Truncation Patterns in English-Speaking Children’s Word Productions

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This study examines English-speaking children’s truncation patterns (i.e., syllable deletion patterns) in multisyllabic words to determine if they are consistent with metrical constraints or perceptual biases. It also examines segmental influences on children’s truncations. Children, age 22–34 months, produced three-syllable novel and real words and four syllable real words, which varied across stress and segmental pattern. Results revealed a significant stress pattern effect on truncation rate, but findings were not consistent with metrical or perceptual salience predictions. The clearest account of the findings came from an analysis of truncation rate across individual words. Children truncated WSW (weak-strong-weak) words and words that contained intervocalic sonorants more frequently than other words. Analysis of truncation patterns in SWW and SWSW words revealed that final unstressed syllables were more frequently preserved than nonfinal unstressed syllables. Findings support the interaction between metrical, syllabic, and acoustic salience factors in children’s multisyllabic word productions.

KEY WORDS: phonological development, stress, prosody

During recent years, the domain of interest in child phonology has shifted from a focus on segmental development alone to both segmental and suprasegmental development. This shift of focus reflects both the emergence of the nonlinear linguistic framework, with its stronger emphasis on prosodic phenomena, as well as the increasing awareness that children display interesting patterns of prosodic behavior. Children delete syllables, add syllables, and alter the stress contour in their productions of multisyllabic words (Allen & Hawkins, 1980; Demuth, 1996b; Fikker, 1994; Gerken, 1994). Of these rhythmic behaviors, children’s syllable deletion patterns, also known as truncation patterns, have received the greatest degree of research attention. Researchers have been particularly interested in explaining why children delete unstressed syllables in certain word positions more than others. Some investigators have accounted for truncation patterns in terms of metrical constraints (Allen & Hawkins, 1980; Fikker, 1994; Gerken, 1994; Wijnen, Krikhaar, & den Os, 1994); other investigators have proposed perceptual biases as the underlying mechanism (Echols & Newport, 1992); still other investigators have observed segmental influences on children’s truncations (Carter Young, 1991; Kehoe, 1994, 1995). This study examines metrical, perceptual, and segmental effects on...
truncation patterns in English-speaking children's multisyllabic word productions.

**Metrical Constraints**

It is well documented that English-speaking children frequently omit the initial weak syllable of a WS word such as *gRAPPE*, producing *RAPPE*, but rarely omit the weak syllable of a SW word such as *MONkey*, producing *MON* (Allen & Hawkins, 1980; Schwartz & Goffman, 1995). (Throughout the manuscript, *S* will refer to a strong or stressed syllable, and *W* will refer to a weak or unstressed syllable. Target lexical items will appear in italics with primary and secondary stressed syllables denoted by uppercase letters.) Observations such as these led Allen and Hawkins (1979, 1980) to propose that children's productions were governed by a trochaic rhythmic bias. They proposed that words with a trochaic stress pattern were easier to produce and/or perceive than words with an iambic stress pattern. Their original claim was that this constraint was universal, but in the absence of rigorous cross-linguistic evidence, the universality of the constraint remains unaddressed.

Subsequent work by Gerken has provided additional support for a trochaic rhythmic bias in early linguistic development (Gerken, 1991, 1994). Gerken redefined the bias as a production-based constraint and applied the constraint to children's productions of longer words. According to Gerken, children align a trochaic (SW)metrical template at the beginning of an intended word. The template works by lining up the first strong syllable of the target word with the strong syllable of the template. Weak syllables that do not fit the template are omitted. For example, Gerken showed that when children are asked to imitate a four-syllable word with the metrical template WSWS, such as *paZAMkaSIS*, they are more likely to omit the first weak syllable than the second because it falls outside the trochaic template. The second weak syllable is less frequently omitted because it forms a trochaic pattern with the strong syllable *ZAM*. Similarly, in the word *ZAMPakoSIS* the second weak syllable is omitted more frequently than the first because it falls outside the trochaic template.

In English, the main support for metrical constraints in word production has come from Gerken's experiments with SWWS and WSWS words. A recent study by Johnson, Lewis, and Antone (1996) found no preferred status for SW patterns in one subject's productions of multisyllabic words, but this subject was younger than the subjects tested in Gerken's studies. Investigations with Dutch-speaking children have shown support for metrical templates using a variety of stress patterns and with children of differing age ranges (Wijnen et al., 1994).

**Perceptual Salience**

Other investigators have accounted for children's truncation patterns on the basis of perceptual or encoding limitations. According to this account, the syllables most likely to be reproduced in multisyllabic words are the ones that receive acoustic prominence from their position in the word and from the application of stress (Blasdel & Jensen, 1970; Klein, 1981a, 1981b). Stressed syllables are acoustically more prominent than unstressed syllables. Word-final syllables are more prominent than nonfinal syllables because they may receive acoustic cues related to phrase boundaries, such as lengthening and accent effects. Attention and memory factors may also make final syllables easier to encode (Slobin, 1973).

The most recent articulation of a perceptual salience model has been provided by Echols and colleagues (Echols, 1993; Echols & Newport, 1992), who gathered data from three English-speaking children during the one-word stage of language development. The children's productions of multisyllabic adult target words were coded in terms of syllable omissions and segmental accuracy. Findings showed that syllables that were either stressed or final in the adult target word were less frequently omitted and more accurately produced than syllables that were unstressed and nonfinal. Echols (1993) proposed that because unstressed nonfinal syllables are acoustically less salient than stressed syllables, they are less fully specified in underlying representation and, thus, are more susceptible to omission and to processes that fill in default segments or spread or copy segments from adjacent stressed syllables.

In recent years, a number of convincing arguments have been advanced against a pure perceptual account of children's truncations (Demuth, 1996b; Fikkert, 1994; Gerken, 1994; Wijnen et al., 1994). One of the most compelling is that children frequently produce segments and features from syllables that are omitted and incorporate them into their retained syllables. Thus, a child might produce *baNAna* as *[ba:næ:]*, suggesting that some of the segmental information contained in the unstressed syllable is perceived and stored. A second argument against a perceptual account is that children frequently alternate between truncated and nontruncated forms in their productions. That is, they might produce the forms *baNAna* and *NA* at similar points in time, again suggesting that their lexical representations are not constrained. A third argument comes from comprehension studies showing that children are sensitive to the existence of function morphemes even though their spontaneous speech displays few examples of morpheme production (Gerken, Landau, & Remez, 1990; Gerken & McIntosh, 1993; Petretic & Twene, 1977). This is consistent with the
parallel behavior of unstressed syllables in words and function morphemes in sentences (Gerken, 1991).

Finally, a direct comparison of a perceptual- versus S/W judgment-based account was conducted by Gerken (1994) in her study of children's imitated productions of novel words. Gerken found that children retain the second weak syllable more frequently in SWS words (e.g., paZAMkoSIS) and the first weak syllable more frequently in SWWS words (e.g., ZAMpakaSIS). A perception-based account cannot explain these findings because neither of the weak syllables occurs in the favored final position.1

There is, however, one stress pattern that a S/W production template has more difficulty accounting for. There are reports suggesting that English-speaking children preserve the second weak syllable more frequently than the first in their productions of SWW words (Echols & Newport, 1992; Klein, 1981b), whereas a S/W production template would predict that the first weak syllable should be more frequently preserved. Gerken (1994) refers to this finding as the "Elephant problem" because productions of Elephant, a SWW word, typically include the second weak syllable (e.g., [ɛfɔn] rather than [ɛn]).

To explain the more frequent preservation of the second weak syllable in productions of SWW words, Gerken proposes that segments conform to a canonical CV(C) as well as S/W template. For example, in the word Elephant, the first syllable fits the S slot of the S/W template but not the CV(C) template. However, because it is the only strong syllable in the word, it is selected. The second syllable fits the W slot of the metrical template but not the CV(C) template. The third syllable fits both the metrical and the CV(C) template and hence it is selected (the final /t/ may be dropped in order to fit the template). An important aspect of this account is that Gerken assumes syllabification of Elephant as EL-e-phant (Fallows, 1981; Wijnen, 1988). For the present, we assume that intervocalic consonants syllabify with the unstressed rather than the stressed syllable, but issues of syllabification will be addressed later in this paper.

**Integrated Effects**

An additional factor that may influence truncation is the segmental content of the target word. Several investigators have examined whether the articulatory difficulty of individual sounds contributes to differential rates of syllable omissions. Carter Young (1991) observed that frequently deleted syllables in children's productions of multisyllabic words contained "difficult" segments, such as /d/ and /t/, for example, the initial unstressed syllables of the words giRAFFE and reFRigerATor. Ultimately, she argued against the influence of individual segments because the same children who deleted syllables with these segments in them were capable of realizing these segments in other words. Similarly, Hura and Echols (1996) showed that articulatory difficulty, as determined by penalty scores for consonant articulation and co-occurrence restrictions on consonant-vowel combinations, had no significant effect on syllable omission.

Although articulatory difficulty per se may not contribute to truncation rate, segmental factors may be implicated in other ways. Kehoe (1994) found very different rates of truncation among words with the same number of syllables and stress pattern in the productions of a group of 27-month-old children. For example, she observed that the SWS words DiNOsAUR and TeLEPHONE were truncated more frequently than another SWS word CRoCoDILE; the SWW word Elephant was truncated more frequently than another SWW word OcToPUS. The respective truncation rates, expressed as percentages, were: DiNOsAUR (43%); TeLEPHONE (37%); CRoCoDILE (6%); Elephant (66%); and OcToPUS (8%). The more frequent preservation of unstressed syllables in CRoCoDILE and OcToPUS compared to DiNOsAUR, TeLEPHONE, and Elephant may reflect the influence of stop consonants on either side of the weak syllable. These findings suggest that further research is needed to test segmental effects on truncation, and underscore the importance of controlling segmental factors when examining stress pattern effects on word production.

**Integrated Account**

Finally, it cannot be ruled out that an approach which incorporates both perceptual- and production-based components may provide the best account of children's word productions. Integrated accounts of perception and production have been advanced in slightly different ways by a number of investigators (Echols, 1993, 1996; Pye, 1983; Johnson, Lewis, & Hogan, in press; Snow, 1995). These accounts tend to be of two types: those that emphasize production factors and those that emphasize perception and representational factors. An example of the former is Pye's (1983) account, stemming from his work in Quiche Mayan, in which he argues that children represent both stressed and unstressed syllables but, when faced with production limitations, produce the most perceptually salient syllable. A similar hypothesis has been recently

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1There have been some recent extensions to the perceptual ailience account that incorporate rhythmic factors (Echols, 1996; Hura & Echols, 1996). Findings from infant perceptual studies (Jusczyk, Cutler, & Redarz, 1993) suggest that children may preferentially extract and store those syllables that are part of a trochaic sequence. Therefore the increased omission of the first weak syllable in SWWS words and the second weak syllable in SWWS words may result from a trochaic segmentation bias rather than from a constraint posed by production. We do not address this account in the paper, but aspects of it are relevant to an integrated account of truncation discussed later in the paper.
proposed by Johnson, Lewis, and Antone (1996) in what they refer to as the "Production-Saliency" account. The authors provide compelling reasons to identify production as the main component in syllable omission but acknowledge that stress and syllable position may interact with production to determine which syllables are retained. An example of an integrated account that focuses on perception includes recent work by Echols and colleagues (Echols, 1993, 1996; Echols & Newport, 1992). Although Echols is most closely allied with a pure perceptual account, she does propose a more moderate version of her findings, in which perception is replaced over time with production-based effects.

Overall, some unanswered questions remain regarding the role of metrical constraints, perceptual salience, and segmental effects in children's truncations. Metrical templates offer a robust account of children's syllable omissions in novel SWSW and SWSW words, but, at least in English, they have not been systematically evaluated in a more diverse range of stress patterns. (However, see Johnson et al., 1996, for a recent evaluation of metrical templates in a single child's productions.) A pure perceptual account (based on representation) has largely been discounted because of its failure to explain the presence of segmental features from deleted syllables in truncated forms, children's comprehension of grammatical morphemes despite their absence in production, and truncation patterns in four-syllable novel words. Nevertheless, reports indicating that weak syllables in word-final position are more frequently preserved than weak syllables in word-medial position suggest that perceptual factors still need to be explored. Gerken (1994) offers one possible explanation with her proposal of CV(C) constraints; however, an investigation of syllable-level constraints in children's productions of multisyllabic words has not been conducted. Finally, the segmental effect observed in Kehoe's (1994) study warrants further investigation, as do accounts suggesting that perception and production interact together to influence which segmental material appears in truncation (Pye, 1983; Johnson et al., 1996; Snow, 1995).

The present study addresses these unresolved issues in word production by examining truncation patterns in English-speaking children's speech. The study tests three age groups of children (22-28 months) to determine whether the influence of metrical constraints, perceptual salience, and segmental effects change over time. The stimuli include three-syllable words with the stress patterns SWS (e.g., DinoSAUR), SWS (e.g., KANGarooi), SWW (e.g., Elephant), and SWS (e.g., baNana) and four-syllable words with the stress patterns ŚWSW (e.g., AlliGAtor) and SWSW (e.g., AvoCado). We test novel in addition to real words to control for imitation and uncontrolled segmental effects on truncation. The choice of stress patterns for the three-syllable words allows us to contrast metrical and perceptual salience accounts of truncation. A metrical account has implications for both the frequency and content of children's truncations, whereas a perceptual account has implications for the content of children's truncations only. In SWW, the metrical and perceptual accounts make different predictions regarding children's truncation patterns. The choice of SWSW and SWSW words allows an additional test of the two hypotheses. A metrical account would predict that neither weak syllable should be omitted in SWSW words because both weak syllables are contained within the metrical template. However, children's utterances may be governed by production limitations such as number of syllables. In which case, if one weak syllable is deleted, either weak syllable in SWSW and SWSW words should be equally likely to be deleted. In contrast, a perceptual account would predict that the perceptually salient syllable, such as the word-final unstressed syllable, should be preserved. In this respect, SWSW words provide a similar test of metrical and perceptual effects, as do SWW words. If only one weak syllable is preserved in SWW and SWSW words, the perceptual account would predict that it is the final weak syllable, whereas the metrical account would not necessarily do so. To test segmental effects on truncation, we examine truncation rates in three-syllable words with the same stress patterns but different segmental patterns. The predictions of each account according to the frequency (i.e., truncation rate) and content of truncations (i.e., truncation patterns) are provided below.

**Predictions**

**Truncation Rate**

If a metrical constraint is operating, truncation rates should be greatest in SWW and SWSW words compared to SWS and SWSW words because application of a SW or trochaic template will result automatically in the deletion of one weak syllable. The pattern of truncations predicted by metrical constraints is shown in (1). The metrical template is displayed as a (X) trochaic foot in keeping with recent grid formalism (Hayes, 1995).

![Diagram of the metrical template](image)

In SWSW and SWSW words, truncation rates should be generally low because both both weak syllables are contained within the trochaic template.

The prediction of the segmental account, based on Kehoe's (1994) findings, is "Words containing weak
syllables bounded by stop consonants should be truncated less frequently than words containing weak syllables bounded by non-stop consonants. The pattern of truncation rate for real multisyllabic words is shown in (2).

(2) Truncation Rates Based on Segmental Effect for Real Words

<table>
<thead>
<tr>
<th>Low Truncation Rates</th>
<th>High Truncation Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>CROcoDILE</td>
<td>DInoSAUR</td>
</tr>
<tr>
<td>TINkerBELL</td>
<td>TElePHONE</td>
</tr>
<tr>
<td>OCtopus</td>
<td>Elephant</td>
</tr>
<tr>
<td></td>
<td>Animal</td>
</tr>
</tbody>
</table>

The perceptual salience account makes no specific predictions regarding truncation rate.

**Truncation Patterns**

The patterns of truncations predicted by metrical template and perceptual salience accounts are contrasted in (3). Note that in ŠWS and SWŠ words, the most likely scenario, based on a metrical template, is that the two stressed syllables should be preserved (in contrast to the first stressed syllable and the unstressed syllable) because the stressed syllable is the obligatory component in the SW template. Therefore in ŠWS and SWŠ words, similar patterns are expected under both accounts.

(3) Truncation Patterns Based on Metrical Template and Perceptual Salience Accounts

<table>
<thead>
<tr>
<th>Metrical Template</th>
<th>Perceptual Salience</th>
</tr>
</thead>
<tbody>
<tr>
<td>ŠWS DInoSAUR</td>
<td>[dášño]</td>
</tr>
<tr>
<td>SWŠ KANGaROO</td>
<td>[kæŋːo]</td>
</tr>
<tr>
<td>SWW Elephant</td>
<td>[ˈɛlænt] or [ɛˈfiːnt]</td>
</tr>
<tr>
<td>WSW baNana</td>
<td>[næˈna]</td>
</tr>
<tr>
<td>ŠSWŠ AlliGAtor</td>
<td>[əlɪɡətər] or [əɡəˈgərə]</td>
</tr>
<tr>
<td>SWŠ SWŠ AvoCAdo</td>
<td>[ɔˈvako] or [ɔˈkədo]</td>
</tr>
</tbody>
</table>

The segmental account makes no specific predictions regarding truncation patterns. We also do not list any predictions for an integrated approach because the way in which perception and production combine is unpredictable. By analyzing the data in terms of differential effects and by examining changing patterns across age, we hope to determine whether an integrated account in contrast to one or other of the approaches offers a superior account of the findings.

**Method**

**Subjects**

Subjects were six 22-month-old, six 28-month-old, and six 34-month-old children, recruited through a subject pool associated with the University of Washington. All children were within a 2-week window of their age. At each age, three subjects were boys and three subjects were girls. Communication development was screened using the MacArthur Communicative Developmental Inventory: Toddlers (CDI; Fenson et al., 1991). Only children whose scores fell between the 20th and 80th percentile for their age-range on the vocabulary section of the CDI were included in the study. Because the CDI screens children only up until 30 months old, a slightly different procedure was used for the 34-month-old children. These children were participants in a study conducted 7 months earlier. At that time, their scores fell between the 20th and 80th percentile on the CDI for their age-range. The parents of these children indicated that there had been no event (illness or accident) since the earlier test that may have influenced the course of speech and language development. All children were from monolingual English-speaking environments. Parents expressed no concern regarding their children's hearing status, and because communication development was judged normal, hearing was not assessed formally.

**Stimuli**

The stimuli included three-syllable real and novel (i.e., experimental) words and four-syllable real words. The three-syllable words consisted of four stress patterns (ŠWS, SWŠ, SWW, and WSW) and two segmental patterns: weak syllable bounded by stop versus non-stop consonants. The four-syllable words consisted of the stress patterns SWŠW and ŠWSW and were selected without attention to segmental patterns. Although we attempted to select real words that were familiar to young children, the real-word set varied in degree of familiarity. We have no formal measure of familiarity, but a gross measure of familiarity was obtained from examining the proportions of spontaneous and imitated productions across individual words. (See Kehoe, 1995, for an analysis of truncation proportions in spontaneous and imitated productions.) Limitations imposed by the restricted size of young children's vocabularies also made it difficult to select real SWS and WSW words so that they conformed to the required segmental patterns. Hence, a third segmental category was formed: weak syllable bounded by both a stop and a non-stop consonant. In creating novel words, the following factors were considered: (a) All words should contain simple syllable structure (i.e., CVCV CV) and begin with a stop consonant to ensure uniformity between

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words—the exception was saNOfa with initial /s/. (b) The consonants /t/ and /d/ should be avoided in medial position because of their potential to flap. (c) Liquids should be avoided in medial position because of their late acquisition and presumed articulatory complexity. (d) All words should be modeled on real English words.

In total, the stimulus set consisted of 24 target words: 20 three-syllable words (12 real and 8 novel) and 4 four-syllable words. The three-syllable word stimuli are presented in Table 1. “Stop” refers to words in which the weak syllable was bounded by stop consonants; “Non-stop” refers to words in which the weak syllable was bounded by non-stop consonants; “Stop & Non-stop” refers to words in which the weak syllable was bounded by both a stop and a non-stop consonant. The four-syllable stimuli included the SWSW words AlligAtor and HEliCoPter, and the SWSW words AvoCAdo and CindeRElla.

In order to accommodate the reduced attention span and linguistic abilities of the 22-month-old children, the stimulus set was reduced by the exclusion of the real words TINkerBELL and CindeRElla and the novel words taKEdo and saNOfa. It was predicted that 22-month-old children would invariably delete the initial weak syllable of WSW words and that truncation results with SWS, SWS, and SWW words would prove of greater interest. Furthermore, patterns of truncation with WSW words could be gleaned from the 22-month-old children's performance with real WSW words.

**Data Collection**

All recordings were conducted in acoustically treated rooms while children interacted with a parent and an experimenter. Children were recorded in two 30–40 minute sessions, separated by a one-week period. The sessions were videotaped using a camera situated in an adjacent test room. Both the experimenter and the child wore vests containing electret microphones connected to FM transmitters. The audio signals from the FM receivers were recorded onto HiFi audio channels of a videotape.

Children were engaged in semistructured elicitation tasks in which they produced multiple repetitions of the stimulus words. To elicit productions of the eight novel words, a fluffy toy was given the name of each of the novel words. Four novel words were taught in each session (three words in the case of the 22-month-olds), each representing a different stress pattern and counterbalanced by child. The experimenter and child engaged in pretend activities with the toys. Subjects were encouraged to imitate the names of the toys and simple phrases such as “Eat BApika” and “Sleep BApika.” All productions of the novel words were imitated, whereas productions of the real words included both spontaneous and imitated productions. An imitation was defined as a production in which the adult model preceded the child's production by not more than two previous utterances.

**Database**

The database consisted of 2464 productions of real and novel words gathered from the 18 subjects. To the extent possible, six productions of each real word and eight productions of each novel word were included for each child. In cases where children produced more than the required number of stimulus words, tokens were selected randomly—with preference given to spontaneous over imitated tokens. To be included in the database, a token had to meet the following criteria: (a) it had to be produced in isolation or in phrase-final position to avoid
possible effects of phrase position; (b) it had to be produced with normal emotional level because excessively high or low emotional level may affect rhythmic patterns; and (c) it had to be produced without noise overlay that would hinder perceptual and acoustic analysis.

Tokens meeting these criteria were subject to analysis. Tokens were acoustically analyzed using CSpeech Version 4.0 (Milenkovic & Read, 1992), a PC-based speech signal processing package. Target words were digitized at a sampling rate of 22,000 kHz with 15 bit resolution and automatic anti-aliasing performed by the CSpeech system. The acoustic analysis was primarily used to determine stress contour, which was the focus of a related study (Kehoe, in press). However, in the present study, it was useful for judging truncation in difficult segmental environments, such as in the words Elephant or TELEPHONE which contained intervocalic sonorants. In these cases, a spectrographic display was employed to facilitate segmental transcription (spectrographic set-up included Frequency Range: 5000 Hz and Bandwidth: 300 Hz). On the basis of this analysis, each token was phonetically transcribed and coded as being either truncated (number of syllables in the child's form was fewer than in the target) or rhythmically correct (number of syllables in the child's form was the same as in the target). Segmental accuracy was not taken into consideration in the coding system.

Tokens classified as truncations included one- and two-syllable productions of three-syllable target words, and two- and three-syllable productions of four-syllable target words. One-syllable truncations of three-syllable words and two-syllable truncations of four-syllable words made up 13% and 30% of the 22-month-old children's productions of three- and four-syllable words, respectively; they were rarely produced by the older children. In this study, we concentrated only on two-syllable truncations in three-syllable words, and three-syllable truncations in four-syllable words. (See Fikkert, 1994, and Kehoe & Stoel-Gammon, 1997, for discussion of other truncation types.) Reproductions of single syllables (e.g., /ʃuʃi/) for CHIMPANZEE or /ʃuʃuʃuʃ/ for sANOfa) represented a small proportion of the data and were not analyzed as truncations. The numbers of truncations and total numbers of productions of each target word for each child were used to compute truncation rate. A second analysis examined the content of children's truncations.

Reliability

Interjudge agreement was calculated using perceptual analysis, whereas intrajudge agreement was calculated using perceptual and acoustic-perceptual analyses. The second judge was a graduate student in speech and hearing sciences who had taken a course in advanced phonetic transcription. She listened to 437 words (18% of the data) evenly selected across age and target words. The first judge (the first author) transcribed the same set of words used by the second judge in the perceptual task and also repeated the original acoustic-perceptual analysis for 513 tokens (21% of the data). The percentage inter- and intrajudge agreement for syllable number in the perceptual task was 87% and 91%, respectively. The percentage intrajudge agreement for the acoustic-perceptual analysis was 99%.

Results

Data Preparation

Statistical tests examined individual proportion scores obtained on each word for each child. The three-syllable word analysis focused on the novel word set because the design was balanced across stress and segmental pattern. However, because the 22-month-old children did not participate in the WSW condition, the design was not completely balanced. This necessitated two analyses for novel words: one based on SWS, SWS, and SWW words for all age groups of children; the other based on SWS, SWS, SWW, and WSW words for 28- and 34-month-old children. These data sets are referred to as “Nov-All Ages” and “Nov-28 & 34,” respectively.

The findings with real words were used to support the findings with novel words. Some statistical tests were conducted with a reduced database consisting of SWS and SWW words, which was balanced evenly across age and segmental pattern. This data set is referred to as “Real-Part.” The entire real-word database is referred to as “Real-All.” To simplify calculations, TINkerBELL was excluded from statistical tests because exemplars were not collected with the 22-month-old children; it was included in the analysis of individual words. Analyses of the four-syllable words were descriptive.

Truncation Rate

Effect of Stress Pattern

The prediction of the metrical hypothesis for three-syllable words was that truncation rates should be highest in SWW and WSW compared to SWS and SWS stress. 2

2The data set contained a high proportion of 0s and 1s, resulting in non-normal distributions of scores and a lack of homogeneity of variance. This is also responsible for the relatively large standard deviations noted in the data. ANOVA is reasonably robust against moderate violations of these conditions (Neter, Wasserman, & Kutner, 1989). Nevertheless, caution must be applied when interpreting effects with borderline significance levels (i.e., around p = .05) because of a potential overestimation of results from violations of normality. Individual proportion scores were arcsine transformed in order to correct for the instability of error term variances. The results reported in the text reflect the analysis based on raw scores; findings based on transformed data were identical to the raw score results.
patterns. The prediction of the perceptual salience hypothesis was that truncation rates should be similar across stress pattern. Means and standard deviations of two-syllable truncations in novel and real words across stress pattern are presented in Table 2. The main effect of stress pattern was tested statistically for the two novel word data sets and the reduced real word data set. Results indicated significant stress pattern effects on two-syllable truncations in both novel word analyses [Nov-All Ages: \( F(2, 30) = 4.74, p = .02 \); Nov-28 & 34: \( F(3, 30) = 3.73, p = .02 \). Post hoc tests (Tukey) indicated that the truncation rate of SWS words was significantly less than SWW words in the Nov-All Ages set, and the truncation rate of SWS words was significantly less than SWW and WSWS words in the Nov-28 & 34 set. There was no significant stress pattern effect in the real word analysis based on SWS and SWW words [Real-Part: \( F(1, 15) = .41, p = .53 \)]. However, qualitative analysis indicated that SWS words were truncated less frequently than all other stress patterns.

**Effect of Segmental Pattern**

The main prediction was that words containing unstressed syllables bounded by non-stop consonants should have higher truncation rates than words containing unstressed syllables bounded by stop consonants. Table 3 presents the means and standard deviations of truncation proportions in novel and real words across segmental pattern. The main effect of segmental pattern on two-syllable truncations was highly significant for the Nov-All Ages analysis \( [F(1, 15) = 7.71, p = .01] \), the Nov-28 & 34 analysis \( [F(1, 10) = 11.00, p = .008] \), and the Real-Part analysis \( [F(1, 15) = 58.15, p < .001] \). As predicted, on the basis of Kehoe’s (1994) findings, weak syllables bounded by non-stop consonants were deleted more frequently than weak syllables bounded by stop consonants in productions of real and novel words.

<table>
<thead>
<tr>
<th>Segmental pattern</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop</td>
<td>.30</td>
<td>.36</td>
<td>.23</td>
<td>.34</td>
<td>.22</td>
<td>.34</td>
</tr>
<tr>
<td>Non-stop</td>
<td>.44</td>
<td>.40</td>
<td>.40</td>
<td>.40</td>
<td>.66</td>
<td>.39</td>
</tr>
</tbody>
</table>

Note. Entries for Nov-All Ages are based on 36 individual proportion scores [2 words x 18 children]; entries for Nov-28 & 34 are based on 24 [2 words x 12 children]; entries for real words SWS, SWW, & WSWS are based on 54 [3 words x 18 children], and SWS words are based on 36 [2 words x 18 children].

**Age by Stress Pattern and Age by Segmental Pattern Interactions**

To determine if the significant stress and segmental pattern effects obtained from the group data were evident at each age range, the interaction between age and stress pattern, and age and segmental pattern on truncation rate was examined. Table 4 shows the proportions of two-syllable truncations in novel and real words across age and stress pattern. In the novel word condition, 22-month-old children produced high proportions of truncations in all stress pattern categories (i.e., SWS, SWS, and SWW); 28-month-old children produced the highest proportion of truncations in SWW words; and 34-month-old children produced the highest proportions of truncations in SWS and SWW words. The main group finding that truncation proportions were low in SWS words was observed only in the 28- and 34-month-old children. In the real-word condition, the main group finding that truncation rates were low in SWS words was observed across all ages. Findings were comparable to the novel-word set in revealing that 22-month-old children produced high proportions of truncations across most of the stress pattern categories, and 28-month-old children produced the highest proportion of truncations in SWW words. The interaction between stress pattern and age on truncations was significant for the Nov-All Ages analysis \( [F(4, 30) = 3.10, p = .03] \) and the Nov-28 & 34 analysis \( [F(3, 30) = 3.45, p = .03] \). It was not significant for the real word analysis based on SWS and SWW stress patterns only \( [F(2, 15) = 0.73, p = .50] \).

Table 5 shows the proportions of two-syllable truncations in novel and real words across age and segmental pattern. In the novel-word condition, the segmental effect was present in 28- and 34-month-old children, but was not present in the 22-month-old children. In the real-word condition, the effect was present at all age ranges. The interaction between segmental pattern and
Table 4. Means and standard deviations of truncation proportions in novel and real three-syllable words across age and stress pattern.

<table>
<thead>
<tr>
<th>Stress pattern</th>
<th>22-Months</th>
<th>28-Months</th>
<th>34-Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Novel words</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWS</td>
<td>.56</td>
<td>.38</td>
<td>.12</td>
</tr>
<tr>
<td>SWW</td>
<td>.56</td>
<td>.41</td>
<td>.26</td>
</tr>
<tr>
<td>WSW</td>
<td>.50</td>
<td>.37</td>
<td>.24</td>
</tr>
<tr>
<td>Real words</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWS</td>
<td>.57</td>
<td>.39</td>
<td>.35</td>
</tr>
<tr>
<td>SWW</td>
<td>.31</td>
<td>.21</td>
<td>.13</td>
</tr>
<tr>
<td>WSW</td>
<td>.60</td>
<td>.45</td>
<td>.51</td>
</tr>
</tbody>
</table>

Table 5. Means and standard deviations of truncation proportions in novel and real three-syllable words across age and segmental pattern.

<table>
<thead>
<tr>
<th>Segmental pattern</th>
<th>22-Months</th>
<th>28-Months</th>
<th>34-Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Novel words</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop</td>
<td>.51</td>
<td>.36</td>
<td>.17</td>
</tr>
<tr>
<td>Non-stop</td>
<td>.57</td>
<td>.39</td>
<td>.25</td>
</tr>
<tr>
<td>Real words</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop</td>
<td>.37</td>
<td>.39</td>
<td>.10</td>
</tr>
<tr>
<td>Non-stop</td>
<td>.70</td>
<td>.39</td>
<td>.60</td>
</tr>
</tbody>
</table>

Note. Entries for novel words are based on 18 individual proportion scores (3 words x 6 children); entries for real words Stop are based on 12 (2 words x 6 children), and Non-stop are based on 24 (4 words x 6 children).

Age on truncations was not significant for the Nov-All Ages analysis \(F(2, 15) = 2.06, p = .16\) or the Real-Part analysis \(F(2, 15) = 0.55, p = .59\).

In sum, the main group findings on stress and segmental pattern were generally observed across each age group with some additional findings: (a) The stress and segmental pattern effects on truncation were less evident in the productions of the 22-month-old children, particularly in the novel word condition. (b) The 28-month-old children truncated WSW words differentially more than other stress patterns. (c) The 34-month-old children displayed greater numbers of truncations than the 28-month-old children in some stress pattern conditions (e.g., SWW novel words and SWS real words). A closer analysis of truncation rates in these words showed that it was non-stop rather than stop words that received the highest truncation rates.

Individual Word Analysis

To more clearly delineate the unusual stress and segmental pattern effects, a word-by-word analysis of truncation rate was conducted. Proportions of two-syllable truncations for the 8 novel and 12 real words, ordered by numerical value, are presented graphically in Figures 1 and 2, respectively. In the real word condition, the findings overwhelmingly show that the words CHIMPanZEE, KANGaROO, OCtopus, CRocodILE, and TINKerBELL were truncated far less frequently than other real words. In the novel-word condition, the findings show, though less dramatically, that the words TAEkeBO, DUfeMO, BApika, and DPAnTOO were less frequently truncated than other novel words.

These findings suggest that the original hypothesis regarding the segmental effect may need to be revised. The novel word DUfeMO and the real words KANGaROO and CHIMPanZEE behave in a manner similar to words belonging to the Stop pattern. This leads to the tentative hypothesis that the segmental effect may be related specifically to whether the onset of the weak syllable is a sonorant or an obstruent. In the real-word task, the effect was present for words with '/n/' or '/l/' as the onset of the weak syllable; in the novel-word task, the effect was present for words with '/n/' as the onset.

The findings are still somewhat unclear for WSW words. Truncation rates were high in WSW words, despite the fact that the initial weak syllable in all cases began with an obstruent. Word-initial position is a vulnerable position for weak syllables, and metrical constraints may outweigh segmental factors. The segmental effect observed in this study appears specifically related to internal weak syllables in SWS, SW$\mathcal{S}$, and SWW words.

Truncation Patterns

A detailed examination of children's truncation patterns provides a further test of metrical versus perceptual predictions. In this section, examples of truncations from all stress patterns will be presented. Guiding principles used in the coding of truncation included the presence of an onset, coda, or vowel from one of the target...
syllables. For example, [æmə] for Animal was noted as a production in which the final syllable was preserved, because it contained the onset from the final syllable. Coding was sometimes complicated by the inclusion of segmental material from all syllables of the target word in the production form, such as the truncation [ɛfɛm] for Elephant. In this case, the syllable with the greatest amount of segmental material (typically the syllable containing the vowel nucleus) was identified as the preserved syllable—that is, the final syllable. When it was not possible to ascertain which syllable the child was attempting (e.g., [dəda] for DinoSAUR), the token was excluded from the analysis.

Three-Syllable Words

As predicted by both metrical and perceptual accounts, children’s truncations of SWS and SWŠ words typically included stressed syllables only. Examples are shown in (4). All examples include subject identification (e.g., 22m1: a 22-month-old male) and an indication as to whether the token was spontaneous (S) or imitated (I).

(4) CrocoDile 34f3  [tʃrobots] (I)  [kɒdɒl] (I)

DinoSAUR 22f1  [dɒsər] (I)  28m1  [dɒsər] (S)

Figure 2. Truncation proportions ordered numerically across individual novel three-syllable words (tack = Takətək; duf = DuFeMO; ban = Baπika; dop = DOPaTOO; tak = takEdo; san = saNOFe; ben = BEnnesSSEE; tan = TANema).

<table>
<thead>
<tr>
<th>Token</th>
<th>Form</th>
<th>Stressed</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>TElePHONE</td>
<td>22f2</td>
<td>[tɛliFə]</td>
<td>(S)</td>
</tr>
<tr>
<td>28f1</td>
<td>[tɛliFə]</td>
<td>(S)</td>
<td></td>
</tr>
<tr>
<td>KANgaROO</td>
<td>22m2</td>
<td>[kɒŋgaːroʊ]</td>
<td>(I)</td>
</tr>
<tr>
<td>34m2</td>
<td>[kɒŋgaːɡəʊ]</td>
<td>(S)</td>
<td></td>
</tr>
<tr>
<td>CHIMpanZEE</td>
<td>22m3</td>
<td>[tʃɪmpən]</td>
<td>(I)</td>
</tr>
<tr>
<td>28f3</td>
<td>[tʃɪmpəz]</td>
<td>(S)</td>
<td></td>
</tr>
</tbody>
</table>

Two-syllable truncated forms of WSW words included the stressed and final syllable, as predicted by both metrical and perceptual accounts.

(5) banAna 22m3  [bænænə] (S)  28m3  [bænænə] (S)

toMAto 22m3  [təməto] (I)  28m3  [mɪtəto] (S)

poTAto 22f2  [pəˈtæto] (S)  28f2  [pəˈtæto] (S)

Now consider two-syllable forms of SWW words:

(6) Animal 22m3  [æməln] (S)  28m1  [æməl] (I)

Elephant 22m1  [ɛlɛfən] (S)  28m1  [ɛlɛfən] (S)

OCtopus 22f1  [ɒkˈtopəs] (S)  28m3  [ɒkˈtopəs] (I)
Table 6 shows the proportions of two-syllable truncations of SWW words in which either the medial or the final weak syllable was preserved. Note that not all children displayed truncated forms for SWW words; only six children produced truncated forms for Octopus. The results strongly indicate that truncations of SWW words most frequently included the weak syllable in final position. A metrical template account is still viable given these findings, but an additional mechanism [such as Gerken’s CV(C) template] is needed to account for selection of the final rather than the nonfinal weak syllable.

Four-Syllable Words

The predictions of the metrical account were that three-syllable truncations should occur infrequently in children’s productions of SWSW (either SWSW or SWSW) words because both weak syllables are contained within the trochaic template. In contrast, the perceptual salience account anticipates the presence of three-syllable forms, because the perceptually salient syllables are the two stressed syllables and the unstressed syllable in final position. Our results reveal that three-syllable truncations were a frequent pattern in the data. The proportions of three-syllable truncations in 22-, 28-, and 34-month-old children’s productions of four-syllable words were .65, .44, and .63, respectively. Examples are shown in (7).

(7) AlliGAtor 34f3  [ælɪgi'ær]  (S)
     34f3  [ɪ'ær]  (S)

HEliCOPter 34f3  [heɪIkɔptə]  (S)
     34f2  [heɪIkɔtə]  (S)

AvoCADO 34f3  [ævəka'do]  (I)
     34m3  [ævəkə'do]  (S)

Table 6. Means and standard deviations of truncation patterns in SWW words.

<table>
<thead>
<tr>
<th>Word</th>
<th>NP</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal</td>
<td>13</td>
<td>.86</td>
<td>.30</td>
<td>.14</td>
<td>.30</td>
</tr>
<tr>
<td>Elephant</td>
<td>17</td>
<td>.95</td>
<td>.13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Octopus</td>
<td>6</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BApika</td>
<td>12</td>
<td>.54</td>
<td>.43</td>
<td>.11</td>
<td>.19</td>
</tr>
<tr>
<td>Tanema</td>
<td>15</td>
<td>.78</td>
<td>.34</td>
<td>.18</td>
<td>.33</td>
</tr>
</tbody>
</table>

*Results are based on a maximum of 18 entries (1 word x 18 children). 1. .35 of productions for BApika were “difficult to classify.” Most of these productions consisted of forms such as [ba:k] or [ba:k] which could potentially be classified as final-syllable reproduction because alveolar consonants may be substituted for target velar consonants (see Echols & Newport, 1992).

Discussion

This study examined truncation rate and truncation patterns in children’s productions of three- and four-syllable words to determine the influence of metrical constraints, perceptual salience, and segmental effects on word production. The findings showed an unusual stress pattern effect on truncation rate in three-syllable words that was not consistent with either metrical constraints or perceptual biases. The findings confirmed the segmental effect observed by Kehoe (1994): Words in which the weak syllable was bounded by stop consonants were less frequently truncated than words in which the weak syllable was bounded by non-stop consonants. There were slight differences in truncation trends across age, but, in general, similar stress and segmental effects were observed across all age groups. To more clearly understand the stress and segmental pattern findings, we conducted an item analysis of truncation rates across individual word. This analysis revealed that SWS words had high truncation rates, but that truncation rates in SWS, SWS, and SWS words were largely determined by segmental factors: (a) Words that contained intervocalic sonorants such as TElePHONE and Animal had high truncation rates. (b) Words that contained intervocalic obstructions such as CRocoDILE and OCTopus had low truncation rates. Finally, an analysis of truncation patterns in SWW and SWSW words indicated that most of the time truncations included the weak syllable in word-final position. In the remainder of this paper, we review the findings in light of metrical, perceptual, and segmental effects and an integrated account of word production that combines all of these factors.

Metrical Constraints

The present results did not provide strong support for a metrical template account of truncation. Without controlling for segmental factors, the stress pattern
effect on truncation rate was uninterpretable in terms of metrical predictions. Instead of recording low truncation rates in both SWS and SW$S$ words relative to the other stress patterns, we recorded low truncation rates in SWS words in the novel-word condition and low truncation rates in SW$S$ words in the real-word condition. Even given a potential confound of imitation in the data at hand, such strikingly different results between real and novel words was unanticipated. The presence of three-syllable truncations in productions of SWS$W$ words was not consistent with syllable preservation by a trochaic template, and the more frequent production of the second weak syllable in SW$W$ and SW$S$WS words implicates additional factors, apart from metrical ones, in truncation. The only evidence of a metrical effect was that WS$W$ words received high truncation rates in the 22- and 28-month-old children's productions. This is consistent with numerous reports indicating that weak syllables in word-initial position are vulnerable to deletion (Allen & Hawkins, 1980; Echols & Newport, 1992; Schwartz & Goffman, 1995).

**Perceptual Salience**

The findings provided partial support for a perceptual salience account of syllable production in that children's truncations retained stressed syllables and unstressed syllables in word-final position. Nevertheless, the same criticisms that previously applied to the perceptual hypothesis still prevail. The perceptual account does not explain why segmental features from so-called deleted syllables appear in truncations and why children's productions often alternate between truncated and nontruncated forms for the same target word. Frequent examples of these types of phenomena were observed in the present study. Gerken offers a possible production-based account of final syllable preservation with her proposal of CV/C as well as metrical templates. This account will be considered in the following section after we examine segmental factors influencing truncation.

**Segmental Effects**

One of the most intriguing findings of the study was that segmental factors appear to influence truncation rates. The item analysis suggested that the effect pertained specifically to internal weak syllables in SWS, SW$S$, and SW$W$ words and was linked more closely to sonorant versus obstructant than to stop versus non-stop, as was originally hypothesized. Possible explanations for the segmental effect include perceptual factors, articulatory factors, the effect of imitation, and syllabification tendencies. These issues are discussed in turn.

The segmental effect may reflect children's inability to perceive syllables that contain sonorant consonants compared to syllables that contain obstructant consonants. This account seems unlikely because sonorant consonants (e.g., /n/ and /l/) have acoustic characteristics, such as formant structure and low frequency energy, similar to vowels, making them acoustically and perceptually more salient than stops or fricatives, which are characterized by low amplitude high frequency energy. Therefore, the segmental effect on truncation does not appear to reflect perceptual factors alone.

The segmental effect may reflect children's avoidance of syllables containing difficult-to-produce consonants. This account explains the findings with /l/, which is a late-acquired sound in phonological development, but does not explain the findings with /n/, which is generally acquired early (Steel-Gammon & Dunn, 1985). Furthermore, if it were solely an articulatory effect, the effect would decrease as children's articulatory capacities become more sophisticated. Instead, the results showed that the effect remained strong with increasing age, at least with respect to the age range tested in this study.

The segmental effect may reflect the influence of imitation on syllable production. For example, words that were produced spontaneously, such as Elephant, TELEPHONE, and DINOSAUR, were often truncated, whereas words that were produced as imitations, such as CHIMPANZEE, CROCODILE, and OCTOPUS, were often not truncated. However, the opposite was also true. The word Animal was most often imitated, yet it was frequently truncated; KANGAROO was most often produced spontaneously, yet it was infrequently truncated (see Kehoe, 1995). Furthermore, the segmental effect was present in the novel word condition in which all words were equal in spontaneous versus imitation effects. Thus, the segmental effect does not appear to result from imitation factors alone.

Finally, the segmental effect may relate to children's syllabification patterns and the manner of articulation of the intervocalic consonant. The initial assumption concerning syllabification was that syllable boundaries were determined by the “maximal onset principle,” which favors consonants in onset rather than in coda position (Kahn, 1976; Pulgram, 1970). Although this principle is widely accepted as a universal code of syllabification, there is experimental evidence that under certain conditions other principles of syllabification may occur. For example, vowel quality (tense versus lax), stress, and manner of articulation may influence whether a single intervocalic consonant is syllabified with the preceding or the following syllable (Fallows, 1981; Treiman & Danis, 1988). Furthermore, several studies suggest that the manner of articulation of the intervocalic consonant may play a significant role in children's syllabification tendencies. First, it has been observed that children are more likely to treat a sonorant consonant as ambisyllabic.
than an obstruct consonant (Fallows, 1981; Gillis & De Schutter, 1996). Second, younger children are more likely than older children to syllabify an intervocalic consonant with the preceding stressed vowel than with the following unstressed vowel (Fallows, 1981; Wijnen, 1988). Given these findings, we may need to reconsider our original syllabic boundaries. If intervocalic sonorants are syllabified with the preceding stressed syllable, the syllification of stimulus words becomes:

<table>
<thead>
<tr>
<th>Real Words</th>
<th>Novel Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRO-co-DILE</td>
<td>TA-cek-BO</td>
</tr>
<tr>
<td>TIN-ker-BELL</td>
<td>DU-fe-MO</td>
</tr>
<tr>
<td>KAN-ga-ROO</td>
<td>DO-pa-TOO</td>
</tr>
<tr>
<td>CHIM-pan-ZEE</td>
<td>BA-pi-ka</td>
</tr>
<tr>
<td>OC-to-pus</td>
<td></td>
</tr>
<tr>
<td>Intervocalic consonant = sonorant</td>
<td></td>
</tr>
<tr>
<td>DIN-o-SAUR</td>
<td>BENN-e-SSEE</td>
</tr>
<tr>
<td>TEL-e-PHONE</td>
<td>TAN-e-ma</td>
</tr>
<tr>
<td>AN-i-mal</td>
<td></td>
</tr>
<tr>
<td>EL-e-phant</td>
<td></td>
</tr>
</tbody>
</table>

Those words with an intervocalic consonant sequence will have unstressed syllables with onset consonants because of phonotactic constraints on consonant clusters (e.g., KAN-ga-ROO is syllabified as KAN-ga-ROO). Those words with a single intervocalic obstruct will have medial weak syllables with onsets (e.g., CRO-co-DILE is syllabified as CRO-co-DILE). Those words with a single intervocalic sonorant will have medial weak syllables without onsets (e.g., TEL-e-PHONE is syllabified as TEL-e-PHONE). The intriguing stress pattern effect observed earlier is almost entirely interpretable in light of these syllabification effects. The reduced truncation rate of novel SWS words and real SWS words can be explained by the segmental characteristics of the words in each set: They all contained intervocalic obstruents (e.g., novel SWS words: TACkeBO and DUfeMO; real SWS words: KAN-ga-ROO and CHIM-pan-ZEE).

In sum, the segmental effect on truncation is most consistent with an account that posits different principles of syllabification according to the manner of articulation of an intervocalic consonant. Children appear to syllabify an intervocalic sonorant with the preceding stressed syllable, resulting in an onset-less medial syllable that is subsequently deleted. Although a pure perceptual explanation was discounted, children’s syllabification tendencies may reflect the influence of perceptual strategies to some extent. The presence of an obstruct onset most clearly defines the syllable, whereas a sonorant onset becomes “smeread” together with the preceding vowel, resulting in a lack of syllable demarcation (Wijnen, 1988). This lack of syllable definition in the child’s perception of the input may be at the root of the truncation patterns observed.

**Gerken’s CV(C) Template: The “Elephant Problem” Revisited**

Given a possible syllable-based account of truncation in SWS, SWS, and SWW words, we now return to the “Elephant problem” (i.e., the finding that the second rather than the first weak syllable is more frequently preserved in SWW words). Gerken’s (1994) template account is also based on the syllabification of SWW words, such as Elephant as EL-e-phant. Children select the second rather than the first weak syllable because it fulfills the CV(C) template. Our syllabification account of truncation is consistent with a CV(C) template, although not entirely. Our results revealed that even when both weak syllables could be syllabified with an onset, the second weak syllable was still more frequently selected. In the case of a word such as Octopus, it is conceivable that the syllable template is sensitive to other elements in the syllable such as coda consonants. Therefore, the final syllable “pus” may be selected over the medial syllable “to” because of its CVc rather than CV form. However, this explanation does not extend to our finding with the novel SSW word BA-pika, because this word contained uniform CV structure in both unstressed syllables, yet the final unstressed syllable was more frequently selected. Additional factors are needed to explain the more frequent preservation of final over nonfinal weak syllables; the most obvious of these is the enhanced acoustic salience of final syllables.

**Integrated Account of Children’s Truncation Patterns**

Our findings are most consistent with an integrated account of word production in which perception- and production-based factors interact to determine which syllables appear in production. Given the strong evidence that children perceive the syllables they omit, we are in agreement with other theorists that children’s underlying representations are reasonably intact, but hypothesize that the inclusion of certain syllables comes about by a weighting of prominence effects. In the present study, these prominence effects include syllable-structure constraints, thus accounting for the segmental effect on truncation; acoustic salience factors, thus accounting for the more frequent inclusion of unstressed syllables in word-final position; and metrical templates. We include metrical templates because it can be shown that when there are two word-internal weak syllables, the weak syllable selected is the one that fits a metrical
template. This was evident in Gerken's study with SWWS words, and it was also evident in the results of an earlier study, which examined 27-month-old children's productions of the SWWSW word, Hippopotamus (Kehoe, 1994). All four-syllable truncations of this word consisted of a SWSW form in which the first and final weak syllables in the word were selected (e.g., /hippopo/). There were no SSWW forms, consistent with the selection of the two weak syllables close to the end of the word (e.g., /hippodoo/). The clearest account of this finding is in terms of a SWmetrical template.

According to our prominence account, under situations of competing production demands, when there is a choice between two syllables with varying relative prominence, the syllable with the greatest relative prominence is selected. The findings in our data suggest the following prominence relationships: (a) Stressed syllables are selected over unstressed syllables. (b) Word-final unstressed syllables are selected over word-medial unstressed syllables. (c) Syllables with onsets are selected over syllables without onsets (or syllables with obstructed onsets are selected over syllables with sonorant onsets). (d) Word-medial weak syllables that fit a S/W template are selected over word-medial weak syllables that do not fit the template. This account resembles a perceptual salience account of syllable omissions, but the key difference is that truncation patterns do not reflect children's underrepresentation of unstressed material but rather competing linguistic factors that operate during production. It also resembles a production-based template account, in which salience as well as syllable and metrical templates appear to influence prosodic patterns.

The main difficulty with posing an integrated account is in determining how perception interacts with production. In a pure perceptual- or production-based metrical account, the mechanism is straightforward and automatic. Weak syllables are deleted either because they are not represented or because of the application of a S/W template. In an integrated account, the psychological mechanism behind the process is more difficult to articulate, because salience, a "perceptual notion," must be translated into production. One possibility is that relative prominence is coded in the child's lexical representation. Under this view, segmental material from stressed and unstressed syllables is present in underlying representation, but some form of weighting system gives heightened attention to word-final unstressed syllables. Such a view is consistent with Wijnen et al.'s (1994) proposal that prominence is an attribute of vowels as they are stored in the lexicon, and the order in which melodic material is mapped to the template is correlated with relative prominence. The idea that prominence is lexically coded is consistent with the notion of activation levels in connectionist models of phonological representation (Stemberger, 1992).

Another possibility is that the role of perceptual salience in production reflects the prior status of perceptual factors in development. According to Echols, children initially delete unstressed syllables because of representational limitations but later, once representations are complete, unstressed syllables remain "at risk" for production-based effects (Echols, 1993). Therefore, although our subjects' truncation patterns now appear to reflect production-based factors, these tendencies may stem from earlier representational limitations. One way to determine whether perceptual factors play a greater role in early development is to examine differences in truncation strategies across age. Our analysis of stress and segmental effects across age did show some interesting trends that may reflect the individual contributions of perception and production during development. First, the youngest children in our study were less influenced by metrical and segmental effects than the older children. They displayed high truncation rates for all sets of words, particularly in the novel word condition. The two older groups of children (28- and 34-month-old children) were sensitive to metrical and segmental effects but in slightly different ways. The 28-month-old children deleted word-initial weak syllables more frequently than word-medial weak syllables. The 34-month-old children experienced less difficulty with word-initial weak syllables but were more sensitive to segmental factors, displaying greater numbers of truncations in words with intervocalic sonorants. It is possible that the reduced metrical and segmental effects evident in the younger children's productions reflect the greater role of perceptual or representational factors, and the metrical and segmental effects evident in the older children's productions reflect the greater role of production-based factors.

This is one interpretation of the results but other interpretations are equally plausible. Johnson et al. (in press), working with a child age 10 to 20 months, convincingly argue that their child's truncation patterns were due to a production—not a representational—limitation. The production-based effects that they report, although not related to metrical templates per se, were similar to some of the effects observed in the 22-month-old children in the present study (e.g., truncation patterns consistent with word not syllable extraction, such as the form [hij] for CHIMPANZEE). Thus, the reduced stress and segmental effects in the 22-month-old children may simply result from production limitations on word length rather than representational factors.

Finally, one way of resolving some of the apparent difficulties is to examine the data in light of a new theoretical framework in linguistics, called Optimality theory (McCarthy & Prince, 1995; Prince & Smolensky, 1993). The basis to Optimality theory is the interaction and ordering of universal constraints. Constraints may be of two types: those that regulate the wellformedness of
the output (i.e., structural constraints) and those that regulate the relationship between the input and output (i.e., faithfulness constraints). In the present study, some of the prominence effects may be directly translatable in terms of constraints that relate to stress, syllable structure, and word edges. For example, the segmental effect on truncation may reflect the interaction between a faithfulness constraint, which requires segmental material in the input to be present in the output, and a structural constraint, which requires syllables to have onsets or disfavors sonorants in onset position. If the structural constraint is ordered higher than the faithfulness constraint, then the syllable will be deleted rather than incur violation of a constraint that requires all syllables to have onsets. The increased preservation of unstressed syllables in word-final position may reflect the operation of a constraint that offers special status to word edges, such as one of the family of Anchor constraints (McCarthy, 1995). Already, a number of investigators have provided compelling optimality accounts of sonority and edge-based effects in children’s truncations (Demuth, 1996a; Gnadesikan, 1995; Pater & Paradis, 1996).

In child data, these constraints may have as their functional base the acoustic salience of stress and word edges (Echols & Newport, 1992) or general cognitive memory strategies (Slobin, 1973). Pater and Paradis (1996) argue that the formalization of functional principles should not detract from the formal account but allow us to recognize the motivation behind these effects and account for their interaction. Optimality theory may, thus, provide a cohesive framework for viewing the important linguistic principles that are at play in children’s word production, while at the same time enabling us to place them within the wider context of adult linguistic systems.

Conclusion

The main finding of this study is that the dichotomy posed between perceptual and metrical accounts of children’s truncations is a vast oversimplification of the findings. Our results are consistent with an integrated account of word production in which perceptual salience interacts with syllable structure and metrical effects to determine which syllables emerge in production. Recent constraint-based approaches within phonological theory may provide a more accurate and principled account of the prominence effects evident in the data.

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