar, though there is no evidence as to the relative ranking of FTBIN with respect to FILL. These have therefore be left unranked with respect to one another.

$$(16) \text{ Demotion of *VV and NO-CODASON } \\ \text{FILL, FTBIN} \gg \{ \text{PARSE-SEG, IDENT[lat], [voice], [V],} \\ \text{NO-CODASON} \} \gg *VV, \text{NO-CODAOBS}$$

(17)	/ba/	FILL	FTBIN	PARSE-SEG	IDENT [lat], [voi], [V]	NO-CODASON	*VV	NO-CODAOBS
i.	[ba]		*!					
ii.	[bo:]				**		*	
iii.	[bau]				*			
iv.	[pav]				**			*
v.	[bal]					*		

All the optimal outputs in (17) are bimoraic Minimal Words, where vowel length is contrastive and used in (17ii) as a means of compensatory lengthening, thereby meeting the prosodic requirements of FTBIN. That it is FTBIN and not PARSE-SEG that is more highly ranked is evidenced by other word shapes found at this time, such as [pɔm] < /bɑ'ɔn/ 'ballon' (Fikkert 1994). Thus, PARSE-SEG is still ranked lower than FTBIN, as are the IDENT constraints. Note, however, that the IDENT constraints are all ranked equally with respect to one another, allowing for several different outputs. Here again the need for a *stratified domination hierarchy* becomes apparent, where groups of constraints may be hierarchically ranked with respect to one another, but where the constraints within a stratum have equal status within the grammar, as illustrated in (18), giving rise to Multiple Optimal Outputs at this stage of development.

- (18) {C<sub>1</sub>, C<sub>2</sub>, . . . , C<sub>3</sub>}  
 >> {PARSE-SEG, IDENT [lat], [voi], [V], NO-CODASON}  
 >> . . . >> {C<sub>7</sub>, C<sub>8</sub>, . . . , C<sub>9</sub>}

But Multiple Optimal Outputs do not persist for long, at least in normally developing children's grammars. This is seen at the next stage of acquisition, where the child's output is now unique and approximates the target form. The child now has an 'optimal' candidate for the target /bal/ 'ball'.

- (19) Stage IV    [ba]        /bal/        'ball'

This can be accounted for if NO-CODASON is demoted so that it is more lowly ranked with respect to the IDENT constraints (20). This is illustrated in the tableau in (21).

- (20) Demotion of NO-CODASON  
 FILL, FTBIN >> PARSE-SEG, IDENT[lat],[voice],[V],  
 >> NO-CODASON, \*VV, NO-CODA OBS

(21)	/bal/	FILL	FTBIN	PARSE-SEG	IDENT [lat], [voi], [V]	NO-CODASON	*VV	NO-CODA OBS
i.	[ba]		*!					
ii.	[bo:]				*!*			
iii.	[bau]				*!			
iv.	[pav]				*!*			
v.	[bal]					*		

All of the candidates which violate the IDENT constraints are now ruled out, and the grammar permits only the candidate in (21v) as an optimal output. The absolute ranking of constraints is not fully evident given only this form, but

*stratified domination hierarchies* are no longer needed to account for the child's output at this stage of development.

Part of the challenge for language learners is to determine not only which constraints play an active role in the language they are learning, but how these need to be ranked with respect to one another. That Constraint Demotion occurs through a process of Error Driven Learning is uncontroversial. Yet a comparison of the tableaux in (13), (17), and (21) shows that Constraint Demotion itself is not sufficient. Rather, some constraints (in this case NO-CODASON) must undergo a *series* of demotions from one stratum to the next. This process may take place over a number of months (or years), giving rise to Multiple Optimal Outputs. Interestingly, a similar phenomenon is found in second language acquisition (cf. Davidson 1997).

This section demonstrates that at early stages of language development certain constraints may not be hierarchically ranked, but rather grouped together in a series of *stratified domination hierarchies*, resulting in Multiple Optimal Outputs. Such forms are qualitatively different from the multiple outputs found in cases of No Contrast, where featural contrasts are not made in the input. The next section considers another case of variation in early language - but one where different surface output forms result from Different Inputs.

### 3.3 Different Inputs

As noted above, another type of variation that occurs in early acquisition is that which results from different target forms, or Different Inputs. Consider the following example from Matthei (1989), where the child's surface form for /mama/ 'mama' at 1;5 years takes two different shapes, [mɔmɔ] and [mɔ]. Note, however, that the targets (inputs) are also different: In (22a) 'mama' constitutes a one-word utterance, whereas it is part of a two-word utterance in (22b). It should therefore come as no surprise that the outputs for these two 'mama' targets might differ.<sup>2</sup>

- (22) Child                      Adult Target  
 a. [mɔmɔ]                      /mama/        'mama'  
 b. [mɔki]                        /mamazki/    'mama's keys'

Examples such as those in (22) illustrate the presence of higher-level prosodic constraints such as those identified by Selkirk (1984) and Nespor & Vogel (1986) operating on this child's early two-word utterances. What appears to be happening in (22) is that the Phonological Phrase (PP) in (22b) is constrained to being the shape of a Phonological Word (PW), where a PW is a binary foot (cf. Demuth & Fee 1995, Demuth 1995, in press). In Optimality-theoretic terms this can be handled by appealing to an ALIGNMENT constraint where PWs are Binary

<sup>2</sup> Note that /a/ is consistently realized as /ɔ/ in these examples. A comprehensive investigation of the child's vocalic inventory would be needed to assess the relationship between the two. However, it is highly likely either that /a/ and /ɔ/ do not contrast, or that /a/ is neutralized to /ɔ/, and that for this reason [mama] does not surface as a possible candidate at this time.

Feet, and a PW is aligned with both the right and left edge of a PP. That is, a PW is prosodically circumscribed. This follows directly from the theory of Generalized Alignment (McCarthy & Prince 1993) which develops an edge-based theory of syntax-prosody interface, and from Selkirk's (1996) typology of prosodic structures, where two PWs which are part of the same PP can be characterized as follows:

- (23) Syntactic Structure [Lex Lex]  
 Prosodic Structure ((lex) PW (lex)PW )PP

In addition, there appears to be a highly ranked constraint in children's grammars that stressed syllables (or at least stressed nuclei) be mapped into output forms (cf. Echols & Newport 1992, Gerken & McIntosh 1993, Demuth 1996c). The following constraints are therefore needed to account for the data in (22).

- (24) ALIGNFT-R/L Align the R/L edge of every Foot with the R/L edge of the Phonological Word
- ALIGNPW-R/L Align the R/L edge of every Phonological Word with the R/L edge of the Phonological Phrase
- PARSESTRESS Parse stressed syllables

Now consider the candidates in (26a) and (26b), where the same constraint ranking holds, but the inputs are different.

- (25) PARSESTRESS, ALIGNFT-R/L, ALIGNPW-R/L, NO-CODA  
 ... >> ... PARSE-SEG

(26a)	/mama/	PARSE STRESS	ALIGN FT-R/L	ALIGN PW-R/L	NO-CODA	PARSE -SEG
i.	[mama]					
(26b)	/mamazkiz/					
i.	[mɔki]					****
ii.	[mamaki]		*!			
iii.	[mamazkiz]		*!			

Thus, the same constraint ranking yields different surface forms for 'mama' when it is embedded in different input forms. This is classic case of Different Inputs, where multiple surface forms result from different underlying inputs/targets. Such forms were initially identified by Grimshaw (in press) in terms of apparently 'optional' structures in adult syntax. However, as Grimshaw showed, such forms are not 'optional', but rather the result of different inputs to the system. It is

Different Inputs that appears to account for the variable appearance of word-initial syllables in early Spanish Phonological Words, these syllables being omitted in the context of a preceding determiner (cf. Gennari & Demuth 1997, Demuth (in press)). The same apparently holds for cases of so-called adult 'variation', where speakers of certain dialects of Dutch alternate between [melk] and [melək] 'milk' depending on the preceding metrical patterns (S-S-S... vs. Sw-Sw-Sw...) within the utterance (Kuijpers & van Donselaar (in submission)).

This section has demonstrated that the empirical data on phonological development contain at least three different types of apparent surface 'variation'. In cases of No Contrast surface variation results from a lack of underlying featural or phonemic contrast. In cases of Multiple Optimal Outputs underlying forms are fully specified, but variation results from 'partially ranked constraints', or *stratified domination hierarchies*. In cases of Different Inputs, multiple forms are present underlyingly, each giving rise to a different surface form. All three types of variation can be handled from an Optimality-theoretic perspective, but only the second provides a challenge for Optimality Theory as originally conceived.

#### 4 Discussion

This paper addresses the issue of intra-speaker variation in language acquisition. It identifies three different types of variation, and demonstrates how each can be dealt with from an Optimality-theoretic perspective. In so doing it raises several issues regarding the nature of Multiple Optimal Outputs, the challenges this raises for Optimality Theory, and some suggestions for how to resolve these issues. In the process it addresses some long standing problems in the field of acquisition, including the nature of children's grammars, the relationship between child and adult grammars, and the notion of 'stages' in the course of acquisition. These issues are briefly summarized below.

Three different types of variation are identified, and while not necessarily exhaustive, they seem to account for much of the variation reported in the acquisition literature. These are:

- (27) Different Types of Variation in Language Acquisition
- No Contrast
  - Multiple Optimal Outputs
  - Different Inputs

Variation which results from No Contrast tends to take place at the segmental level, where a full inventory of featural contrasts may not yet be present. This is generally thought to be a phonological (phonemic) problem, though there might be perceptual components to it. To the extent that featural contrasts contribute to higher-level prosodic structures, as they do in the case of long vowels contributing to syllable and word structure, No Contrast types of variation may also have implications for higher levels of prosodic structure. This type variation is typical of normally developing children especially at early stages of acquisition, and



appears to be the basis for some of the variation found in children with phonological disorders. It may also account for some of the variation in the speech of adult language learners, where different phonemic/featural contrasts are not perceived.

The variation that results in the case of Different Inputs is due to a difference in input form, or target utterance. This typically occurs in children's utterances where higher-level prosodic constraints influence the shape of output forms, often at the level of Phonological Words or Phonological Phrases, and certain words or syllables are omitted. However, the same phenomena occurs in adult phonology (and syntax), as in the case of stressed and cliticized (reduced) pronouns and auxiliaries. Thus, the 'variation' found with Different Inputs is not a true type of 'variation', but rather one which is influenced by grammatical (and discourse) context. Context effects are frequently ignored in child language research, giving rise to cases of apparent 'variation' of this type.

The last and only 'true' type of variation is that of Multiple Optimal Outputs, where there is only one underlying representation, which is (phonemically) wellformed. Nonetheless variation in output occurs as a result of constraint interaction at different levels of structure (e.g. segmental, prosodic). That is, Multiple Optimal Outputs are not random articulatory events, but principled phonologically constrained forms, each of which is 'optimal' given a certain ranking of constraints. Critically, certain constraints must be equally ranked with respect to one another, rather than hierarchically ranked. This 'partial constraint ranking', or set of *stratified domination hierarchies*, allows for multiple candidates to be optimal, but only if constraints violated within a given strata are not evaluated gradiently, and if constraints which are ranked extremely lowly cease to be evaluated. The latter may be a characteristic of early child grammars which arises from memory and processing limitations, and the former may exist during early stages of acquisition enroute to an exhaustive hierarchical ranking of constraints. Thus, even if the child begins the language learning process with unranked 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 to become increasingly hierarchically ranked, gradually converging on the target adult grammar. Multiple Optimal Outputs are then typical of the early stages of acquisition in normally developing children, and may persist in children with Specific Language Impairment.

Other proposals regarding the nature of variation, such as fluctuation between two different grammars (Grimshaw's 1994), seem unnecessary in accounting for the data presented here. We can understand an Alternate Grammars approach 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, and/or what would be gained by positing such a system.

Optimality Theory therefore provides a useful framework for exploring issues of variation, as well as change over time. It also provides a mechanism for exploring the issue of 'stages' of acquisition. In the narrowest sense, any change in constraint ranking could be considered another 'stage' in the acquisition process. However, as illustrated above, certain rerankings will have a larger impact on the nature of output forms than others, sometimes giving rise to apparent surface 'regression'. Thus, even though the acquisition process is deterministic, certain surface 'stages' may appear. That these 'stages' may not be categorical is due once again to the nature of constraint interaction, and the presence of *stratified domination hierarchies*. It is this constraint-based nature of Optimality Theory which lends itself to exploring these issues more fully.

In conclusion, this paper has shown how an Optimality-theoretic approach to variation in terms of Multiple Optimal Outputs in acquisition can be handled with '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, problems of aphasic speech, and processes of historical change, contain cases of Multiple Optimal Outputs, or are better treated as instances of Different Inputs or No Contrast. This paper has attempted to illustrate how Optimality Theory can provide a framework for exploring these issues in greater depth.

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