The Optimal Initial State[1]

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ABSTRACT

The 'initial state' of a child's phonology has been much discussed but rarely empirically investigated within an Optimality Theory framework. The most common assumption has been that, at the onset of word production, all markedness constraints strictly dominate all faithfulness constraints. In this paper, the early phonologies of 20 children, five each learning one of four languages (English, French, Japanese, and Welsh), are analyzed for evidence of the ranking of markedness versus faithfulness phonotactic constraints. Neither markedness nor faithfulness constraints are found to consistently dominate in these phonologies, suggesting that, at the onset of word production, exposure to the distributional characteristics of the ambient language have already had a significant impact on the child's phonology. The results also provide empirical verification of the need for gradient constraint ranking during the acquisition process, and suggest that children may develop idiosyncratic markedness constraints in response to their experience of salient patterns in the ambient language.

The INITIAL STATE of a child's phonology has been much discussed in the Optimality Theory literature. Within this theory, phonology is taken to consist of universal sets of MARKEDNESS CONSTRAINTS, which specify which features, patterns, or structures are typically preferred by human languages, and FAITHFULNESS CONSTRAINTS, which specify which features, patterns, or structures of the "input" (presumed underlying representations of words) are preferentially preserved in production universally and in specific languages. Faithfulness corresponds approximately to linguistic conventionality among the speakers of a language, with contrast maintenance as its motivation. That is, words must be different enough from each other to be distinguishable. Markedness constraints, on the other hand, reflect preferred output forms – which are typically, but not always, phonetically grounded. Thus, many markedness constraints may be based upon human physiological limitations, experienced by the learner through his/her prelinguistic and early linguistic vocal activities. Those constraints are "inductively grounded" to begin with (Hayes, 1999; Boersma 1999), and are then "phonologized" at some point into categorical phonological constraints.

Based upon systematicity and abstraction away from articulation, errors attributed to phonologized constraints can be differentiated from those that are directly reflective of articulatory difficulty. That is, these phonologized constraints represent generalizations to cases in which the motivating physiological limitations are not applicable. In pre-OT models, such phonologized constraints have been referred to as "word recipes" or "templates", and their emergence has been taken to signal the onset of phonological system (Menn, 1976, 1983; Macken 1978, 1979; Vihman & Velleman, 1989; Vihman & Velleman, 2000).

The markedness of a form can be determined independently of the target, while faithfulness can only be determined by comparison of the output to the target. According to this theory, each language has an established RANKING for the set of faithfulness and markedness constraints, which are presumed to be universal. The ranking of the constraints determines which sounds and combinations of sounds are present in any given language. The ranking further determines which characteristics of a given underlying form are actually preserved and which are sacrificed in a given output (production).

A common assumption is that phonological constraints are present in the form of an innate linguistic endowment in all humans at birth:

> The ranking, but not the constraints, differs from language to language. The constraints are therefore universal. If phonological constraints are universal, they should be innate. (Gnanadesikan, 1995, p. 1)

Although the constraints are considered to be present from birth, most studies of the initial state hypothesis have focused on the child's first words (Roark & Demuth, 2000; Dinnsen et al., 2000; Gnanadesikan, 1995; Hayes, in press; but see e.g., Smolensky, Davidson & Jusczyk 2002). Children's output at this point is notoriously variable (Ferguson & Farwell, 1975), as are different theoreticians' explanations of that variability. Hale and Reiss (1996, 1998), for example, claim that children’s misproductions of adult target words are not violations of faithfulness but merely performance errors unrelated to markedness. In fact, they propose that all faithfulness constraints are ranked above all markedness constraints at the onset of word production: FAITH>>MARK.

The distinction between markedness violations and non-linguistic articulatory inaccuracy (i.e., performance errors) has yet to be empirically tested. If child variability reflects articulatory difficulty, then errors should represent articulatory simplifications of the target – consonant cluster reduction, omission of codas, etc. Furthermore, such errors should be universal: children from all language groups should demonstrate similar error patterns, with the exception that children cannot make errors on structures that do not occur in their language. For example, all children's error patterns should be similar with respect to ONSET, the constraint that mandates an initial consonant for every syllable. This follows from the fact that CV syllables occur in all languages. In contrast, consonant cluster simplification errors would be nonexistent, by default, in a language that does not include consonant clusters. Another possible consequence of all faithfulness constraints initially being ranked above all markedness constraints is that children's productions should be phonetically gradient: that is, if the errors are due to articulatory incoordination, mistiming, or other inaccuracies, they should often involve noncategorical values of features such as voicing and nasality – partial voicing or devoicing, partial nasalization or denasalization. Futhermore, U-shaped learning curves (i.e., apparent regressions) should not occur (Stemberger, Bernhardt, and Johnson 1999).

More common than Hale and Reiss' (1996, 1998) proposal that all faithfulness constraints initially outrank all markedness constraints is the proposal that all markedness constraints are initially ranked above all faithfulness constraints (e.g., Demuth, 1995; Gnanadesikan 1995; Levelt & Van de Vijver 1998; Smolensky 1996; Smolensky, Davidson & Jusczyk 2002). This proposal (MARK>>FAITH) implies that language-specific effects should not be evident at the "initial state," a claim that awaits cross-linguistic verificiation. If errors reflect constraints rather than articulatory difficulty, then they should consist of "phonologized" (and, in most perspectives, therefore categorical) patterns that are more general and therefore less phonetically grounded and less phonetically gradient, abstracted away from concrete phonetic limitations.

One must be careful in distinguishing phonetically gradient versus categorical patterns in that even categorical patterns may be gradient in their implementation. That is, a categorical pattern does not necessarily apply all of the time. In fact, this idea is one of the foundations of Optimality Theory: that the effects of any given constraint may or may not be evident in the production of a particular word, depending on the ranking of that constraint with respect to other constraints that may apply in that context. Some have taken this idea further, suggesting that the constraint rankings themselves may be gradient (Boersma, 1999; Boersma & Hayes, 2001; Boersma & Levelt, 2000; Hayes & MacEachern, 1998; Hayes, 2000); that is, each constraint has a normally distributed range of ranking values. Therefore, constraint A that normally dominates constraint B may occasionally be violated in favor of B if their ranges of ranking values overlap. The constraints remain categorical in nature (i.e., their descriptions refer to abstract elements and structures, not to fine-grained articulatory or acoustic distinctions), but their application patterns are, to some extent, stochastic. Furthermore, the constraints are continuously rather than discretely ranked. Smolensky, Davidson and Jusczyk (2002) have recently shown the usefulness of such a model in accounting for the variable productions of adults under different task conditions.

Some recent results "cast doubt on the idea that constraints are innate and universal" (Levelt & Van de Vijver, 1998, p. 18; Boersma, 1998). For example, Levelt and Van de Vijver, in a comparison of the development of syllable types in Dutch children versus syllable type occurrence cross-linguistically, found two stages in the emergence of syllable types that did not correspond to any adult grammars. Conjoined constraints were required to account for these developmental stages, but not for any of the cross-linguistic adult grammars studied. The authors propose that such stages may be acquisition-specific, and that "re-ranking of constraints in acquisition ..[may be].. different from re-ranking constraints in cross-linguistic grammars" (p. 18). The breadth of application of consonant harmony and of metathesis in early child phonology has long presented a similar stumbling block for nativist positions (Goad 1996, 1997; Velleman 1996): the constraints on such processes in child phonology differ in important ways from those affecting adult phonology.

Arguing from an algorithmic model rather than actual child data, Boersma (1998) demonstrates that without innate constraints a learner can still "acquire an adequate grammar [for a specific ambient language] from a realistic amount of overt data" (p. 269). He proposes that "[markedness] as well as faithfulness constraints are learned, not innate. Each language uses a finite set of these constraints, learned in the process of perceptual categorization and motor learning" (p. 292). Several other recent optimality theoretic models of phonological development have also explored this process of perceptual categorization. The core aspects of the child's developing grammar have been shown to derive from characteristics of the literal ambient language input, especially its statistical properties (Roark & Demuth 2000; Levelt & Van de Vijver 1998; Smolensky, Davidson, & Jusczyk, 2000; Johnson & Jusczyk, in press; Tesar, 2000; Tesar & Smolensky, 1998; Foulkes, Docherty, & Watt, 1999; Docherty, Foulkes, Tillotson, & Watt, 2002;) and its phonetic properties (Stoel-Gammon, Buder & Kehoe, 1995; Escudero & Boersma, 2001; Foulkes, Docherty, & Watt, 1999; Docherty, Foulkes, Tillotson, & Watt, 2002; Johnson & Jusczyk, in press; Vihman, Nakai & DePaolis, 2002).

Though some continue to strongly deny such a possibility (Dinnsen, McGarrity, O'Connor & Swanson 2000), several authors have entertained the idea that at least a subset of constraints may be learned rather than innate (Boersma, 1999; Guest, Dell & Cole, 2000; Hayes, 1999; Hayes, in press; Menn, in press; Pater, in press; Smolensky, Davidson & Jusczyk 2000; Velleman & Vihman, 2002). According to this view, the probabilistic and templatic influences of prelinguistic perceptual and production experience (implicit learning) contribute to the learning process.

If some constraints, especially markedness constraints, are "inductively grounded" in phonetic experience (Hayes, 1999), then we might expect a child's prelinguistic vocal experience to affect the set of markedness constraints with which the child begins word production. Similarly, prelinguistic perceptual experience might be expected to have already exerted an influence on the ranking of the child's faithfulness constraints by the time meaningful linguistic output begins. Interactions between perception and production (Vihman, Velleman, & McCune, 1994) would affect the rankings of markedness and faithfulness constraints with respect to each other. (Whether the child has separate perception versus production rankings is an open question; see e.g., Hayes, in press; Boersma 1998; Pater , in press). In that case, the onset of word production would not be the initial, totally-markedness-dominated state of the child's phonology that some continue to assume (e.g., Rose 2000).

The status of markedness and faithfulness constraints at the onset of word production has yet to be verified using actual child data. The hypothesis that both markedness and faithfulness constraints are grounded in prelinguistic perceptual and articulatory experience, already primitively phonologized at the onset of first words, is empirically testable. Such an empirical test is the primary purpose of the study to be reported here. Through the analysis of the earliest word productions of twenty children, each exposed to one of four languages -- English, French, Japanese, and Welsh -- we will explore the influences of universal and ambient-language patterns, preferences, and priorities (faithfulness and markedness constraints and their rankings) on their emergent phonological systems. Specifically, at the earliest points in children's word production, we will look for evidence of:

- rankings of markedness versus faithfulness constraints, both generally (Are all markedness constraints ranked above all faithfulness constraints?) and specifically (Is each markedness constraint ranked above the corresponding faithfulness constraint?); and
- systematic variability i.e., variability that cannot be attributed to articulatory factors alone, that has been generalized to multiple word forms (phonologized), and that can be modeled using gradient constraint rankings.

Our presentation of the data will include global results by language group and also the results of in-depth analyses of one particular child from each language group. In our analyses of individual children, we will report all output forms of each target word in order to assess variability within the context of our hypothesis. For these participants, we will consider two different developmental points in early word use.

In summary, this study will constitute a relatively large N cross-linguistic empirical test of some of the competing hypotheses concerning the initial phonological state. Our results bear directly upon constraint rankings (markedness versus faithfulness) at the onset of word use, with implications for whether or not the onset of word use is indeed the phonological initial state. If all markedness constraints are ranked above all faithfulness constraints, then faithfulness constraint violations should abound. Critically, markedness constraint violations should occur only where two different markedness constraints contradict one another. If, due to their influence on the form of children's word productions, some faithfulness constraints can be shown to dominate some markedness constraints (either generally or specifically), then the initial state of the child's phonological grammar has already been changed by prelinguistic experience. If the individual children's variability includes error forms that violate more universal markedness constraints than their targets and that demonstrate generalization to multiple word forms, then such violations can be assumed not to result merely from articulatory imprecision but to reflect more abstract phonological patterns.

METHOD

The purpose of this paper is to explore early constraint rankings using data from twenty children, five each learning one of four languages: English, French, Japanese, and Welsh. Data from each of the twenty children were analyzed at the same developmental point: production of 20-30 different words within a half-hour recording session. We will refer to this as the 25-WORD POINT. This typically corresponds to the point at which parents report a productive lexicon of 40-60 words (see Vihman & Miller, 1988 for correspondences between parental diary lexicon sizes and numbers of words produced per 30-minute play session). Each token of each word produced by each child in each session was considered with respect to the core set of phonotactic markedness and faithfulness constraints relevant to early child phonologies (as suggested by Bernhardt & Stemberger 1998, Demuth 1996, Fee 1996, Gnanadesikan 1995, Kehoe & Stoel-Gammon 1997, Levelt & Van de Vijver 1998, and others). To facilitate mark-faith comparisons, markedness and faithfulness constraints were paired with respect to their effects on the output. For instance, the frequency of violations of the markedness constraint that requires a consonantal onset for every syllable – ONSET – was compared to the frequency of violations of a faithfulness constraint against omitting or adding an onset to the heard form – CORRESPONDENCE(ONSET), a.k.a. CORR(ONSET). The relative ranking of ONSET versus CORR(ONSET) was compared within children and also across children from different language backgrounds. Frequencies of violation of these pairs of related markedness and faithfulness constraints were compared to derive a probabilistic constraint ranking for each child. The purpose was to determine whether or not markedness constraints consistently outranked faithfulness constraints (either generally or specifically), whether strict or gradient rankings of these constraint pairs could be identified, and further whether children's errors reflected articulatory difficulty only or other more abstract factors as well.

The initial plan for this research was to evaluate the children’s constraint violations at their 25-word points, as the earliest point at which a substantial number of word types and tokens is available in a child’s speech. However, given the somewhat surprising results found at the 25-word points (to be discussed below), four children (one per language) were considered in greater depth. These children's constraint rankings were studied at the four-word-point as well. The four-word point is the point at which three to six different word types are produced per half-hour session, and parents report a productive lexicon of 8-10 words. Two four-word point sessions were used for each child to increase the number of word tokens available for analysis.

The source of information for each child’s phonology at each point was the same: transcripts of the child’s word productions during unstructured 30-minute audio- and video-recorded parent-child play sessions. The two developmental points, the four-word point and the 25-word point, were defined as the sessions in which the child’s expressive lexicon reached a level of approximately 10 or 50 words, respectively, as evidenced by:

- parental diary report of 5-10 or 40-60 words, respectively, and
- the production of at least four or 20-30 words, respectively, during the 30-minute recording session. (See Vihman and McCune 1994 for the protocol for distinguishing words from babble vocalizations).

Data for English and Japanese were collected in California, USA; for French in Paris, France; and for Welsh in Bangor, Wales (UK). All children were being raised as monolinguals in their respective languages at the time of the recordings (See Vihman & McCune, 1994 and Boysson-

Bardies & Vihman, 1991 for further details). The participants' pseudonyms, languages, and ages at the two data points (where applicable) are given in Table 1.

Table 1 about here.

Native transcribers prepared transcripts of each child using the International Phonetic Alphabet. Reliability was first tested within each language. Although many prelinguistic vocalizations were included in these measures, agreement as to the specific identity of the consonant ranged from .75 (Japanese) to .80 (French and English). Crosslinguistic reliability was also checked for some pairs of languages, with percentage of agreement ranging from .81 to .86. (See Vihman et al., 1985 and Boysson-Bardies & Vihman, 1991 for further details.)

Every token of every word type produced during each session was analyzed in two ways:

- Markedness: Each token was categorized as either satisfying or violating each markedness constraint. For example, if a syllable of the word as produced did not begin with a consonant, that syllable was coded as violating the constraint 'ONSET', regardless of the target word.
- Faithfulness: Each token was categorized as either matching or violating the target word's status with respect to each constraint. For example, if the overt form were onsetless, but the child produced an onset, this would be considered to be a violation of the constraint 'CORR(ONSET)', even though the child's production was respectful of markedness. An inherent limitation of this procedure is that it assumes that just one target/overt form is stored by the child, and that it fully matches one invariant form produced by adults. This simplifying assumption is made quite consciously here. Its impact on the results will be discussed later in this paper.

Note that the set of faithfulness constraints considered here come from the CORRESPONDENCE category within OT (as described in McCarthy & Prince 1995 and elsewhere). These correspondence constraints dictate the ways in which the output (production) must match the heard form (typically referred to in OT as the "input"; here referred to as the "overt form" or the "target") and vice versa. It was impossible, within the context of this paper, to differentiate between child underlying forms that differ from the adult overt forms due to perceptual (markedness or faithfulness) constraints versus output forms that differ from the corresponding adult overt forms due to production-based (markedness or faithfulness) constraints, if in fact two such sets of constraints exist (Hayes, in press; Boersma 1998; Pater , in press). The main point of this paper is to identify possible influences of adult overt forms on the child's output forms, so the distinction is not critical in this context.

Correspondence as it is used here embraces both the "input-output" Maximality (MAX) and the "output-input" Dependence (DEP) constraint families. For example, one Max constraint might state that, 'all input nasals must correspond to output nasals'. This would indicate that if there is a nasal in the target word, it must be produced. To put it another way, nasals may not be deleted. The related DEP constraint would state that all output nasals must correspond to UR nasals. That is, nasals may not be added. The correspondence faithfulness constraints considered here encompass both MAX and DEP: overt forms and outputs must match, so neither deletions nor additions are allowed. This simplification of the usual approach to faithfulness is considered to be appropriate here, given that the research question is whether or not any evidence for faithfulness in general can be found in such early productions, rather than what the influence of specific types of faithfulness constraints might be. Details of specific correspondence violations will be provided as appropriate. For similar reasons, simplified constraint names are used to highlight the relationships between specific markedness and faithfulness constraints (e.g., ONSET and CORR(ONSET)).

The core set of paired phonotactic faithfulness and markedness constraints that were considered for each of the child's productions of each word type were the following:

PEAK: Every syllable must have a vowel as its peak (nucleus).

Sample violation: A syllable with a syllabic consonant as its peak, such as the second syllable of the word *button*: [bʌʔn̩].

CORR(PEAK): If the target syllable contains a vowel peak, the produced syllable must also. If the target syllable does not contain a vowel peak, the produced syllable must not.

Sample violation: A syllable with a syllabic consonant as its peak reproduced with a vowel as its peak (e.g., *bottle* produced as [bɑtʌl] rather than [bɑɾl̩]), or a syllable with a target vowel peak produced with a syllabic consonant peak (e.g., *umbrella* produced as [m̩bwɛlə]).

ONSET: Every syllable must have an onset consonant.

This constraint was considered in two versions due to the difficulty of reliably transcribing glottals (Vihman et al., 1985) as well as to disagreement within the field about whether or not glottal stop should be considered an onset and whether or not phonemically vowel-initial words are in fact consistently pronounced with a glottal onset in American English (Dilley, Shattuck-Hufnagel, & Ostendorf 1996). Thus, the two versions of this constraint included one in which [ʔ] was included as a possible consonantal onset ('ONSET w/ ʔ'), and one in which it was not ('ONSET w/o ʔ'). When not specified, the expressions 'ONSET' and 'CORR(ONSET)' should be taken to refer to 'ONSET w/o ʔ'.

Sample violation: A syllable that begins with a vowel, such as the first syllable of the word *apple*. The form [ʔæpl̩] for *apple* would be considered a violation of 'ONSET w/o ʔ' because glottal stop would not be counted as an onset under this version of the constraint, but not as a violation of 'ONSET w/ ʔ'.

CORR(ONSET): If the target syllable begins with a consonant, the produced syllable must also. If the target syllable does not begin with a consonant, the produced syllable must not.

Sample violation: [bæpu] for *apple*; [eɪp] for *grape*. [ʔeɪp] for *grape* would be considered a violation of CORR (ONSET w/o ʔ), but not of CORR (ONSET w/ ʔ). Similarly, [ʔæpu] for *apple* is a violation of CORR (ONSET w/ ʔ) but not of CORR(ONSET w/o ʔ).

Syllables were parsed as having onsets whenever possible. That is, a production such as [æpəl] was syllabified as [æ.pəl]. The analyses were thus biased in this sense towards satisfying the markedness constraint: the assumption in ambiguous cases was that ONSET was not violated.

NOCODA: Syllables must not end with consonants.

Sample violation: A syllable that ends with a consonant, such as the word *cat*.

CORR(CODA): If the target syllable ends with a consonant, the produced syllable must also. If the target syllable does not end with a consonant, the produced syllable must not.

Sample violation: *cat* produced as [kæ] or *bye* as [bɑɪp].

FOOTBINARITY, a.k.a. FTBIN: A foot is composed of two units: either two syllables or two moras (units of syllable weight). Separated into its two possible instantiations:

SyllabicBinarity, a.k.a. SYLBIN: Feet must be made up of two syllables; words must include an even number of syllables (i.e., a four-syllable word could still be made up of binary feet; a five-syllable word could not).

Sample violation: A foot that is not made up of two syllables, such as the feet in the words *dog* (only one syllable in the foot), or *tricycle* (three syllables in the foot or one syllable (the last) that is 'unfooted' -- i.e., not in any foot).

CORR(SYLBIN): If the target word includes an even number of syllables (and, therefore, binary feet), the produced word must also. If the target word does not include an even number of syllables, the produced word must not.

Sample violation: *dog* produced as [dɔdɔ] or *open* produced as [pɛn].

MORAICBINARITY (MORBIN): A syllable must include two moras. These two moras may consist of a vowel plus a consonant (including ʔ), a sequence of vowels, or one prolonged vowel (as indicated in transcription).

Sample violation: A syllable with only one monophthongal vowel, such as [nɪ] or [bʊ].

CORR(MORBIN): If the target syllable includes two moras, the production must also. If the target syllable does not contain two moras, the production must not.

Sample violation: *hi* produced as [hɑ] (diphthong reduced to monophthong), or *apple* produced as [ɑɪpl̩] (monophthong increased to diphthong).

COMPLEX (C): No sequences of consonants. (Note that '' indicates a disallowed occurrence and '$' indicates a syllable boundary.)

Two versions of this constraint were considered:

*CC: No sequences of consonants within the same syllable (i.e., no syllable-initial or syllable-final clusters).

Sample violation: Syllable-initial or -final clusters, as in *block* and *beads*, respectively.

*C$C: No sequence of consonants across a syllable boundary.

Sample violation: Any word-medial cluster, such as those in the words *pantry*, *sister*, and *whisper*. (Recall that word-medial clusters were always divided among the two syllables, to maximize ONSET, yielding e.g., 'sis$ter', rather than 'si$ster'.

CORR(COMPLEX(C)): The output must match the overt form with respect to consonant sequences. Specifically:

CORR(CC): If the target syllable includes a cluster, the production must also. If the target does not include a cluster, the production must not.

Sample violation: [bɛd] for *bread*; [brɛd] for *bed*.

CORR(C$C): **Among the multisyllabic words produced (not only attempted) by the child,** if the target word includes a word-medial cluster, the production must also. If the target does not include a medial cluster, the production must not.

Sample violation: [wɪpɚ] for *whisper*; [kɛkli] for *kitty*. CORR(C$C) is irrelevant to child monosyllabic productions with multisyllabic targets, as there is no possibility of a match in these cases, and the violation is attributed to SYLBIN.

All sequences of consonant features were treated as clusters with respect to markedness, on the grounds that affricates as well as clusters represent phonetically complex consonants and that it would be preferable to treat all phonetically complex consonants from all languages in the same manner. Such sequences were broken up in keeping with ONSET. For example, *badger* was syllabified as [bæd.ʒɚ]. This decision had implications primarily for markedness; the parsing [bæd.ʒɚ] violates NOCODA and *C$C, while the parsing [bæ.dʒɚ] violates *CC.

*COMPLEX (V), a.k.a. *VV: No sequences of vowels.

Sample violation: A syllable or word containing a sequence of vowels without hiatus, as in English words containing diphthongs ([ɑʊ] as in *cow*.)

CORR(COMPLEX (V)), a.k.a. CORR(VV): If the target syllable contains a sequence of uninterrupted vowels, the production must also. If the target syllable does not contain a sequence of uninterrupted vowels, the production must not.

Sample violation: [kɑ] for *cow* or [frɑɪd] for *Fred*.

CODACONDITION (GEMINATE), a.k.a. GEM: Related to *C$C. If two consonants occur in an intersyllabic sequence within a word (i.e., C$C), the coda (the first C) must be the geminate of the following onset (the second C). In other words, the two consonants must be identical. Note that this is not the same as the OCP (Obligatory Contour Principle; McCarthy 1988); the OCP does not allow a geminate to be represented as one root node branching to two consonant slots. The assumption here is of a sequence of two identical consonants. Note that this constraint is very low-ranked in English, but is higher-ranked in languages such as Japanese.

Sample violation: A word with two (or more) different medial consonants, as in *Oscar, umbrella*, or *Bambi*.

CORR(GEM): If the target word includes a sequence of geminate consonants, **and the production also includes a sequence of consonants in the same position**, then the two consonants in the production must be identical also. If the target word includes a sequence of consonants that differ by at least one feature, and the production also includes a sequence of consonants in the same position, then the two consonants in the production must also differ by at least one feature.

Sample violation: Japanese [nenne] 'sleeping' produced as [nente]. Not violated e.g., if Japanese [pitʃɑ] 'splash' is produced as [tæpt^{h}æ], because the two medial consonants are different in both target and output. Not relevant if, for example, [nenne] is produced as [nene], because the output does not include a sequence of medial consonants.

In summary, the pairs of constraints listed in Table 2 were considered for each token (production) of each type (word) for each child in each language group.

Table 2 about here.

In each case, the percentages of occurrence of violations of each constraint of the pair (e.g., ONSET and CORR(ONSET)) were calculated and compared to determine the relative ranking of markedness versus faithfulness constraints. This differs from earlier non-optimality-oriented studies which have demonstrated the effects of the ambient language on early phonologies in the sense that, in this study, such effects are sought on a word-by-word basis. That is, each word production is directly compared to its target. In earlier studies, it has been shown that, for example, children learning a language with final consonants do produce more final consonants overall in their early word productions than children learning languages that do not violate NOCODA (Vihman & Boysson-Bardies, 1994). In this sense, ours is a finer-grained analysis than has been attempted before.

Standard OT procedures of comparing potential candidates to determine which is the ultimate output are not applicable to early child phonology, as they are based on the assumption that the child produces one consistent output form for each target. As will be exemplified in the description of Deborah's early words below, too many contradictory candidates for any one overt form are actually produced by the same child within the same session to permit a ranking of the constraints based upon outputs for specific forms. Therefore, rank orders were determined using percentages of violations (over tokens) for each constraint. For each language, the rank-orders of each constraint were averaged over all subjects to determine the average rank ordering of the set of constraints for children from that language group. Rank orders were used for these calculations rather than averaging percentages as it is inappropriate to treat percentages as ratio data under these circumstances. Data from one child per language were examined in more detail, focusing on interactions among related and closely-ranked constraints.

RESULTS

Group Results

In this section, group results from all five children from each of the four languages studied will be considered first. We use the grouped children's constraint rankings, listed in Table 3, to address the following questions :

- Do all markedness constraints uniformly outrank all faithfulness constraints?
- If the answer to the first question is 'no', does each markedness constraint outrank the corresponding faithfulness constraint (e.g., ONSET outranks CORR(ONSET) although some other faithfulness constraint may outrank ONSET)?
- Do the constraints strictly dominate each other, or do they appear to apply in a gradient manner (in the sense of Boersma & Hayes 2001)?
- Do errors reflect articulatory simplification, or do other, more abstract factors appear to be at work?
- Are there differences among the four languages considered with respect to the ranking of either markedness or faithfulness constraints, or both?

Table 3 here.

The children's violations of the phonotactic constraints studied range from 0% to 100%. Certain universal markedness constraints, especially PEAK, appear to be very highly ranked in all of the children's systems, regardless of the language of exposure. However, the languages studied here provide few opportunities for violation of this constraint; therefore, CORR(PEAK) is at the top of their constraint rankings as well: When there is a vocalic peak in the target – which is virtually always the case – the children preserve it.

Similary, the markedness constraint NOCODA dominates the related faithfulness constraint CORR(Coda) for all languages except Welsh. However, the position of NOCODA in the overall ranking differs from language to language. For example, in Japanese NOCODA is ranked very highly while CORR(Coda) is quite frequently violated – the children frequently omit the few target codas, especially in word-final position, and when they do produce a coda (typically in syllable-final word-medial position), it may not have been present in the target. For example, Emi produces *wan-wan* 'doggy' as [wɑwɑ] (occasionally with a word final glottal stop), yet one of her productions of *mama* is [mɑmmɑʔ]. In the other three languages, both NOCODA and CORR(Coda) fall towards the middle of the overall ranking. Welsh may over-ride the tendency for NOCODA to dominate CORR(Coda) due to a combination of factors. First, Welsh includes many final consonants (as does English, but not French or Japanese). Furthermore, despite a trochaic stress pattern, these final consonants are typically released (unlike final consonants in English).

Thus, certain markedness constraints do tend to dominate the corresponding faithfulness constraints in the majority of the languages studied. However, as shown in the table, the children's markedness constraints do not consistently outrank their faithfulness constraints. Several faithfulness constraints, such as CORR(PEAK), CORR(CC), and CORR(ONSET) appear near the top of the rankings in all four languages. Furthermore, as exemplified by NOCODA and CORR(Coda) in Welsh, the lack of dominance of markedness constraints applies at the level of specific constraints as well as generally. That is, not only do all markedness constraints **not** dominate all faithfulness constraints, but specific markedness constraints also fail to dominate the related faithfulness constraints. For example, CORR(ONSET) dominates ONSET in all languages except Japanese, in which the two constraints are very closely ranked but in the opposite direction. Clearly, the frequency or salience of vowel-initial words in English, French, and Welsh have already made an impact on these children's phonologies by early in the word production process, such that they produce vowel-initial words as such despite the relative articulatory difficulty of doing so.

Similarly, CORR(SYLBIN) dominates SYLBIN for all languages. As is known from other types of psycholinguistic studies (Aitchison & Chiat 1981; Smith, Macaluso, & Brown-Sweeney, 1991; Vihman, 1981), the number of syllables in a word – or perhaps the rhythmic patterns derived from even versus odd numbers of syllables – is highly recognizable and this apparently has an impact on the child's early phonological system. However, binarity constraints in general are very low-ranked in all of the children's phonologies, across all languages. Thus, binarity may not play as strong a role as has sometimes been assumed (Demuth, 1996; Fee, 1996).

This finding, that all markedness constraints dominate all faithfulness constraints neither generally nor specifically, holds true for each individual language as well. In English, for instance, particular markedness constraints do outrank the corresponding faithfulness constraints. For example, *CC dominates CORR(CC), reflecting the fact that intrasyllabic consonant clusters are often simplified to singletons. Similarly, NOCODA is violated less often than CORR(Coda); the children tend to omit codas even when they appear in the target (e.g., Emily's [bɪ] for *bib*). NOCODA and CORR(Coda) appear fairly low in the overall ranking, however, indicating that both are frequently violated. Furthermore, there is a wide range in the children's rankings of NOCODA – from near the top of the hierarchy (rarely violated) to near the bottom (rarely satisfied). In fact, two of the children (Molly and Sean) actually rank CORR(Coda) somewhat higher than NOCODA. In addition, certain faithfulness constraints, such as CORR(ONSET), are very rarely violated in English. Other individual faithfulness constraints that are sometimes violated (such as CORR(ONSET), CORR(SYLBIN), and CORR(GEM)) nonetheless do dominate the corresponding markedness constraints (i.e., ONSET, SYLBIN, and GEM).

The French children, like the English-learners, show clear evidence of faithfulness to phonotactic features of target words at this early stage of word production. Not surprisingly, given that French has fewer codas than English and Welsh, the universal markedness constraint against codas does dominate faithfulness to syllable-final consonants in their speech. However, CORR(ONSET), CORR(SYLBIN) and CORR(MORBIN) all outrank the corresponding markedness constraints for all of the French children.

For Japanese, too, we see several high-ranked faithfulness constraints, both generally and also specifically. Particular faithfulness constraints such as CORR(SYLBIN) and CORR(GEM) outrank the corresponding markedness constraints. Kazuko, for instance, always produces a geminate when one is called for by the adult form, but never produces any other medial consonant sequence as a geminate (though she does sometimes geminate singleton medial consonants).

In Welsh, faithfulness to syllable binarity, to the presence/absence of an onset, and to the presence/absence of a coda are more highly ranked than the related universal markedness principles. The ONSET and NOCODA markedness constraints are particularly low-ranked, far below the corresponding faithfulness constraints. The fact that final consonants are generally released in Welsh may be a factor in the low ranking of NOCODA. Interestingly, the Welsh children not only preserved codas as targeted but also added codas even where these were not required by the target. For example, Elen produced *baby* as [babap] as well as [baba]. In contrast, many of the words that these children attempted began with vowels or glottals ([h] or [ʔ]); these non-salient onsets may have influenced them to downgrade ONSET.

For each language, several Faith-Mark pairs are ranked closely enough to suggest that their relationships may be gradient, but in order to address this question individual children's data must be considered. For that purpose we turn to in-depth analyses of one child per language group.

Individual Results

In this section, word productions from one child from each language will be analyzed in more detail at the four-word point as well as at the 25-word point, for closer examination of the questions considered above.

Deborah (English)

At the 25-word point, Deborah produced 19 word types (see Appendix). Her constraint ranking is shown in Table 4. Recall that this ranking is based upon percent occurrence: number of occurrences divided by number of opportunities; the latter typically differs for MARK versus FAITH constraints. Those constraints that are violated least often (satisfied most often) are the highest ranked and are at the top of the list. Thus, this table displays the relative percentage of violations of related markedness and faithfulness constraints for Deborah at this 25-word point. The right-most column indicates the frequency with which these violations reflect the dominance of the corresponding faithfulness constraint (e.g., the child violated SYLBIN, because the overt form demanded it by including an odd number of syllables, as in [tɑ˞] for *down*) or the dominance of the corresponding markedness constraint (e.g., the child violated CORR(CODA) by omitting a coda -- as NOCODA would require -- from a target form that was marked due to including a syllable-final consonant, as in [bwa] for *bird*).

Table 4 about here.

As can be seen in this table, Deborah's treatment of codas largely bears out the hypothesis that markedness constraints dominate faithfulness constraints. She only violates NoCoda (that is, produces a syllable-final consonant) in 2% of the syllables that she produces, yet she violates Corr(Coda) in 26% of the opportunities. Put simply, when the target demands a coda, she typically fails to produce one. When NoCoda and Corr(Coda) agree (i.e., there is no final consonant on the target syllable), she usually complies with both. However, the two cases in which she violates NoCoda are cases in which the target syllable does not include a coda: her productions of *kitty*'as [t͜l̰et͜l̥ʼi] and [kʰek͜li][2]. This pattern is illustrated in Table 5.

Table 5 about here.

It must also be noted that Deborah generally attempts words with closed syllables less often than words with open syllables; only nine out of 19 word types that she attempts include a target closed syllable. Thus, her production lexicon forces her to choose between faithfulness (preserving a target final consonant) and markedness (omitting a target final consonant) less than 50% of the time.

With respect to other constraints as well Deborah seems to avoid the choice between markedness and faithfulness by only attempting words for which the two types of constraints agree. For example, although English child-directed speech does include many words with syllabic consonants (*button, curtain, little,* etc.), she almost never violates either Peak or Corr(Peak) because she almost never attempts or produces syllables that do not include a vowel peak. (The only exception was *monkey*, which included a syllabic nasal peak her production –

[hm̩ mæ̃:] -- and could perhaps be argued to include a target syllabic nasal peak in some adult productions – [mŋ̍ki]). Thus, even more than with CODA, she seems to be choosing words to attempt that fit her own production capabilities.

Similarly, Deborah violates both *VV and CORR(VV) between 14 and 19% of the time. When she violates *VV it is usually in order to satisfy CORR(VV) (75% of the time), and vice versa. In other words, when she does produce a sequence of vowels, it is because the target demands it (e.g., she produces *bye* as [pʰɑːɪ]). But, similarly, when her vowel sequence production does not match the target, it is because she has simplified (reduced a diphthong to a single vowel, as in [tɑː] for *down* and [ʔɑː] for *eyes*). She does not produce a complex vowel if it is not called for by the target, but she doesn't always match an adult complex vowel, either. Thus, CORR(VV) does not strictly dominate *VV; their rankings overlap, permitting each to determine the outcome some proportion of the time.

If [ʔ] is not credited as an onset, Deborah violates ONSET 12% of the time, almost always (92% of the time) for the sake of faithfulness. However, all of her productions of target syllables, and most of her productions of epenthesized syllables, have at least an initial glottal. If [ʔ] is considered to be an onset, Deborah almost never violates ONSET (<1% of the time). She even produces marked onsetless words with initial [ʔ], as in [ʔɑɪ] for *eyes* and [ʔɑ:] for *up*, resulting in 9% violations of CORR(ONSET) if [ʔ] is credited as an onset.

Deborah also violates all four markedness and faithfulness constraints relating to consonant clusters about equally, and at a relatively low level (between 6% and 12% of the time). In contrast to the complex vowel case, however, she does not appear to be trading off between markedness and faithfulness. Only 17% of her violations of *CC are for the sake of accuracy (faithfulness), and none of the violations of *C$C are demanded by the target (i.e., her two productions of *kitty* that include an intersyllabic consonant sequence). Her simplifications of **intra**syllabic clusters are more often for the sake of markedness (such as [siː:] for *three*; accounting for slightly over half of the non-matches between target and actual disyllabic words). Yet when she does produce a medial cluster (e.g., [kʰekli] for *kitty*) it is never because this is demanded by the phonotactic structure of the target, even though medial clusters are presumed to be universally more difficult than singletons articulatorily. Examples are provided in Table 6.

Table 6 about here.

It might be suggested that Deborah is producing affricates rather than consonant clusters in these attempts at *kitty*, or that her inclusion of [l] within the medial cluster relates to segmental faithfulness – i.e., the production of a lateral to match the (presumed) phonetic target [ɾ]. In either case, she is violating both phonotactic markedness and phonotactic faithfulness by producing a type of complex consonant that is universally marked and is also not required by the overt form. Thus, other constraints (perhaps faithfulness to a perceived lateral) appear to sometimes dominate both markedness and faithfulness structural constraints relating to clusters, and the latter two constraints do not appear to strictly dominate each other.

Finally, in some respects Deborah prioritizes being true to the overt form over avoiding universally difficult structures. For example, she satisfies CORR(SYLBIN) 99% of the time, but SYLBIN is only respected 26% of the time. In other words, she produces the target number of syllables with little regard for the markedness of the target with respect to binarity. Furthermore, when she violates SYLBIN, it is for the sake of faithfulness 88% of the time. The few times when she does violate CORR(SYLBIN), e.g., by producing as disyllabic a target monosyllabic word or vice versa, it is for the sake of markedness only about half the time (53%). In contrast, CORR(MORBIN) and MORBIN are quite low-ranked, and are violated about equally often (73% vs. 67%).

Although SYLBIN, CORR(MORBIN), and MORBIN appear to be low-ranked for Deborah, she does seem to maintain foot binarity as a phonotactic minimum. Of the monosyllabic word tokens that she produces (regardless of their targets), 92% are transcribed as including either a complex vowel, a final consonantal element (including [ʔ]), or a lengthened single vowel. A deleted syllable is almost always marked in this way (e.g., [pʰɑʔ] and [bɑː] for *bottle*, the exception being [wɑ] for *water*). Thus, the binary footed word appears to be a minimum for Deborah, although binary feet are not a constant throughout her phonology.

There are too many conflicting output forms to use Deborah's productions in a standard OT tableau in order to reveal a deterministic constraint rank order. A tableau for the target word *kitty* is provided in Figure 1 by way of illustration. The constraints listed across the top are in the percentage-occurrence ranking order given in Table 4. However, the listed forms in the lefthand column are not candidates; each one is one of Deborah's actual outputs. Thus, no one of them can be said to 'win'; each occurred once. Note also that the most faithful potential candidate for American English, [kɪɾi], is not among Deborah's outputs, although it should not be ruled out in principle by her constraint ranking. Overall, however, those constraints that percent occurrence ranks lowest (as shown in Table 4) are in fact violated more often by these outputs than those that are higher-ranked.

Figure 1 about here.

In summary, within Deborah's constraint ranking at the 25-word point, faithfulness clearly outranks universal markedness with respect to syllabic binarity. Furthermore, the majority of her violations of SYLBIN have the effect of satifsying CORR(SYLBIN). Markedness appears to outrank faithfulness with respect to NOCODA, though not by as much. Again, the majority of her violations of CORR(Coda) have the effect of satisfying NOCODA. In contrast, the violation rates of *C$C and CORR(C$C) only differ by 2%. Several other pairs of constraints (PEAK and CORR(PEAK), *C$C and CORR(C$C), *VV and CORR(VV), *CC and CORR(CC), MORBIN and CORR(MORBIN), ONSET and CORR(ONSET) - regardless of the status of [ʔ] – also differ with respect to their frequencies of occurrence by small amounts – between 1 and 12%. With respect to these constraints, Deborah seems either to select target words that do not lead her to violate either markedness or faithfulness or, especially in the cases of MORBIN versus CORR(MORBIN), *VV vs. CORR(VV), and *C$C versus CORR(C$C), to freely incur violations -- violating both markedness and faithfulness, and not always for the sake of the other. It would be inappropriate to claim that these pairs of opposing constraints strictly dominate each other; continuous constraint ranking with overlapping probabilities (i.e., gradient constraint ranking) seems to match the latter cases far better.

Perhaps this result reflects changes that have already occurred in the child's phonology before the 25-word point. (Recall that this corresponds to a productive lexicon of approximately 50 words, cumulatively.) Many constraints could have been reranked (demoted or promoted) in this time since the onset of regular word use (in Deborah's case, a period of 4.5 months). To investigate this possibility, all analyses were performed again, this time on Deborah's four-word-point productions. Over the course of her two four-word-point sessions, Deborah produced 5 different words an average of 15 times each, as shown in the Appendix. The results of these analyses are shown in Table 7.

Table 7 about here.

As these summaries show, at the four-word point Deborah already shows significant effects of the ambient language. She frequently violates markedness constraints in order to satisfy CORR(ONSET) (unless glottal stops are counted as onsets) and CORR(MORBIN), and sometimes to satisfy CORR(SYLBIN). She satisfies both markedness and faithfulness constraints with respect to intrasyllabic consonants (CC) and PEAK (and, almost always, CODA) because she attempts words that are phonotactically simple (universally unmarked) in these respects. Even at the onset of word use, Deborah sometimes preserves intersyllabic sequences of consonants, although she produces these sequences as geminates rather than as the two distinct consonants in the target. Specifically, *monkey* is produced consistently as [mVm$mV], although the vowel quality changes from one token to another.

In short, even at the four-word point, several of Deborah's faithfulness constraints have higher probabilities of satisfaction than the corresponding markedness constraints, though the ranking value ranges must overlap, as markedness sometimes dominates in particular tokens of the same word types. Only GEM seems not to overlap in its range of ranking values with a directly competing constraint. Neither the assumption that Markedness outranks Faithfulness at the onset of word production nor the assumption that constraints are strictly ranked is borne out by Deborah's productions of her first few words.

CAROLE (FRENCH)

At the 25-word point, Carole produced 27 word types (see Appendix). Table 8 indicates that at this point she violates markedness constraints at a rate of 1 - 83%, and faithfulness constraints at a rate of 1 - 31%. Moraic Binarity is satisfied far less often than any other constraint in either category, with 72% of these violations apparently occurring for the sake of faithfulness (i.e., CORR(MORBIN) dominates MORBIN). That is, if the syllables of the target word are not moraically binary, her productions typically are not either. She never violates *CC, and almost never violates PEAK (1% of the time). However, she also almost never violates CORR(PEAK) -- also 1% of the time. This implies that she is rarely attempting the limited set of French words that do not have vowels as syllable peaks. This may be due, at least in part, to their limited distribution in French, which has syllabic consonants only when a sonorant follows a stop such as the final [ʀ] in words like *poudre* 'powder', as well as to the articulatory difficulty of that consonant.

Table 8 about here.

As seen in Table 8, Carole does appear to avoid producing codas and clusters within syllables despite the presence of these in the target words. In these respects, markedness wins out in her productions. Several CODA examples are provided in Table 9. Interestingly, she preserves the stop (rather than the fricative or approximant) in the input even if this is not in onset position, moving a stop to onset position if need be (e.g., *sac* 'bag' is produced as [ka]). Thus, featural faithfulness to stops is ranked higher than to fricatives and approximants, and higher than to stop positional faithfulness.

Table 9 here.

However, other markedness constraints are lower-ranked. For example, Carole violates ONSET (i.e., produces a vowel-initial syllable) 9% of the time. When she does so, about one third (29%) of those violations are carried out in order to be faithful to the target word. Thus, 71% of her violations of ONSET are not due to faithfulness. The majority of the time when she produces a syllable without an onset, this is due to neither faithfulness nor universal markedness. In fact, many of these onsetless syllables are preposed on target words. Examples include [apa] for *poire* 'pear', [epɪ] for *pelle* 'shovel' and [akaka] for *canard* 'duck'.

Note that the status of glottal stop -- whether it is considered to be an onset or not -- makes no difference in Carole's phonology at this point. When she produces a word without a supraglottal onset, it is typically vowel-initial. These phonetically minimal "empty" initial syllables may serve the purpose of lengthening a monosyllabic word (such as *poire*), of holding the place of a weak syllable (as in *tortue* [aty]), or they may reflect an overgeneralization of the function word + content word patterns in French nouns and verbs (such as *la poire, `a voir).* However, Vihman & Velleman (2001) demonstrate a lack of correspondence in this period between children's frequency of use of vowel-onset words and their frequency of use of preposed filler-type syllables. Thus, a morphological basis cannot be assumed at this point in development.

In fact, very few of Carole's markedness violations are incurred in order to preserve aspects of the (presumed) overt form. She tends to be faithful to the number of syllables in a word, even when this violates Syllabic Binarity, but even this accounts for less than half of her violations of SYLBIN. In other words, sometimes she is producing an uneven number of syllables -- yielding a non-binary foot -- despite the fact that this is neither appropriate to the target word nor dictated by universal markedness.

CORR(SYLBIN), as for Deborah, is interesting. Carole often fails to reproduce the same number of syllables as in the target word (about one third of the time), but less than half of these violations result in a production that is presumed, on the basis of universal markedness, to be phonetically easier (binary). For example, the target word *bebe* ('baby') is already a binary foot: an optimal output with respect to markedness. Because both markedness and faithfulness dictate a two-syllable output, one would not expect anything else. Yet Carole produces *bébé* sometimes as the expected disyllabic word (e.g., [be:be], [βybeb]), sometimes monosyllabically (e.g., [beb]), and sometimes with three syllables (e.g., [m̩: be bi]). The number of syllables she produces per word appears to be unrelated to either syllabic binarity or the number of syllables in the target word. Carole does add moras to some of these syllables, but apparently not always to achieve foot binarity. The coda added to the form [beb] does compensate for the lack of a second syllable with respect to foot binarity, but both [be:be] and [βybeb] are already binary feet; the lengthened vowel in [be:be] and the final coda in [βybeb] are therefore unnecessary from this point of view.

In short, Carole's violations of markedness rarely appear to be for the sake of faithfulness, and her violations of faithfulness are only for the sake of markedness with respect to about half of the constraints studied. Even when two constraints (such as SYLBIN and CORR(SYLBIN)) are in accord with each other with respect to the optimal outcome, Carole sometimes produces some other, apparently non-harmonic form.

Once again, to assess the possibility that these patterns are due to changes that may have occurred in Carole's phonology between the onset of word production and the 25-word point, the analyses were repeated for the combination of two four-word point sessions for Carole (during which she produced five word types; see Appendix). And again, her profile at this earlier point in time (shown in Table 10), while different from that at 25 words, supports neither the MARK>>FAITH nor the FAITH>>MARK hypotheses.

While at the 25-word point the NOCODA markedness constraint appeared to dominate CORR(CODA), the two appear to be approximately equally ranked in these earlier sessions. Furthermore, faithfulness to intersyllabic consonant sequences ("C$C") already outranks markedness considerations, although the two appeared to be approximately equally ranked four months later. In other words, markedness constraints that appear to have already been demoted below or at an equal ranking with faithfulness at four words seem to have been promoted again at 25 words -- an example of phonological regression. As at 25 words, SYLBIN is violated about equally with respect to markedness and faithfulness, and many of the violations are for "no apparent reason". Markedness considerations do appear to have some slight priority over faithfulness constraints with respect to intrasyllabic clusters ("CC") and CODA, but this is not consistent. *CC is violated less than 1% of the time, never resulting in an increase in faithfulness, while CORR(CC) is violated 5% of the time, usually (86% of the time) for the sake of markedness. NOCODA is only violated 3% of the time, never resulting in an increase in faithfulness, while CORR(CODA) is violated 6% of the time, usually (75%) for the sake of markedness.

Table 10 about here.

Taro (Japanese)

Taro produced 20 word types at the 25-word point (See Appendix). A summary of his data are given in Table 11. Like Carole at four words, Taro ranks no markedness constraints above the corresponding faithfulness constraints. He is faithful to intersyllabic sequences of consonants, even though he only attempts one word with a target geminate (several times) -- [kottʃi], 'this one'. That is, he more typically targets clusters and produces them as sequences of distinct consonants. These productions violate the markedness constraint GEM, and the faithfulness constraint CORR(GEM) applies primarily to preserve non-geminates as such.

Table 11 about here.

Several of Taro's constraints are about equally ranked. PEAK and CORR(PEAK) are not often violated. However, when Taro does violate either the markedness or the faithfulness PEAK constraint, his production nonetheless fails to satisfy the other constraint. The same is true of syllable binarity. Taro sometimes omits and at other times adds a syllable in a target bisyllabic word; in both cases, he violates both SYLBIN and CORR(SYLBIN), as shown in Table 12. In the syllable omission cases, he does preserve binarity moraically (e.g., [ḁk] for *pakun*, [wɑɪ̯] for *wani)*, but the cases in which he adds a syllable are divided in that respect. Moraic binarity is provided by the final glottal stops on some productions of 'meow', 'sleeping' and 'this one' (although the coda in the **FIRST** syllable of 'this one' is problematic), but not by the extra syllables on his productions of 'car' and some of his productions of 'baby'.

Table 12 about here.

At the four-word point Taro produces six different word types (see Appendix). He has a preponderance of similarly-ranked constraints, as illustrated in Table 13. The rankings are so close that no markedness constraints can really be claimed to dominate any faithfulness constraints or vice versa. Some of these pairs (e.g., *CC and CORR(CC)) are both satisfied the vast majority of the time, indicating that Taro is not attempting words that differ in this respect (i.e., the words he attempts do not include intrasyllabic consonant clusters). However, all four binarity constraints are violated often; in this case, the constraints must have overlapping gradient ranking ranges since each dominates about half of the time.

Table 13 about here.

CORR(ONSET) is the faithfulness constraint that ranks the farthest above the related markedness constraint, ONSET. And here Taro goes too far, sometimes violating ONSET when this is not necessary, as in his production of *gao* ('roar') as [əɣɑ] (which is also sometimes produced with a consonant onset).

Fflur (Welsh)

Fflur's constraint ranking at 20 months (25-word point, at which she produced 23 words as listed in the Appendix) is given in Table 14. Markedness outranks faithfulness with respect to sequences of vowels. Faithfulness outranks markedness with respect to CODA, ONSET (if glottal stop is counted as an onset) and SYLBIN.

Table 14 about here.

Again, however, there is a certain amount of apparent randomness, in which constraint violations do not appear to occur for the sake of avoiding violations of related constraints. This is illustrated in Table 15 with respect to ONSET W/O ʔ. Fflur produces target glottal stop-initial syllables as such, but she also produces some syllables that have target supraglottal onsets in the same way, thereby violating both faithfulness and markedness.

Table 15 about here.

Similarly, she sometimes omits codas when they are called for (as markedness would predict), but also adds them when they are not (predicted by neither faithfulness nor markedness). Examples for CODA are provided in Table 16.

Table 16 about here.

The four-word point, when Fflur produces 11 different words in the two sessions (listed in the Appendix), is shown in Table 17. Many markedness constraints are ranked above the corresponding faithfulness constraints. However, CORR(PEAK), CORR(Coda), and CORR(MORBIN) are more often satisfied than the related markedness constraints. Furthermore, with the exception of CC and GEM, most pairs of related constraints fall very close to each other in the ranking, suggesting an overlap in their ranking value ranges.

Table 17 about here.

Fflur's few intersyllabic consonant clusters are of interest. They are not necessarily productions of target clusters. For example, *bwni* 'bunny' is produced as [ʔɛn:xə] and [ʔɛnŋɛ]. These productions are categorized as violations of CORR(C$C), and of GEM; CORR(GEM) is irrelevant, as there is no intersyllabic sequence of consonants in the target. But 'bunny' is also produced as [ʔʌnnɛ:], which violates CORR(C$C) but not GEM, and [hʊni]), which violates neither and is therefore the more expected output form. In contrast, target geminates are usually reproduced faithfully (e.g., *gag-gag* 'quack-quack' produced many times, mostly as [gaggak]). Thus, output geminates and output intersyllabic clusters may or may not have their source in a consonant sequence in the target word; in some cases they satisfy neither markedness nor faithfulness.

CONCLUSIONS/DISCUSSION

The results of this study disconfirm the common assumption that all markedness constraints outrank all faithfulness constraints at the onset of word production. Our findings also cast doubt upon the assumption of strict constraint domination, at least in child phonology. Every child in the study exhibited at least one pair of mark-faith related constraints for which the resulting word productions varied in their outcome, sometimes violating the markedness constraint and sometimes the faithfulness constraint; most exhibited several such pairs. These variable outcomes could not be attributed to within-word coarticulatory effects, as they occurred across multiple productions of the same word. Given that these children were at or just barely emerging from the one-word stage of production, this variability cannot be attributed to phrasal effects. However, only phonotactic constraints were considered in this study. It is quite possible that some of the violations of these constraints could be due to the influences of segmental constraints. For example, Deborah's productions of *kitty* with a [tl] or [kl] medial consonant cluster could reflect a faithfulness constraint requiring that the lateral feature of the medial flap be preserved. Even if so, the fact remains that Deborah also produced this word without a medial cluster upon occasion (e.g., as [k^hiwe]). Therefore, the CORR(Lateral) constraint applied variably i.e., gradiently.

Evidence in these results for gradient constraint ranking also includes evidence against articulatory limitations as an adequate explanation for discrepancies between target forms and child forms. In many cases, the children's errors constitute more difficult productions than required by the target. Something other than motor difficulty is compelling the child to produce a different, more articulatorily challenging form. Phonologization, i.e., generalization of grounded constraints beyond their motivating word forms, seems the most likely explanation. Another possible explanation is that the child, having been exposed to systematically variable forms of the targets, has stored underlying forms that include such gradient information, and that her/his outputs reflect those variable targets. It has been assumed, due to Richness of the Base (e.g., by Dinnsen, McGarrity, O'Connor & Swanson, 2000), that the child's underlying representations of words match one canonical surface adult form. Thus, all children learning the same language are presumed to have the same, invariant, output targets. This assumption ignores the child's perceptual experience of variable adult productions (Foulkes, Docherty, & Watt, 1999; Docherty, Foulkes, Tillotson, & Watt, 2002; Matthews, 2002; Scobbie, 2002). If constraints, underlying forms, or both are "induced" based upon statistical learning from the ambient overt forms, based upon the child's own motoric experience, or both, then variability should be a hallmark of the child's output, as it will have pervaded his/her experience of both types. The results of this study confirm this assumption.

A potentially puzzling finding of this study is that children from all four languages were consistently found to violate both faithfulness and markedness constraints. That is, in cases where the target satisfies markedness, and therefore is expected to be produced faithfully, the child often produces a more marked, unfaithful form. Typically, these "double violations" (in which the child form satisfies neither universal markedness nor faithfulness to the target) correspond to frequently-occurring patterns in the target language, as illustrated in Table 18. Thus, for example, the English-speaking child exhibits this type of unexpected pattern with respect to clusters and the Welsh-speaking child with respect to codas, in each case reflecting the frequencies of these structures in these languages. The French- and Japanese-speaking children show 'double violations' with respect to ONSET and Syllabic Binarity, reflecting the frequency of vowel-initial words and lengthy words with an uneven number of syllables, respectively, in their languages.

We propose that, based upon phonotactic probabilities in their ambient languages, the children have already developed language-specific constraints that may contradict universal grounded constraints. In a sense, these constraints reflect faithfulness to general tendencies in the language. However, faithfulness constraints are defined with respect to their interactions with particular targets, while markedness constraints can be determined independent of specific targets. Thus, these learned constraints must be considered to be markedness constraints despite their debt to the ambient language. This claim that children develop such "statistically faithful" markedness constraints, taken together with the other results of this study, implies that children in the very early stages of word production have already moved on from phonological universals in two respects: They already show a high degree of faithfulness to individual word forms, and their sets of markedness constraints have been altered (as well as re-ranked) to match the tendencies of the languages to which they have been exposed. This finding further confirms our claim that the onset of word production is not actually 'the initial [phonological] state', and that the frequently asserted assumption that all universal markedness constraints dominate all faithfulness constraints at that developmental point can no longer be maintained.

REFERENCES

Aitchison, J., & Chiat, S. (1981). Natural phonology or natural memory? The interaction between phonological processes and recall mechanisms. *Language and Speech, 24*(311-326).

Bernhardt, B. H., & Stemberger, J. P. (1998). *Handbook of phonological development from the perspective of constraint-based nonlinear phonology*. San Diego: Academic Press.

Boersma, P. (1998). *Functional phonology*. The Hague: Holland Academic Graphics.

Boersma, P. (October 4, 1999). On the need for a separate perception grammar. Ms, University of Amsterdam.

Boersma, P., & Hayes, B. (2001). Empirical tests of the gradual learning algorithm. *Linguistic Inquiry* **32.** 45-86.

Boersma, P. & Levelt, C. (2000). Gradual constraint-ranking learning algorithm predicts acquisition order. *Proceedings of Child Language Research Forum* **30**. Stanford, California, pp. 229-237 (Rutgers Optimality Archive 361-1199).

Boysson-Bardies, B. de., & Vihman, M. M. (1991). Adaptation to language: Evidence from babbling and first words in four languages. *Language* **67**. 297-319.

Demuth, K. (1995). Markedness and the development of prosodic structure. In Beckman, J. (ed.), *Proceedings of the North Eastern Linguistic Society 25*. Amherst, MA: GLSA, University of Massachusetts. 13-25.

Demuth, K. (1996). The prosodic structure of early words. In Morgan, J. L. & Demuth, K. (eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition*. Mahwah, NJ: Lawrence Erlbaum Associates. 171-184.

Dilley, L., Shattuck-Hufnagel, S., & Ostendorf, M. 1996. Glottalization of word-initial vowels as a function of prosodic structure, *Journal of Phonetics* **24**. 423-444.

Dinnsen, D. A., McGarrity, L. W., O'Connor, K. M., & Swanson, K. A. B. (2000). On the role of sympathy in acquisition. *Language Acquisition* **8**. 321-361.

Docherty, G., Foulkes, P., Tillotson, J., & Watt, D. (2002). On the emergence of structured phonological variation. To appear in Goldstein, L., Best, C., & Anderson, S. *Varieties of phonological competence: Proceedings of the Eighth Conference on Laboratory Phonology*. Yale University.

Escudero, P. & Boersma, P. (2001) Modelling the perceptual development of phonological contrasts with OT and the Gradual Learning Algorithm. (ROA 439-0601). To appear in *Proceedings of the 25th Penn Linguistics Colloquium*.

Fee, E. J. (1996). Syllable structure and minimal words. In Bernhardt, B., Gilbert, J., & Ingram, D. (eds.), *Proceedings of the UBC International Conference on Phonological Acquisition*. Somerville, MA: Cascadilla Press. 85-98.

Ferguson, C. A., & Farwell, C. B. (1975). Words and sounds in early language acquisition. *Language* **51**. 419-439.

Foulkes, P., Docherty, G. J., & Watt, D. J. L. (1999). Tracking the emergence of sociophonetic variation. *Leeds Working Papers in Linguistics and Phonetics* **7**. 1-25.

Gnanadesikan, A. E. (1995). Markedness and faithfulness constraints in child phonology. Ms., University of Massachusetts, Amherst. To appear in Kager, R., Pater, J., & Zonneveld, W. (eds.), *Fixing priorities: Constraints in phonological acquisition*.

Goad, H. (1996). Consonant harmony in child language: Evidence against coronal underspecification. In Bernhardt, B., Gilbert, J., & Ingram, D. (Eds.), *Proceedings of the UBC*

International Conference on Phonological Acquisition. Somerville, MA: Cascadilla Press. 187-200.

Goad, H. (1997). Consonant harmony in child language: An Optimality-theoretic account. In Hannahs, S. J. & Young-Scholten, M. (Eds.), *Focus on Phonological Acquisition*. Amsterdam: John Benjamins. 113-142.

Guest, D. J., Dell, G. S., & Cole, J. S. (2000). Violable constraints in language production: Testing the transitivity assumption of Optimality Theory. *Journal of Memory and Language* **42**. 272-299.

Hale, M., & Reiss, C. (1996). Competence and performance in child phonology. Ms., Concordia University, Montreal.

Hale, M., & Reiss, C. (1998). Formal and empirical arguments concerning phonological acquisition. *Linguistic Inquiry* **29**. 656-683.

Hayes, B. (1999). "Phonetically-driven phonology: The role of optimality theory and inductive grounding". In Darnell, M., Moravscik, E., Noonan, M., Newmeyer, F. & Wheatly, K. (eds.), Functionalism and formalism in linguistics, Volume I: General papers. Amsterdam: John Benjamins. 243-285.

Hayes, B. P. (2000). Gradient well-formedness in optimality theory. In J. Dekkers, J. , Leeuw, F. van der, & Weijer, J. van de (eds.), *Optimality theory: Phonology, syntax, and acquisition*. Oxford: Oxford University Press. 88-120.

Hayes, B. (in press). Phonological acquisition in Optimality Theory: The early stages. In Kager, R., Pater, J., & Zonneveld, W. (eds.), *Fixing priorities: Constraints in phonological acquisition*.

Hayes, B. & MacEachern, M. (1998). Quatrain form in English folk verse. *Language* **64**. 473-507.

Johnson, E. K., & Jusczyk, P. W. (2001). Word segmentation by 8-month-olds: When speech cues count more than statistics. *Journal of Memory and Language* **44**. 548-567.

Kehoe, M., & Stoel-Gammon, C. (1997). The acquisition of prosodic structure: An investigation of current accounts of children's prosodic development. *Language* **73**. 113-144.

Levelt, C., & Van de Vijver, R. (June 1998). Syllable types in cross-linguistic and developmental grammars. Paper presented at the Third Biannual Utrecht Phonology Workshop, Utrecht, the Netherlands.

Macken, M. A. (1978). Permitted complexity in phonological development: One child's acquisition of Spanish consonants. *Lingua* **44**. 219-253.

Macken, M. A. (1979). Developmental reorganization of phonology: A hierarchy of basic units of acquisition. *Lingua* **49**. 11-49.

Matthews, B. (2002). On variability and the acquisition of vowels in normally developing Scottish children (18 -36 months). To appear in Goldstein, L., Best, C., & Anderson, S. *Varieties of phonological competence: Proceedings of the Eighth Conference on Laboratory Phonology*. Yale University.

McCarthy, J. (1988). Feature geometry and dependency: A review. *Phonetica* **43**. 84-108.

McCarthy, J. J., & Prince, A. S. (1995). Faithfulness and reduplicative identity. In Beckman, J. N., Dickey, L. W., & Urbanczyk, S. (eds.), *Papers in Optimality Theory*. Amherst, MA: Graduate Linguistic Student Association, University of Massachusetts. 249-384.

Menn, L. (1976) *Pattern, control, and contrast in beginning speech: A case study in the development of word form and word function*. Doctoral dissertation, U. of Illinois.

Menn, L. (1983). Development of articulatory, phonetic, and phonological capabilities. In Butterworth, B. (ed.), *Language production, vol. 2*. London: Academic Press. 3 – 50.

Menn, L. (in press). Saving the baby: Making sure that old data survive new theories. In Kager, R., Pater, J., & Zonneveld, W. (eds.), *Fixing priorities: Constraints in phonological acquisition*.

Pater, J. (in press). Bridging the gap between receptive and productive development with minimally violable constraints. In Kager, R., Pater, J., & Zonneveld, W. (eds.), *Fixing priorities: Constraints in phonological acquisition*.

Roark, B. & Demuth, K. (2000). Prosodic constraints and the learner's environment: A corpus study. In Howell, C. et al. (eds.), *BUCLD 24 Proceedings*. Somerville, MA: Cascadilla Press. 597-608.

Scobbie, J. M. (2002). Flexibility in the face of incompatible English VOT systems. To appear in Goldstein, L., Best, C., & Anderson, S. *Varieties of phonological competence: Proceedings of the Eighth Conference on Laboratory Phonology*. Yale University.

Smith, B. L., Macaluso, C., & Brown-Sweeney, S. (1991). Phonological effects shown by normal adult speakers learning new words: Implications for phonological development. *Applied Psycholinguistics, 12,* 281-98.

Smolensky, P. (1996). On the comprehension/production dilemma in child language. *Linguistic Inquiry* **27.** 720-731.

Smolensky, P., Davidson, L., & Jusczyk, P. (2000). The initial and final states: Theoretical implications and experimental explorations of richness of the base (Rutgers Optimality Archive ROA-428). To appear as Chapter 16, "Optimality in language acquisition I: Phonology" in Smolensky, P. and Legendre (in press), *The Harmonic Mind: From neural computation to Optimality Theoretic grammars*. Cambridge: Blackwell.

Stemberger, J. P., Bernhardt-Handford, B., & Johnson, C. E. (1999). U-shaped learning in phonological development. Ms., University of British Columbia.

Stoel-Gammon, C., Buder, E. H., & Kehoe, M. M. (1995). Acquisition of vowel duration: A comparison of Swedish and English. Proceedings of the 13th International Congress of Phonetic Sciences **4.** 30-37.

Tesar, Bruce (2000). Using inconsistency detection to overcome structural ambiguity in language learning. RuCCS Technical Report TR-58, Rutgers University.

Tesar, Bruce, B. & Smolensky, P. (1998). Learnability in Optimality Theory. *Linguistic Inquiry* **29**. 229-268.

Velleman, S. L. (1996). Metathesis highlights feature-by-position constraints. In Bernhardt, B., Gilbert, J., & Ingram, D. (eds.), *Proceedings of the UBC International Conference on Phonological Acquisition*. Somerville, MA: Cascadilla Press. 173-186.

Velleman, S. L., & Vihman, M. M. (2002). Whole-word phonology and templates: Trap, bootstrap, or some of each? *Language, Speech, and Hearing Services in the Schools* **33**. 9-23.

Vihman, M. M. (1981). Phonology and the development of the lexicon: Evidence from children's errors. *Journal of Child Language* **8**. 239-264.

Vihman, M. M. (1996). *Phonological development: The origins of language in the child*. Cambridge, MA: Blackwell Publishers Inc.

Vihman, M. M., & Boysson-Bardies, B. de. (1994). The nature and origins of ambient language influence on infant vocal production. *Phonetica* **51**. 159-169.

Vihman, M. M., Macken, M. A., Miller, R., Simmons, H., & Miller, J. (1985). From babbling to speech: A reassessment of the continuity issue. *Language* **61**. 395-443.

Vihman, M. M., & McCune, L. (1994). When is a word a word? *Journal of Child Language* **21.** 517-542.

Vihman, M. M., & Miller, R. (1988). Words and babble at the threshold of language acquisition. In Smith, M.D., & Locke, J. L. (eds.), *The emergent lexicon: The child's development of a linguistic vocabulary*. New York: Academic Press. 151-184.

Vihman, M. M., Nakai, S. & DePaolis, R. A. (2002). Getting the rhythm right: A cross-linguistic study of segmental duration in babbling and first words. To appear in Goldstein, L., Best, C., & Anderson, S. *Varieties of phonological competence: Proceedings of the Eighth Conference on Laboratory Phonology*. Yale University.

Vihman, M. M., & Velleman, S. L. (1989). Phonological reorganization: A case study. *Language and Speech* **32.** 149-170.

Vihman, M. M. & Velleman, S. L. (2000). The construction of a first phonology. *Phonetica* **57**. 255-266.

Vihman, M. M., & Velleman, S. L. (2001). More crosslinguistic evidence on fillers in the late single-word period. *Journal of Child Language* **28**. 279-282.

Vihman, M. M., Velleman, S. L., & McCune, L. (1994). How abstract is child phonology? Towards an integration of linguistic and psychological approaches. In Yavas, M. (ed.), *First and Second Language Phonology*. San Diego: Singular Press. 9-44.

Waterson, N. (1971). Child phonology: A prosodic view. *Journal of Linguistics* **7**. 179-211.

Name	Age @ 25 words	Ages @ 4 words
ENGLISH		
Deborah	1;3.24	0;11.4 & 0;11.11
Emily	1;3.29	
Molly	1;2.20	
Sean	1;3.23	
Timmy	1;4.22	
FRENCH		
Carole	1;2.5	0;10.26 & 0;11.10
Charles	1;3.19	
Laurent	1;5.15	
Marie	1;7.24	
Noel	1;5.23	
JAPANESE		
Taro	1;11.2	1;03.09 & 1;03.14
Emi	1;4.7*	
Haruo	1;7.17	
Kazuko	1;3.28	
Kenji	1;6.17	
WELSH		
Fflur	1;5.2	1;1.6 & 1;1.20
Carys	1;5.29	
Gwyn	1;2.24	
Elen	1;6.6	
Nona	1;6.18	

*Last session @ 19-word point.

TABLE 1: List of subjects by language, name, and age

Markedness	Faithfulness
PEAK	CORR(PEAK)
ONSET	CORR(ONSET)
NOCODA	CORR(CODA)
FTBIN:	
SYLBIN	CORR(SYLBIN)
MORBIN	CORR(MORBIN)
*COMPLEX(C):	
*CC	CORR(CC)
*C$C	CORR(C$C)
*COMPLEX(V) a.k.a. *VV	CORR(VV)
GEM	CORR(GEM)

Table 2: Constraints Considered

Rank	English	French	Japanese	Welsh
1.	CORR(PEAK)	CORR(PEAK)	CORR(PEAK)	CORR(PEAK)
2.	PEAK	PEAK	PEAK, *CC	PEAK
3.	*CC	*VV	CORR(CC)	*CC
4.	CORR(ONSET)	*CC	CORR(GEM)	CORR(CC)
5.	CORR(GEM)	CORR(CC)	CORR(VV)	CORR(CODA)
6.	*VV	CORR(ONSET)	*VV	CORR(SYLBIN)
7.	CORR(VV)	NOCODA	ONSET	CORR(ONSET)
8.	CORR(CC)	ONSET	CORR(ONSET)	*C$C
9.	ONSET	CORR(CODA)	NOCODA	CORR(GEM), *VV
10.	*C$C	*C$C, CORR(C$C)	CORR(SYLBIN)	CORR(C$C)
11.	CORR(SYLBIN)	CORR(SYLBIN)	CORR(CODA)	SYLBIN
12.	NOCODA	CORR(MORBIN)	GEM	CORR(MORBIN)
13.	CORR(C$C)	CORR(GEM)	CORR(C$C)	MORBIN
14.	GEM+	GEM SYLBIN	ONSET	
15.	CORR(CODA)	SYLBIN	*C$C	NOCODA, CORR(VV)
16.	CORR(MORBIN)	MORBIN	CORR(MORBIN)	GEM
17.	MORBIN	CORR(VV) - N/A	MORBIN	
18.	SYLBIN			

Table 3: Average constraint rankings by language group

Constraint	Percent violated	For satisfaction
CORR(ONSET W/O ʔ)	0	NA
CORR(PEAK)	0	NA
PEAK	1	100
ONSET W/O ʔ	1	0
CORR(SYLBIN)	1	53
CORR(ONSET W/ ʔ)	1	0
NOCODA	2	0
*CC	6	17
*C$C	10	0
ONSET W/ ʔ	12	92
CORR(CC)	12	54
CORR(C$C)	12	0
CORR(VV)	14	75
*VV	19	75
CORR(CODA)	26	93
CORR(MORBIN)	27	100
MORBIN	33	91
SYLBIN	74	88

Table 4: Deborah (25 wds) Constraints Rank-Ordered by Percent Violated and Percent of those Violations that Result in Satisfaction of Related Constraint

Note: "ONSET W/O ʔ" refers to the ONSET constraint, calculated without including glottal stops as possible onsets. "ONSET W/ ʔ" refers to the same constraint, recalculated including glottal stops as possible onsets.

Target	Actual
bird	[b^{w}ɑ], [βu̯œ]
cheese	[si:]
corn	[k^{h}ɔ:] (2), [k^{h}ɔʔɔ], [k^{h}ɔːɛ], [k^{h}ɔi]
down	[tɑ:] (3), [tæː]
duck	[tæ:]
eyes	[ʔɑː], [ʔɑɪ], [ʔeː] (2)
kitty	[t̰let̪l̥ːi], [k^{h}ek̬li], [k^{h}iwe], [t̪l̥ːi]
monkey	[hm mæ̃ː]
up	[ʔɑː], [ʔɑ^h] (2)

Table 5: Deborah (25 wds): NoCoda >> Corr(Coda)

Note: Each actual form is produced in the manner indicated only once unless otherwise noted

Target	Actual
Omit CC:	
three	[siːː] (6), [seː]; [tsi]
monkey	[hm̩.mæ]
Add CC:	
bird	[bwɑ]; [βu̯œ]
kitty	[t̥l̥ɛt̥l̥ːi], [kek̥l̥i], [t̥l̥ːi]; [k^{h}iwe]
moo	[bwoːʌ]; [boː], [bʌː], bɔ^{h}waː], [bɔʔɔ], [bɔhʊː], [bɔːhə], [buːə]two [t^{S}i]; [t^{h}i]

Table 6: Deborah (25 wds): *COMPLEX(C) ≅ CORR(CC)

Note: Each actual form is produced in the manner indicated only once unless otherwise noted

Constraint	Percent violated	For satisfaction
PEAK	0	NA
*CC	0	NA
GEM	0	NA
CORR(PEAK)	0	NA
CORR(CODA)	0	NA
CORR(CC)	0	NA
CORR(C$C)	0	NA
NOCODA	3	100
CORR(ONSET W/O ʔ)	4	0
*C$C	11	100
ONSET W/ʔ	14	0
CORR(MORBIN)	19	100
CORR(ONSET W/ ʔ)	34	0
CORR(SYLBIN)	41	50
MORBIN	48	97
SYLBIN	57	67
ONSET W/O ʔ	65	11
CORR(GEM)	100	100

Table 7: Deborah (4 wds) Constraints Rank-Ordered by Percent Violated

Constraint	Percent violated	For satisfaction
*VV	1	0
PEAK	1	0
CORR(PEAK)	1	0
CORR(ONSET)	5	60
NOCODA	6	22
*CC	7	20
CORR(CC)	7	17
*C$C	8	0
ONSET	9	29
GEM	9	100
CORR(C$C)	10	100
CORR(CODA)	28	87
CORR(MORBIN)	31	29
CORR(SYLBIN)	31	42
SYLBIN	33	46
MORBIN	83	72
CORR(GEM)	100	100

Table 8: Carole (25 wds) Constraints Rank-Ordered by Percent Violated

Target	Gloss	Actual
sac	bag	ka (4), ka^h (2), kəka, cata
tas	cup	ta, ssikajeta
babar	Babar	baba
ãkor	again	^{h}akɔ, ɐka, ɐkɔ (2), kɔːkɔ, hækɔ, kɔː, heta, hɔkɔ, ækɔ
pɛl	shovel	pɪ, ^{e}pɪ
(a) bwar	drink	ba, aba

Table 9: Carole (25 wds): NoCoda >> Corr(Coda)

Constraint	Percent violated	For satisfaction
GEM	0	NA
*CC	<1	0
PEAK	1	0
CORR(PEAK)	1	50
CORR(C$C)	2	0
NOCODA	3	0
CORR(CC)	5	86
CORR(CODA)	6	75
CORR(ONSET)	6	12
ONSET (W/ or W/O ʔ)	9	0
CORR(SYLBIN)	24	50
SYLBIN	26	45
*C$C	29	0
MORBIN	83	90

Table 10: Carole (4-word point): Constraints Rank-Ordered by Percent Violated

Constraint	Percent violated	For satisfaction
CORR(GEM)	0	NA
CORR(ONSET) – either	5	0
ONSET w/o ʔ	10	58
ONSET w/ ʔ	11	56
CORR(PEAK)	11	0
PEAK	12	0
CORR(VV)	12	12
CORR(CC)	12	24
*CC	13	32
*VV	14	20
NOCODA	19	79
CORR(CODA)	22	81
CORR(C$C)	26	60
CORR(MORBIN)	32	70
CORR(SYLBIN)	33	11
SYLBIN	36	17
*C$C	43	76
GEM	42	82
MORBIN	44	73

Table 11: Taro (25-word point): Constraints Rank-Ordered by Percent Violated

Target	Gloss	Actual
Omit syllable		
wani	‘alligator’	ʰwɑ͜ɪ (7), wɑ͜ɪ (4), hw͜ɔːɪ (2), hwɑː, ʰm͜wʌ͜ᴵ, hmwɑ˞
pakun	‘bite sound’	ɑ̥k (2), hḁᵏkʰŋ (3), ɑ̥kŋ (2), ɑkŋːn (2), hakŋ, ɑkmŋ
Add syllable		
bebi	‘baby’	ɑbebi, ʌbɪbɪː, jɑːpi, bɪbɪʔ
bubu	’car’	əbʊbʊ
kottʃi	‘this one’	kʊt.tʃʊ.ʔʊʔ, hɔ̥kuʔt,ʊ̥, kutʃʊʔ, kʊt͜ᵗʃəʔ, kʊʔtsʊʔ, kʊtᵗʃʊʔ (4)
nɥao	’cat’/’meow’	nn̩æʔ (2), næʊ
nenne	‘sleeping’	ənenеʔ, nenne (2), ⁿnenne (3), mɛnɛʔ

Table 12: Taro (25 wds): SYLBIN versus CORR(SYLBIN)

Constraint	Percent violated	For satisfaction
PEAK	0	NA
*CC	0	NA
GEM	0	NA
CORR(PEAK)	0	NA
CORR(CC)	0	NA
CORR(ONSET) (either)	2	0
NOCODA	5	0
CORR(CODA)	8	50
*C$C	9	0
CORR(C$C)	14	67
ONSET W/ ʔ	17	36
ONSET W/O ʔ	18	30
MORBIN	41	81
CORR(SYLBIN)	41	15
SYLBIN	44	21
CORR(MORBIN)	52	91

Table 13: Taro (4-word point): Constraints Rank-Ordered by Percent Violated

Constraint	Percent violated	For satisfaction
CORR(PEAK)	1	0
PEAK	2	0
CORR(ONSET W/O ʔ)	3	40
ONSET W/O ʔ	7	70
*VV	10	50
*CC	11	19
CORR(CC)	12	43
CORR(SYLBIN)	12	18
CORR(GEM)	14	100
GEM	18	0
CORR(CODA)	21	14
CORR(ONSET W/ ʔ)	23	6
MORBIN	23	65
*C$C	28	48
ONSET W/ ʔ	33	27
CORR(MORBIN)	33	76
CORR(C$C)	40	52
SYLBIN	40	78
NOCODA	54	79
CORR(VV)	59	22

Table 14: Fflur (25-word point): Constraints Rank-Ordered by Percent Violated

Target	Gloss	Actual
ʔaʊ	ow	ʔaʊ (3), ʔax, ʔaʊːtθ, ʊaʊ
ʔɛto	again	ʔəθɑ^{h}, ʔəθʔɑx, t^{h}ɒ^{h}
hʊnɑ	this	ʔəɲa, ʔɔ^{n}‿na
vana	there	m̩a^{h}, n̩a^{h}, ʔɛ^{n}næː, ʔə^{m}‿mɑ^{h}, ʔʌ^{m}‿mə^{h}
gwałt	hair	ʔaχ

Table 15: Fflur (25 wds): CORR(ONSET)>>ONSET

Target	Gloss	Actual
Omit Coda:		
mʊŋki	‘monkey’	k^{h}iθɛ^{h}, gʌ^{g}gɪ^{h}, k^{h}ʌ^{g}gɪ^{ʔ}
sʌrθjɒ	‘fall’	ʔəzɒ, ʔəsɒ^{h}, ʔɪsɒ^{h}, ʔʌsː.sɑ^{h}, tθ‘.ɪɒ^{h}
gaggag	‘quack-quack’	gagag, gaʊkag, g^{w}agək, gwakak, gəgak^{h}, kxəgag, d^{h}agag, g^{ʊ}agak, χʌ.gaːg, x.gag, ga^{g}gak, g^{h}a^{g}gak, ga^{g}gag (2), gaːk^{h}, ga^{g}gaːk, g^{w}a^{g}gak, ga^{g}gæk, ,ga^{g}gak^{h}, ga^{g}gwag, da^{d}daːg,
Add Coda:		
ʔɑʊ	‘ow’	ʔaʊːtθ, ʔax, ʔaʊ (3), ʊaʊ
vanku	‘here’	k^{h}ux, klʊ^{h}
ʔɛto	‘again’	ʔəθʔɒx, ʔəθɑ^{h}, t^{h}ɒ^{h}
bʊni	‘bunny’	ʔɛnxə, ʔɛ^{n}ɲɛ (2), ʔʌ^{n}ɲɛ^{h}, ʔʌ^{n}na, ʔʌnɛ, ʔʌ^{n}nɛː, ʔəɲɛ, naneː^{h}

Table 16: Fflur (25 wds): Corr(Coda)>>NoCoda w/violations of both

Constraint	Percent violated	For satisfaction
CORR(PEAK)	3	0
*CC	3	50
PEAK	4	0
*VV	4	0
ONSET W/ʔ	8	0
CORR(VV)	9	25
SYLBIN	12	100
ONSET W/O ʔ	13	0
GEM	13	100
CORR(SYLBIN)	13	100
CORR(CODA)	15	36
CORR(CC)	15	91
CORR(ONSET) (both)	15	45
NOCODA	17	4
*C$C	23	14
CORR(C$C)	39	33
CORR(MORBIN)	45	33
MORBIN	50	44
CORR(GEM)	50	0

Table 17: Fflur (4-word point): Constraints Rank-Ordered by Percent Violated

Child	Language	Phonotactic pattern
Deborah (25 wd pt.)	English	CC, MORBIN, C$C, VV
Carole (25 wd pt)	French	ONSET, SYLBIN
(4 wd. pt)		SYLBIN
Taro (25 wd. pt.)	Japanese	SYLBIN
(4 wd. pt.)		ONSET
Fflur (25 wd. pt.)	Welsh	ONSET, CODA
(4 wd. pt.)		C$C, GEM

Table 18: Double violations: Phonotactic patterns for which some child forms satisfy neither universal markedness nor faithfulness to the target

See text for specific examples.

/kɪɾi/	Corr (Onset)	Onset	Corr (SylBin)	NoCoda	*CC	*C$C	Corr (CC)	Corr (C$C)	Corr (Coda)	SylBin
t̥let.l̥:i				*	*	*	*	*	*	
kʰi.we										
kʰek̬.li				*		*		*	*	
t̥l:i			*		*		*			*

Figure 1: Deborah tableau for *kitty*

Appendix: Lexicons of Children Analyzed in Detail

See Vihman (1996) for lists of phonological variants of these words.

(Note: Number of tokens indicated in parentheses.)

Deborah: 25-word point

'A' (1)

baby (7)

ball (7)

bird (2)

bottle (2)

bye (1)

cheese (1)

corn (5)

down (4)

duck (1)

eyes (4)

hi (14)

kitty (4)

monkey (1)

moo (8)

three (8)

two (2)

up (3)

water (5)

Deborah: 4-word point

baby (7)

hi(ya) (29) [1]

uh-oh (5)

music ([hu-hu-hu]) (29)

monkey (4)

[1] Because this word had a phonotactically variable overt form, both monosyllabic and disyllabic productions were considered to match the target from the point of view of faithfulness.

Carole: 25-word point

Babar (3) (name)

bébé (9) 'baby'

Brun (4) (name)

chapeau (4) 'hat'

cuiller (2) 'spoon'

fromage (1) 'cheese'

lapin (2) 'rabbit'

main (1) 'hand'

Mimi (souris) (3) 'Name (mouse)'

papa (1)

(la) poire (1) '(the) pear'

(c’est) quoi (1) '(it's) what?'

tasse (2) 'cup'

(petite) voiture (2) '(little) car'

(la) balle (2) '(the) ball'

(à) boire (1) '(to) drink'

canard (3) 'duck'

(la) clef (2) '(the) key'

encore (10) 'again, more'

(il y en) a plus (1) 'no more'

lunette (2) 'glasses'

maman (6) 'Mama'

néné/nounours (5) 'teddy bear'

pelle (1) 'shovel'

Popi (1) (name)

sac (8) 'bag'

tortue (4) 'turtle'

Carole: 4-word point

bébé (36) 'baby'

Mickey/Kiki (2) (name)

papa (24)

balle (19) 'ball'

nounours/néné (3) 'teddy bear'

Taro (25-word point)

ball (1)	be(e)bi(i) (4) ‘baby’
bubu (1) ‘car’	hai (2) ‘here you are’
haitta (1) ‘gone inside’	jaja (5) ‘sound of pouring water’
juusu (4) ‘juice’	kocchi (10) ‘this one, this way’
kukku (1) ‘shoe’ (BT)	nainai (1) ‘put away’ (BT)
(o)nenne (7) ‘sleep(ing)’ (BT)	nya(a)(o) (3) ‘kitty’ (BT)
ototo (1) ‘fish’ (BT)	pak(k)un (12) ‘biting sound, bite-bite’
pipi (2) ‘birdie’ (BT)	picha picha (2) ‘splashing sound’ (BT)
ringo (3) ‘apple’	wani (16) ‘alligator’
wanwan (4) ‘doggy’ (BT)	yoisho (1) ‘oof’

Taro (4-word point)

bubu (11) ‘car’	gao (5) ‘roar’
haitta (2) ‘gone inside’	koko (6) ‘here’
iya (3) ‘no’	yoisho (5) ‘oof’

Fflur (25-word point)

aw (6) 'ouch'

bôch (1) 'cheek'

bwni (10) 'bunny'

crocodeil (1) 'crocodile'

(nos) da (3) 'good night'

diod (2) 'drink'

drwg (6) 'bad'

eto (3) 'again'

gag-gag (21) 'quack-quack'

gwallt (1) 'hair'

hwnna (2) 'this'

llaw (1) 'hand'

mam (3) 'mom'

mwnci (3) 'monkey'

moron (7) 'carrot'

Po (2) (Tellytubby character)

pws (4) 'puss'

rhein (1) 'these'

styc (1) 'stuck'

syrthio (5) 'fall'

tri (1) 'three'

fanna/fyna (5) 'over here'

fan'cw (2) 'over there'

Fflur (4-word point)

agor (5) 'open'

blodyn (4) 'flower'

ceg (5) 'mouth'

geegee (4) 'horse sound'

golau (2) 'light'

me(me) (7) 'sheep sound'

na (13) 'no'

sannau (3) 'socks'

sgidie (3) 'shoes'

ENDNOTES

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[2] Word-internal sequences of consonants were assumed to be singletons (e.g., CVC$CV rather than CV$CCV) in all cases. If these productions of *kitty* are assumed to be of the forms CCV$CCV - as her frequent production of consonant harmony forms might suggest - and CV$CCV, then Deborah never violated NoCoda. Further discussion of these errors follows later in this section.