Stress error patterns in English-speaking children’s word productions

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Abstract

This study examined the patterns of stress errors in English-speaking children’s productions of multisyllabic words to determine whether they were consistent with the rule-based acquisition of stress. Children (aged 22–34 months) produced three-syllable novel and real words and four-syllable real words which varied across stress pattern. Children’s productions were examined acoustically and perceptually. Results indicated significantly greater numbers of stress errors in SWS words and a tendency for greater numbers of stress errors in SWSW words, findings consistent with the increased association of stress errors with exceptional forms. Additional findings indicated that stress errors were more frequent in imitated compared to spontaneous productions, and that stress errors may be associated with articulatory and phonetic-control factors. The relevance of these findings to disordered populations is explored in the discussion.

Keywords: stress patterns, child phonology, acoustics, stress errors.

Introduction

How do children acquire the stress pattern of their native language? This question is of current interest in the light of rich and diverse developments in linguistic theory, which focus on the prosodic realm, namely non-linear phonology, metrical phonology, and prosodic morphology (Goldsmith, 1990; Halle and Vergnaud, 1987; Hayes, 1981, 1995; McCarthy and Prince, 1986, 1990, 1993). Yet despite these developments there are very few studies of stress acquisition in English. Presently, there exists little information on whether English-speaking children display consistent errors of stress, and whether these errors conform to a rule system. In contrast, studies conducted with Spanish- and Dutch-speaking children reveal a systematic pattern of stress acquisition, and implicate a strong role of prosodic theory in accounting for the data (Fikkert, 1992, 1994; Hochberg, 1988b; Nouveau, 1993; Wijnen, Krikhaar and Den Os, 1994).

In view of the scarce information that exists on stress development in English-
speaking children, this study documents the patterns of stress errors in English-speaking children and the role of linguistic theory in accounting for these errors. Specifically, the present study examines whether there is support for the rule-based acquisition of stress, and explores additional factors in stress acquisition, such as the influence of imitation, articulatory focus, and lack of phonetic control. A companion article to this one provides a more detailed analysis and interpretation of children's stress errors in light of recent linguistic models (Kehoe, 1996). The main theoretical framework employed in both of these studies is metrical phonology, a linguistic theory that pertains to stress and rhythm. Although these findings are based on normally developing children, they also have implications for disordered populations. These issues will be explored in the discussion. As an introduction to this paper I provide a brief overview of metrical phonology and a review of studies on stress acquisition.

Metrical phonology

Metrical phonology offers a departure from previous linear approaches to stress, by representing stress not as the property of a segment, but as the hierarchical relationship of relative prominences (Liberman and Prince, 1977). In metrical theory stress is viewed as the relative prominence of syllables and higher-level units. Most metrical theories are couched within a parametric framework, where stress assignment is expressed in terms of the setting of binary parameters. The main parameters involved in the assignment of stress are listed in (1).

(1) A. Parameters of foot type
   (a) Size (bounded/unbounded)
   (b) Quantity-sensitivity (heavy syllables may/may not occur in the weak position of a foot)
   (c) Headedness (feet are strong on the left/right)

B. Parameters of foot construction
   (d) Direction of parsing (L→R/R→L)
   (e) Presence of extrametrical syllables (yes/no)

C. Main stress parameter
   (f) Main stress (the word-tree is strong on the left/right)

At the core of the metrical framework is a unit called a foot, which typically consists of a stressed and an unstressed syllable. Feet that contain two syllables are referred to as bounded, and feet that contain more than two syllables are referred to as unbounded. Terms from traditional metrics are employed in the labelling of foot types: an iambic foot has the head syllable on the right and a trochaic foot has the head syllable on the left. An important aspect of the stress system is whether it pays attention to the weight or heaviness of the syllable. If stress is attracted to a syllable which is heavy (contains a long vowel or an additional consonant), the foot is referred to as quantity-sensitive; if stress is unconcerned with syllable structure it is quantity-insensitive. Other parameters within the system refer to whether stress is assigned from the right side of the word or from the left, known as directionality of parsing, and to whether certain syllables of a word are ignored for the purposes of stress assignment, known as extrametricality. Finally, there is a parameter which
Stress error patterns

is concerned with the assignment of main stress to one of the feet within a word, known as the main stress parameter.

There exist many variations of metrical theory, each of which expound different formalisms for representing stress (Halle and Vergnaud, 1987; Hammond, 1984; Hayes 1981, 1995; Prince, 1983). This study is based on Hayes' (1995) metrical stress theory. The stress-foot of English is a moraic trochee, in which syllable weight is expressed in units of subsyllabic structure known as moras. The moraic trochee consists of two possible feet-types: a bisyllabic foot and a monosyllabic bimoraic foot.

(2) moraic trochee
possible feet (X .) (X)
\[ \mu \mu \mu \mu \]
where /X/ = stressed syllable; /./ = unstressed syllable; /\mu/ = mora; /\mu\mu/ = heavy syllable and /\mu\mu\mu/ = light syllable

Review of stress acquisition studies

The principal question asked in stress acquisition literature is: Do children acquire stress on a word-by-word basis or by rule (Fikkert, 1994; Hochberg, 1988b)? Some researchers propose that children, from their first exposure to speech, extract a rule of stress. Given the acoustic salience of stressed syllables and the rhythmic alternation of stressed and unstressed syllables in the input, children may form simplified hypotheses regarding metrical structure (Gerken, 1990), or within a universal grammar (UG) approach, children may set parameters (Fikkert, 1994). Metrical parameters are part of children's innate linguistic endowment, and acquisition represents a process of determining the appropriate setting for each parameter, given the input. On the other hand, some researchers propose that stress is lexically coded and not derived by rule (Daelemans, Gillis and Durieux, 1994; Gillis, Daelemans and Durieux, 1994a,b). Studies based on machine learning reveal that stress assignment may be performed on the basis of similarity with items stored in memory. The advantage of a rule system is one of economy. The vast amount of memory required for the lexical listing of all stress patterns suggests that a rule-based approach is the most expedient one. Support for lexical coding comes from the fact that, when learning stress, children have heard all the words that they will produce, correctly stressed (Hochberg, 1988b). In principle they need only memorize the stress pattern of each individual word. Because stress-rule learning is often complicated by large numbers of exceptional forms, the proportion of which may even be enhanced in input to young children, memorization is by far the simplest route for the learner to take (Hochberg, 1988b).

It is generally argued that examination of children's error patterns should provide important clues into distinguishing between a lexical versus a rule-based approach and, if a rule system is supported, elucidate what that rule system is (Fikkert, 1992, 1994). If children memorize individual stress patterns, one should observe relatively

1The term 'rule' will be used loosely in this paper to refer to any process of structured abstraction in which linguistic theory plays a role. Thus, it encompasses parameter setting and even constraints as in optimality theory (Prince and Smolensky, 1993). The main dichotomy is between rule-based versus lexical, the latter referring to the claim that stress is stored in the lexicon or assigned through analogy with stored items (e.g. exemplar-based models).
inconsistent and random errors of stress. If children internalize rules of stress, one should observe consistent and systematic errors when new words deviate from conventional stress. In the following section, evidence for the rule-based and lexical acquisition of stress is examined.

Support for rule-based versus lexical acquisition of stress

Of those studies which have focused on stress acquisition in children, Klein's (1984) study in English supports the lexical acquisition of stress, whereas Hochberg's (1988b) study in Spanish, and Fikkert's (1994) study in Dutch support the rule-based acquisition of stress.

Klein (1984) recorded the stress errors (or stress shift)\(^2\) of a single English-speaking child, Peter (aged 21 months). The inconsistent and unsystematic nature of Peter's stress errors led Klein to propose that stress was acquired lexically rather than by rule. She observed that stress patterns were most closely associated with whether Peter's productions were spontaneous or imitated. Peter used the correct target stress pattern for tokens that he knew (as measured by a high percentage of spontaneous productions), and level or random stress patterns for tokens that were less familiar (as measured by a high percentage of imitated productions). Ultimately, Klein's (1984) study does not shed much light on the issue of rule-based learning, because the corpus of words Peter produced were predominantly disyllabic words with initial stress. Systematic deviations of stress are not expected in these words, because the trochaic pattern conforms to the stress pattern of English. Klein's study would have been strengthened if she had examined Peter's stress errors on a wider variety of stress patterns, including exceptional stress patterns. Her study also suffers from the fact that it was not set within any theoretical linguistic framework, so it is unclear from her analysis what type of stress rule she is searching for (Archibald, 1995).

Hochberg (1988b) predicted that if children learn stress rules then: (a) words with regular stress should be easier to pronounce than words with irregular stress, and (b) there should be a tendency for words with irregular stress to be made regular but the reverse should not be seen, that is, words with regular stress should not be made irregular. She tested her first prediction (ease of pronunciation) by measuring the percentage of structure-changing errors, such as deletions or additions of segments, and stress shifts that alter the CV skeleton or stress contour. She tested her second prediction by determining whether children's structure-changing errors result in the word becoming more regular or irregular.

Results from imitated and spontaneous speech with a group of Spanish-speaking preschoolers (aged 3–5 years) supported a rule-based learning system. In the imitated data, errors were greatest for words with prohibited stress patterns (56%), intermediate for words with irregular stress (43%), and least for words with regular stress (22%). In addition, the more irregular the word, the more likely it was that errors resulted in a change towards regularity. The spontaneous data supported the rule-based hypothesis, though less strongly than the imitated data.

Nouveau (1993), following a similar paradigm to that of Hochberg's (1988b), also demonstrated that Dutch-speaking children display greater proportions of stress errors.

\(^2\)The terms 'stress shift' and 'stress errors' will be used interchangeably throughout the paper.
Stress error patterns

Finally, Fikkert's (1992, 1994) study of Dutch-speaking children revealed support not only for the rule-based acquisition of stress, but for parametric metrical acquisition (Dresher and Kaye, 1990). Her quantitative findings showed that children produce greater numbers of stress errors in disyllabic words with final stress compared to disyllabic words with initial stress, consistent with the increased association of stress errors with exceptional forms. Her qualitative analysis indicated distinct stages in stress development and stress error patterns consistent with mapping to a metrical template and the setting of parameters.

Additional reasons for stress errors

The previous discussion has focused on stress errors that may result from the potential application of a stress rule system, but other sources of stress errors have been implicated in the literature. These include the effect of imitation, segmental or articulatory factors, and phonetic control.

The influence of imitation on stress errors is of particular importance because multisyllabic words are infrequent in children's early spontaneous repertoires. Because unstructured naturalistic observation does not always provide sufficient numbers of productions to allow for a systematic study of stress development, investigators have often examined children's imitated productions, either of real or novel (i.e. experimental) words (Hochberg, 1988b; Kehoe, 1995; Klein, 1984; Pollock, Brammer and Hagerman, 1993; Schwartz and Goffman, 1995). Studies which have compared the frequency of stress errors in spontaneous and imitated speech generally show that children display greater proportions of stress errors in imitated speech (Klein, 1984; Hochberg, 1988b). Hochberg (1988b) explains this finding by arguing that children in their spontaneous speech have mastered the stress system and any individual exceptions, whereas their unfamiliarity with novel words in an imitation task leads to a rule-based approach. These results suggest that careful attention must be paid to the differential effects of imitated versus spontaneous productions in the analysis of stress errors.

Some investigators have observed that children may shift stress to an unstressed syllable for articulatory reasons. Klein (1984) noted that her English-speaking subject, Peter, consistently produced words such as PUzzle, TAble, and WAter with incorrect stress. Because these words end in a syllabic consonant she argued that the increased articulatory difficulty associated with syllabic elements was responsible for the stress shift. Hochberg (1988a) reported a similar phenomenon with Spanish-speaking children. She observed that the segmental challenge of producing a syllable with /r/ or a consonant cluster created a shift in stress to that syllable. Klein's (1984) and Hochberg's (1988a) observations suggest that careful attention must be given to segmental factors in the analysis of stress inaccuracies.

Finally, it must be remembered that perceptually identifiable stress depends upon control of acoustic/phonetic parameters, such as fundamental frequency ($F_0$), dura-

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3Hochberg's (1988b) and Nouveau's (1993) findings have been recently challenged by Gillis et al. (1994a, b), who show that an artificial learner, without any form of rule abstraction, produces a similar pattern of stress errors to Spanish- and Dutch-speaking children. Gillis et al.'s exemplar-based approach will be returned to in the discussion.
tion, and amplitude. Consequently, stress errors in young children may also arise from lack of control of these phonetic parameters. It is well documented that young children display considerable variability in stress accuracy, and that a certain proportion of their multisyllabic productions may be perceived as unreliable; that is, judges are unable to agree on stress placement. Two studies employing acoustic data in the analysis of children's stress patterns show that 'unreliable' tokens are often characterized by minimal acoustic differentiation between syllables, and trading effects between phonetic features (Kehoe, Stoel-Gammon and Buder, 1995; Pollock et al., 1993).

The difficulty of obtaining reliable stress transcription in young children implies that caution must be exercised when interpreting all types of children's stress errors in terms of the development of prosodic structure. Studies of stress development may benefit from the use of acoustic analysis in combination with perceptual analysis. Acoustic analysis may enhance the reliability of stress judgement and shed light on the complex interaction between phonetic and phonological factors in stress acquisition.

The review of the literature reveals that acquisition of stress as a rule-based system has been shown with Spanish- and Dutch-speaking children, but presently there exists little evidence that English-speaking children acquire stress in a systematic or rule-governed way. The first aim of the study is to examine whether English-speaking children display increased proportions of stress errors on exceptional stress forms, implicating some form of rule abstraction. The second aim is to examine the influence of imitation (Hochberg, 1988b; Klein, 1984), articulatory focus (Hochberg, 1988a; Klein, 1984), and phonetic control (Kehoe et al., 1995; Pollock et al., 1993) on children's stress pattern productions. In order to gain insight into phonetic factors in stress development, and to facilitate the transcription of stress, the analysis procedure includes an acoustic as well as perceptual component. The study is based on the following metrical framework:

**Metrical framework and predictions**

Hayes' (1995) metrical analysis is employed using modified grid notation. Basic principles of syllabification are assumed. That is, an intervocalic consonant forms the onset of the following syllable as dictated by the maximal onset principle (Kahn, 1976; Pulgram, 1970). The study concentrates on the assignment of stress to monomorphic English nouns, in particular, to three-syllable words with the stress patterns ŠWS (e.g. *Telephone*), SWŠ (e.g. *Kangaroo*), SWW (e.g. *Elephant*), WSW (e.g. *Banana*) and four-syllable words with the stress patterns ŠWSW (e.g. *Alligator*) and SWŠW (e.g. *Avocado*).4,5

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4Common English verbs spoken by children tend to be monosyllabic and therefore not suitable for stress analysis. The study focuses on three- and four-syllable words, rather than on two-syllable words, because the use of longer words should allow a more thorough analysis of a metrical system.

5The stress patterns of target words will be indicated by the following notation: S = stressed syllable; W = unstressed syllable. When there is more than one stressed syllable in a word, primary stress will be indicated by Š. In addition, target lexical items will appear in italics with primary and secondary stressed syllables denoted by upper-case lettering and unstressed syllables denoted by lower-case lettering.
The main generalization of stress in English nouns is that primary stress falls on the penult if it is heavy and on the antepenult, if the penult is light. Closed syllables and syllables with tense vowels and diphthongs are heavy; syllables with lax vowels are light. The basic component of the English stress rule is a quantity-sensitive left-dominant foot (moraic trochee) assigned from the right side of the word. This accounts for stress assignment in the majority of English nouns with the addition of final-syllable extrametricality. Main stress in English is determined by End Rule Right. Once extrametricality and foot application have taken place, a grid mark is placed on the highest column from the right side.

Some nouns in English receive stress (primary or secondary) on the final syllable also. Those with long vowels word-finally are subject to a rule of tense or long vowel stressing (Hayes, 1981). In the exceptionless case the stressing of the final syllable precedes the extrametricality rule, and main stress is assigned to the next stressed syllable from the right. Words that receive main stress on the final syllable must be marked as [-Extrametrical]. To account for words in which stress falls on final syllables with short vowels, an individual stress diacritic must be used. A metrical analysis of two selected target words is shown in (3). The lowest line in the analysis indicates the application of final-syllable extrametricality and, where necessary, application of long vowel stressing; the next line (the line above) is the foot construction layer; and the line above is the word construction layer.

(3)
(a) SWW (e.g. Elephant)

\[
\begin{align*}
(X & ) & \text{End rule Right} \\
(X .) & \text{Moraic trochee, } R \rightarrow L \\
\langle \rangle & \text{Extrametricality} \\
\tilde{e} & \tilde{o} \text{ fint}
\end{align*}
\]

(b) ŠWS (e.g. TElePHONE)

\[
\begin{align*}
(X & ) & \text{End Rule Right} \\
(X .) & \langle(X)\rangle & \text{Moraic trochee, } R \rightarrow L \\
\langle(X)\rangle & \text{Long vowel stress, Extrametricality} \\
\tilde{t} & \tilde{e} \tilde{o} \text{ fon}
\end{align*}
\]

Given a metrical representation of stress patterns, predictions can be made about the frequency of stress errors across stress pattern. The stress pattern SWS can be distinguished from the stress patterns SWW, ŠWS, and WSW, because it does not observe the rule of final-syllable extrametricality of nouns in English; the stress pattern ŠSWŠ can be distinguished from the stress pattern SWŠW because it does not adhere to the main stress rule of English, which assigns main stress to the foot closest to the end of the word, barring the final (extrametrical) syllable. Therefore, if children are acquiring a stress system consistent with a metrical framework, the prediction is: (1) stress errors will be greatest in SWŠ words among the three-syllable words, (2) and in ŠSWŠ among the four-syllable words, because these are exceptional English stress forms. A metrical representation of stress errors is shown in (4).
(4) Target form Predicted error form
\[
\begin{align*}
\text{Target form} & \quad \text{Predicted error form} \\
-x & \quad \langle x \rangle \\
\text{Application of} & \quad \text{Application of End} \\
\text{extrametricality} & \quad \text{Rule Right}
\end{align*}
\]

Method

Subjects

Subjects were six 22-month-old, six 28-month-old, and six 34-month-old children, recruited through an experimental 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 on the basis of the MacArthur Communicative Developmental Inventory: Toddlers (Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick and Reilly, 1991). Only children whose scores fell between the 20th and 80th percentile of their age range on the vocabulary section of the MacArthur Inventory were included in the study. Because the MacArthur Inventory screens children only up until 30 months of age, a slightly different procedure was used for the 34-month-old children. These children were participants in a study conducted 7 months previously when they were aged 27 months. At that time their scores fell between the 20th and 80th percentile on the MacArthur Inventory for their age range. 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 stimulus set consisted of 20 three-syllable words (12 real and eight novel words) and four four-syllable words. Novel words were employed, in addition to real words, to control for imitation and uncontrolled segmental effects on rhythmic productions. The three-syllable words included four stress patterns: ŠWS, SWŠ, SWW, and WSW, and the four-syllable words included two stress patterns: ŠWSŠ and ŠWSW. Limitations imposed by the restricted size of young children's vocabularies made it difficult to select equal numbers of real words across all stress patterns. In particular, only two real ŠWS words were selected, in contrast to three real ŠWS, SWW, and WSW words. In order to accommodate the reduced attention span and linguistic abilities of the 22-month-old children, a smaller corpus of words was selected. The real words excluded were TINKERBELL and CINDERElla; the novel words excluded were the WSW words, TAKESO and SANOFA. The word stimuli organized by stress pattern are presented in Table 1.

\( ^6 \) Four rather than three real ŠWS words were initially selected, but because one of the words, i.e. TINKERBELL, was not tested with the 22-month-old children, only three words were included in the main analyses. The exclusion of the WSW words in the novel-word condition with the 22-month-old children pertained to predictions regarding truncation results which was the focus of a related study (see Kehoe and Stoel-Gammon, 1996).
Stress error patterns

Table 1. Stimulus words

<table>
<thead>
<tr>
<th>Number of syllables</th>
<th>Stress patterns</th>
<th>Real</th>
<th>Novel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three</td>
<td>ŠWS</td>
<td>CROcoDILE</td>
<td>TAckeBO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TINkerBELL</td>
<td>DUFeMO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TELEPHONE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DinSAUR</td>
<td></td>
</tr>
<tr>
<td>SWŠ</td>
<td></td>
<td>KANgaROO</td>
<td>DOpaTOO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHIMpanZEE</td>
<td>BENnesSEE</td>
</tr>
<tr>
<td>SWW</td>
<td></td>
<td>OCtopus</td>
<td>BApika</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elephant</td>
<td>Tanema</td>
</tr>
<tr>
<td>WSW</td>
<td></td>
<td>poTAto</td>
<td>taKEdo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>toMAto</td>
<td>saNOfa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>baNAna</td>
<td></td>
</tr>
<tr>
<td>Four</td>
<td>ŠWSW</td>
<td>AlliGAtor</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>HELiCOPtler</td>
<td></td>
</tr>
<tr>
<td>SWŠW</td>
<td></td>
<td>AvoCAdo</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CINdeRElla</td>
<td></td>
</tr>
</tbody>
</table>

Data collection

Children interacted with a parent and an experimenter in two recording sessions, separated by a 1-week interval. All sessions were videotaped using a camera situated in an adjacent experimental room. The experimenter and the children wore vests containing small microphones connected to FM transmitters. The audio signals picked up from the FM receivers were recorded on to separate hifi audio channels of a videotape simultaneously with a video signal.

Children participated in semi-structured elicitation tasks in which they were encouraged to produce multiple productions of the stimulus words. To elicit productions of the novel words, eight fluffy toys were given the names of each of the novel words. Four novel words were taught in each session (three words in the case of the 22-month-old children), each representing a different stress pattern and counterbalanced by child. The experimenter and children engaged in pretend activities with the toys, making them eat, drink, and go to sleep. Children imitated the names of the toys and imitated simple phrases such as ‘Eat BApika’ and ‘Sleep BApika’. Most productions of the novel words were imitated, whereas productions of the real words included both spontaneous and imitated productions.⁷

Data base

The findings of the present study are based on the analysis 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. To be included in the data base a token had to meet the following criteria: (a) it had to be produced as an isolated form or in phrase-final

⁷An imitation was a production in which the adult model preceded the child’s production within the previous two utterances. Thus, this category included both immediate and delayed imitations.
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 part of an utterance with falling intonation.\(^8\)

In addition, attention was paid to the rhythmic productions of the experimenter and parent, because occasionally they altered the target stress pattern, particularly in the novel-word condition. Only children’s imitations of rhythmically correct adult models were included in the data set.

Tokens meeting the above criteria were subject to analysis. Tokens were acoustically analysed using \textit{CSpeech Version 4.0} (Milenkovic and 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. Visual inspection of the time waveform and \(F_0\) contour was used to facilitate stress transcription. Pitch contours were tracked by the CSpeech ‘pitch’ command which invokes a centre-clipped autocorrelation algorithm.

On the basis of the acoustic–perceptual analyses, each token was coded according to whether it contained stress shift or was rhythmically correct. Only primary stress was considered in the categorization of stress shift. Less attention was given to secondary stress due to the difficulty of distinguishing between an unstressed unreduced syllable and a syllable with secondary stress. In addition, segmental accuracy was not taken into consideration in the coding system.

In the coding procedure a distinction was made between systematic and unsystematic forms of stress errors. Systematic stress errors were coded according to whether there was perception of incorrect primary stress or perception of level stress. In three-syllable words with the stress patterns ŠWS and SWŠ, incorrect stress was stress shift to the other stressed syllable in the word (e.g. [dámásť] for \textit{DinoSAUR}; [kæŋgaru] for \textit{KANgaROO}). In SWW words, incorrect stress was stress shift to the final syllable (e.g. [ôktapós] for \textit{Octopus}). In WSW words, incorrect stress was stress shift to the initial or final weak syllables (e.g. [támédő] or [támédó] for \textit{toMAto}). In ŠWS and SWŠ words, level stress was perception of equal stress on both stressed syllables, and in SWW words, on the stressed and final syllables (e.g. [dámosť] for \textit{DInoSAUR}; [kæŋgaru] for \textit{KANgaROO}; [ôctapós] for \textit{OCiopus}). In WSW words, level stress was perception of level stress on the initial and stressed syllables or on the stressed and final syllables (e.g. [ôctámedő] or [támédó] for \textit{toMAto}).\(^9\)

Productions with unusual stress patterns, such as equal stress on all three syllables (e.g. [dámáśť] for \textit{DlnoSAUR}) or stress on the medial weak syllable of ŠWS, SWŠ and SWW words (e.g. [dámásť] for \textit{DInoSAUR}) were considered unsystematic.

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\(^8\)Pilot work indicated that a rising intonation may interfere with the accurate classification of stress. Specifically, a rising intonation may result in the unstressed syllable having greater \(F_0\) than the stressed syllable, causing the listener to perceive this syllable as if it were stressed.

\(^9\)In the case of ŠWS and SWŠ forms, shift of stress to the other stressed syllable in the word may be motivated by ‘quantity’ or other rule-related factors. The reader may be less convinced of the distinction between systematic and unsystematic forms of stress errors in SWW and WSW words, because stress shift is not motivated in these words at all. It is possible, however, that the final syllable in SWW words may function like a stressed syllable and therefore stress shift to the final syllable may be more frequent than to the medial weak syllable. In WSW words, stress shift to the initial weak syllable may be driven by rule-based factors; that is, to create word-initial stress; stress shift to the final syllable may be influenced by the full vowel quality of the final vowel in words such as \textit{poTAto} and \textit{toMAto}. It must be noted that this coding system biases WSW words to receive more systematic stress errors than other words, because there is less opportunity to code errors as unsystematic.
examples of stress shift and were placed in a separate 'other' category. These were not included in the statistical count of stress errors.

In four-syllable words, incorrect stress was shift of stress to the other stressed syllable in the word (e.g. [ælægəræ] for AlliGAtor, [ɔvækəðo] for AvoCAdo), and level stress was the perception of equal stress on the two stressed syllables in the word (e.g. [ælægəræ] for AlliGAtor, [ɔvækəðo] for AvoCAdo). Unusual stress patterns such as main stress on the final syllable were coded as 'other' (e.g. [ɔvækəðo] for AvoCAdo).

Truncation in the presence of stress shift did not alter the coding of stress pattern. For example, the truncated productions [kæŋrʊ] for KANgaROO and [ægəræ] for AlliGAtor were still coded as incorrect stress forms.

The numbers of tokens with stress shift (incorrect and level) and the total number of productions of each target word for each child were tabulated and entered into a statistical analysis program (SYSTAT for Windows, Version 5, 1992).

Reliability

Inter-judge and intra-judge reliability were conducted on subsamples of the final data set. The inter-judge reliability consisted of perceptual analysis, whereas the intra-judge reliability consisted of both 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 (approximately 18% of the data) evenly selected across age range and target words. The first judge (the author) transcribed the same set of words used by the second judge in the perceptual task, and also repeated the same procedure that was used in the original acoustic-perceptual analysis for 513 tokens (approximately 21% of the data). Reliability was determined on the basis of primary stress placement and not on segmental accuracy. The findings revealed adequate reliability for both inter- and intra-judge measures based on perceptual coding (81% and 83%, respectively) and good reliability for intra-judge measures based on acoustic-perceptual coding (93%).

Results

Effect of imitation

Because previous literature findings have shown an effect of imitation on stress errors, the analysis first examines whether children's imitated productions were subject to a higher proportion of stress errors than their spontaneous productions. The analysis focuses specifically on productions of real words because they contained both spontaneous and imitated productions; the majority of novel-word productions

10The effect of imitation on stress errors most likely reflects word familiarity, but because there is no simple way to judge word familiarity in young children, the binary distinction between imitated versus spontaneous production was used. Note that the relationship between word familiarity and imitated productions is not completely straightforward. For example, there were some words (e.g. Animal) that were familiar to children (as judged by parental report) but were rarely produced spontaneously due to difficulties of word elicitation. In general, however, unfamiliar words (e.g. CHIMpanZEE, AvoCAdo) were more likely to be imitated than familiar words (e.g. baNAna, Elephant).
were imitations. Table A-1 (in the appendix) lists the percentages of spontaneous productions in the real word set across age and individual word. The percentages varied greatly according to these two variables: a greater percentage of the older children’s productions were spontaneous compared to the younger children’s, and some words (e.g. banana, elephant) were characterized by higher percentages of spontaneous productions than other words (e.g. chimpanzee, animal).

To determine the effect of imitation on the frequency of stress errors, the numbers of stress errors were counted in spontaneous and imitated productions, respectively. This analysis was performed with all age groups combined and across each individual age group. It was not calculated across each individual word because of the tendency for some words to be predominantly imitated and some words to be predominantly spontaneous productions. The percentages of stress errors in spontaneous and imitated productions of real three-syllable words were 15% and 27%, and in spontaneous and imitated productions of four-syllable words were 16% and 24%, respectively. The findings across individual age groups are shown in Table 2.

Chi-square analyses revealed that 22- and 28-month-old children displayed greater proportions of stress errors in imitated productions of three-syllable words (22 months: $\chi^2(1) = 6.133; p = 0.013$; 28 months: $\chi^2(1) = 11.112; p = 0.001$), and 28-month-old children displayed greater proportions of stress errors in imitated productions of four-syllable words ($\chi^2(1) = 4.082; p = 0.043$). These findings are consistent with other reports indicating that stress errors occur more frequently in imitated speech.

**Table 2. Percentages of stress errors in spontaneous and imitated productions of real words across age**

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Words</td>
<td>22 months</td>
</tr>
<tr>
<td><strong>Three-syllable</strong></td>
<td></td>
</tr>
<tr>
<td>Spontaneous</td>
<td>15 (16)*</td>
</tr>
<tr>
<td>Imitated</td>
<td>27 (59)</td>
</tr>
<tr>
<td><strong>Four-syllable</strong></td>
<td></td>
</tr>
<tr>
<td>Spontaneous</td>
<td>28 (8)</td>
</tr>
<tr>
<td>Imitated</td>
<td>20 (10)</td>
</tr>
</tbody>
</table>

*Values in parentheses indicate numbers of productions. The respective totals of spontaneous and imitated productions in the three-syllable word condition were 107 and 216 for the 22-month-old group; 197 and 157 for the 28-month-old group; 244 and 121 for the 34-month-old group. The respective totals of spontaneous and imitated productions in the four-syllable word condition were 29 and 50 for the 22-month-old group; 57 and 49 for the 28-month-old group; 79 and 52 for the 34-month-old group.
cipate in one of the stress conditions (i.e. WSW words), two analyses for the novel-word condition were necessary: one based on the data set which included ŠWS, SWŠ, and SWW words for all age groups of children; and one based on the data set which included ŠWS, SWŠ, SWW, and WSW words for 28- and 34-month-old children. These data sets will be referred to as 'Novel Words—All Ages' (Nov—All Ages) and ‘Novel Words—28 and 34 Months’ (Nov—28 & 34), respectively. Statistical tests were based on proportion scores obtained on each word for each child. Analyses with the three- and four-syllable real words were principally descriptive and did not include statistical tests. Stress errors in this analysis include both level and incorrect forms.

Three-syllable words

The prediction was that if children internalize a rule of stress, increased proportions of stress errors should occur on exceptional or marked forms. In the three-syllable word set this includes SWŠ words which are exceptions to the rule of final-syllable extrametricality. Table 3 shows the proportions of stress errors across stress pattern for novel and real three-syllable words. The findings indicate that stress errors were present in all stress pattern categories but substantially higher proportions were present in SWŠ words. Statistical analyses revealed a highly significant stress pattern effect for the Nov—All Ages \( F(2,30) = 14.015; \ p < 0.001 \) and for the Nov—28 & 34 conditions \( F(3,30) = 7.275, \ p < 0.001 \). Post-hoc tests (Tukey) indicated that there were increased proportions of stress errors in SWŠ words compared to SWŠ and SWW words in the Nov—All Ages analysis, and increased proportions of stress errors in SWŠ words compared to SWŠ, SWW, and WSW words in the Nov—28 & 34 analysis. Although no statistical tests were conducted, findings in the real-word condition closely paralleled those in the novel-word condition. Representative examples of stress errors in SWŠ words are shown in (5). All examples include an

<table>
<thead>
<tr>
<th>Stress pattern</th>
<th>Nov—All Ages</th>
<th>Nov—28 &amp; 34</th>
<th>Real—All Ages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>ŠWS</td>
<td>0.22</td>
<td>(0.28)</td>
<td>0.25</td>
</tr>
<tr>
<td>SWŠ</td>
<td>0.49</td>
<td>(0.30)</td>
<td>0.50</td>
</tr>
<tr>
<td>SWW</td>
<td>0.15</td>
<td>(0.22)</td>
<td>0.18</td>
</tr>
<tr>
<td>WSW</td>
<td></td>
<td></td>
<td>0.22</td>
</tr>
</tbody>
</table>

Entries for Nov—All Ages are based on 36 individual proportion scores (2 words \( \times \) 18 children); entries for Nov—28 & 34 are based on 24 scores (2 words \( \times \) 12 children); entries for real words SWŠ, SWW and WSW, are based on 54 scores (3 words \( \times \) 18 children) and SWŠ words are based on 36 scores (2 words \( \times \) 18 children).

The 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 and Kutner, 1990). 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 analyses based on raw scores; however, the findings based on transformed data were identical to the raw score results.
identity label showing age, sex, and subject number (e.g. 22m1 = a 22-month-old male child), and an indication as to whether the production was spontaneous (S) or imitated (I). Phonetic transcription complies with the International Phonetic Alphabet (IPA), with the exception of stress diacritics, where the American system of placing the diacritic above the stress-bearing vowel is employed.

(5) KANgaROO /kæŋɡərʊ:/ 22f1 [wáwɔ] (I)
    34f2 [tʰéndʒərʊ] (S)
CHIMpanZEE /ˈtʃɪmpəntsi:/ 22f1 [bɪfɪ:] (I)
    34f2 [tʃɪˈbændɪ:] (S)
BEEnesSEE /bɛnəsɪ:/ 22f3 [bæːʃi] (I)
    34m2 [bɛnəsɪ] (I)
DOpaTOO /dəpətʊː:/ 22f3 [dádʊ] (I)
    34m2 [dʌfətʊ] (I)

Table 4 shows the proportions of stress errors across age and stress pattern for novel and real three-syllable words. Findings show that 22- and 34-month-old children produced stress errors predominantly in SWS words, whereas 28-month-old children also produced stress errors in other stress pattern categories, in particular, ŠWS words. The interaction between stress pattern and age was not significant for the Nov—All Ages analysis ($F(4,30) = 2.114; p = 0.104$), but was significant for the Nov—28 & 34 analysis ($F(3,30) = 3.494; p = 0.028$), indicating that the 28-month-old children performed differently from the 34-month-old children in their stress error tendencies, when all stress pattern categories were included in the analysis.

**Four-syllable words**

The prediction for four-syllable words was that, if children internalize a rule for stress, increased proportions of stress errors should be observed in ŠWSW words

<table>
<thead>
<tr>
<th>Stress pattern</th>
<th>Age</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22 months</td>
<td>28 months</td>
<td>34 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novel words</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>ŠWS</td>
<td>0.18</td>
<td>(0.19)</td>
<td>0.41</td>
<td>(0.38)</td>
<td>0.08</td>
</tr>
<tr>
<td>ŠWSW</td>
<td>0.46</td>
<td>(0.31)</td>
<td>0.44</td>
<td>(0.26)</td>
<td>0.57</td>
</tr>
<tr>
<td>SWW</td>
<td>0.09</td>
<td>(0.14)</td>
<td>0.30</td>
<td>(0.29)</td>
<td>0.07</td>
</tr>
<tr>
<td>WSW</td>
<td>—</td>
<td>—</td>
<td>0.23</td>
<td>(0.31)</td>
<td>0.21</td>
</tr>
<tr>
<td>Real words</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>ŠWS</td>
<td>0.26</td>
<td>(0.33)</td>
<td>0.25</td>
<td>(0.30)</td>
<td>0.11</td>
</tr>
<tr>
<td>ŠWSW</td>
<td>0.41</td>
<td>(0.29)</td>
<td>0.25</td>
<td>(0.22)</td>
<td>0.44</td>
</tr>
<tr>
<td>SWW</td>
<td>0.11</td>
<td>(0.26)</td>
<td>0.14</td>
<td>(0.20)</td>
<td>0.06</td>
</tr>
<tr>
<td>WSW</td>
<td>0.19</td>
<td>(0.27)</td>
<td>0.22</td>
<td>(0.29)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Entries for novel words are based on 12 individual proportion scores (2 words × 6 children); entries for real words ŠWS, SWW and WSW are based on 18 scores (3 words × 6 children) and ŠWS words are based on 12 scores (2 words × 6 children).
compared to SWŚW words, because these are exceptions to the English main stress rule. The analysis focuses on findings with the older subjects, 28- and 34-month-old children, because one of the stimulus words, CINdeRElla, was not tested with the younger subjects, and also because there was a high degree of missing data with four-syllable words in the younger age group. In addition, results across individual words are indicated because of the small numbers of words in the stimulus set.

The proportions of stress errors in the SWŚW words AlliGAtor and HELiCOpter were 0.07 and 0.18, respectively, and in the SWŚW words AvoCAdo and CINdeRElla were 0.27 and 0.19, respectively. These figures suggest that there was no systematic stress pattern effect in four-syllable words, because the highest proportion of stress errors occurred in AvoCAdo, a SWŚW word, and the lowest proportion in AlliGAtor, a SWŚW word, findings opposite to the predictions. It is possible that the stress error findings in four-syllable words were confounded by spontaneous versus imitated production effects. An examination of the percentages of spontaneous productions in four-syllable words (see Table A-1) shows that AvoCAdo was characterized by the lowest percentage of spontaneous productions (23% of productions were spontaneous), whereas AlliGAtor was characterized by a higher percentage of spontaneous productions (62%). AlliGAtor may have received such a low proportion of stress errors because it was familiar to children and thus more likely to have been memorized with its target stress pattern. The pattern of stress errors in four-syllable words may reflect imitation rather than rule-related factors.

**Additional findings with four-syllable words**

In order to obtain more information on children’s acquisition of the main stress rule, I present additional data from a separate study, which tested 27-month-old children’s (n = 11) productions of four- and five-syllable words (Kehoe, 1994). The advantage of these data was that the words belonging to the two stress pattern types SWŚW and SWŚW (including SWWW and SWŚWW) were more familiar to subjects (as judged by percentages of spontaneous productions) and thus less likely to be contaminated by imitation effects. Again, the prediction was that children should display fewer stress errors in SWŚW-type words compared to SWŚW words.

The findings with the 27-month-old children appeared to offer more systematic information on children’s acquisition of main stress. The percentages of stress errors (incorrect and level stress forms) in SWŚW words were 24% (12 errors in 56 productions) in AlliGAtor, 56% (19/34) in HELiCOpter, and 41% (11/27) in CAterPillar; the percentages of stress errors in SWŚW-type words were 18% (4/22) in RHINOceros, 12% (4/33) in HippoPOtamus, and 11% (3/27) in AvoCAdo. Thus, there was a tendency for fewer stress errors to be associated with SWŚW, SWWW, and SWŚWW words, and greater numbers of stress errors to be associated with SWŚW words. For example, children assigned main stress to the right-most foot in RHINOceros and HippoPOtamus,

(6) RHINOceros /rʊːnɒsərəs/ 27f1 [rənɔsrs] (I) 
27m2 [wɔtnɔswis] (S)
27f5 [wɔntəsi] (S)

HIppoPOtamus /hiːpəpɔtəməs/ 27f5 [hipɔpɔdə] (I)
[həpɔpəmɪs] (S)
27m6 [hipɔpədms] (S)
but they also assigned main stress to the right-most foot in \textit{AlliGator}, \textit{CAterPillar}, and \textit{HEliCOPter}, providing tentative support for the hypothesis that children initially assign main stress to the foot closest to the end of the word.

\begin{itemize}
\item \textit{AlliGator} \( /\text{\ae l\text{"a}\text{"e}\text{"a}r}/ \)
\begin{itemize}
\item 27m2 [\ælågêtœ] (S)
\item 27m3 [ôgêda] (S)
\end{itemize}
\item \textit{CAterPillar} \( /\text{kå\text{"e}\text{"o}pil\text{"a}r}/ \)
\begin{itemize}
\item 27f3 [kåpila] (S)
\item 27m6 [kåepadila] (S)
\end{itemize}
\item \textit{HEliCOPter} \( /\text{h\text{"e}\text{\dot{a}}\text{k\text{"o}p\text{"e}t}\text{"a}r}/ \)
\begin{itemize}
\item 27f1 [hèkôptœ] (S)
\item 27f5 [hèlaúptœ] (I)
\end{itemize}
\end{itemize}

\textbf{Effect of articulatory focus and phonetic control}

The analyses paid attention to stress errors which may result from articulatory focus or lack of phonetic control. Stress errors consistent with articulatory factors were observed in the 27- and 28-month-old children's productions from the two separate studies (Kehoe, 1994, and the present study). Specifically, stress errors were associated with the rhotacized vowel \( /\text{\ae}/ \) in the words \textit{AlliGator} and \textit{HEliCOPter}. The articulatory strength and duration given to the final syllables of these words was perceived on occasions as primary or secondary stress. Some examples are shown below:

\begin{itemize}
\item \textit{HEliCOPter} \( /\text{h\text{"e}\text{\dot{a}}\text{k\text{"o}p\text{"e}t}\text{"a}r}/ \)
\begin{itemize}
\item 27f1 [hèlokâptœ] (S)
\item 27m1 [æ dû dœ] (S)
\item 28f2 [hûlåkßåpdœ] (S)
\item 28m1 [hûpåkßåpdœ] (S)
\end{itemize}
\item \textit{AlliGator} \( /\text{\æl\text{"a}\text{"e}\text{"a}r}/ \)
\begin{itemize}
\item 27m1 [ålågdœ] (S)
\item 28m2 [ålågåtœ] (S)
\item 27m3 [ågåjœ] (S)
\item 28f3 [ålågêrœ] (S)
\end{itemize}
\end{itemize}

In these productions, children appeared to actively explore their productive capacities with rhotacized vowels. Acoustically the stressed vowel was associated with increased duration, but rarely with pitch accent, thus suggesting it was not cognitively intended as stress. Nevertheless its occurrence coincided with a developmental period when children displayed a tendency for final-syllable stress, so it cannot be completely ruled out as part of the same phenomena (Kehoe, 1996).

There were other types of stress errors more suggestive of phonetic-control than rule-based factors. In particular the productions of one 28-month-old child, 28m1, showed a strong tendency for medial-syllable prominence in \textit{SWS}, \textit{SWW}, and \textit{SWSW} words, as shown in (9).

\begin{itemize}
\item \textit{CROcoDILE} \( /\text{krákådã\text{"u}l}/ \)
\begin{itemize}
\item 28m1 [kʰåkʰôdáujœ] (I)
\item [k‘åkódûl. ð] (S)
\end{itemize}
\item \textit{TElePHONE} \( /\text{têlåføn}/ \)
\begin{itemize}
\item 28m1 [tèvåfœ] (S)
\item [tèwåføn] (I)
\end{itemize}
\item \textit{OCtopus} \( /\text{\text{"a}ktåpas}/ \)
\begin{itemize}
\item 28m1 [håhåpûs] (S)
\item [håkʰpûpûs] (S)
\end{itemize}
\item \textit{TAceBO} \( /\text{tåkåbø}/ \)
\begin{itemize}
\item 28m1 [tåkibø] (I)
\item [hèkåbø] (I)
\end{itemize}
\item \textit{HEliCOPter} \( /\text{hèlåkåptœ}/ \)
\begin{itemize}
\item 28m1 [hèbøkåptœ] (S)
\end{itemize}
\end{itemize}
It is unlikely that 28m1 was guided by a stress rule such as ‘apply stress to the second syllable from the beginning of the word’, because there is no evidence in English that would lead him to form such a rule. Furthermore, the phonetic quality of 28m1’s stress errors was different from the phonetic quality of other children’s stress errors. The medial syllable of words such as CROcoDILE, TElePHONE, and OCtopus was produced with higher than expected fundamental frequency and amplitude, but it was not produced with increased duration, so overall it did not sound the same as the medial stressed syllable in a WSW word. Nevertheless, the higher F0 and amplitude on the medial syllable created an effect of prominence that could be reliably transcribed as stress. This child does not seem to be able to coordinate the phonetic features of stress so that one syllable is consistently longer, louder, and higher in pitch. Rather, his lack of control over the phonetic features of stress, in particular pitch accent, creates an unusual prominence effect.

Discussion

The present study of stress errors in English-speaking children’s word productions revealed systematic stress pattern effects: Significantly greater numbers of stress errors were present in SWS words and a tendency for greater numbers of stress errors was observed in SWSW words, findings consistent with the increased association of stress errors with exceptional forms. From a metrical perspective stress errors in SWS words are consistent with acquisition of final-syllable extrametricality, and stress errors in SWSW words are consistent with acquisition of the English main stress rule, End-Rule Right.

In the three-syllable word set, the findings showed that similar stress patterns effects were present across the three age ranges of subjects, although the 28-month-old children also produced greater numbers of stress errors in other stress patterns. Interestingly, the trends documented with 28-month-old children were replicated in an independent study with a similar age range of children (Kehoe, 1994), offering some indication that this period, in particular, represents an experimental time of stress development. The stress error findings in four-syllable words were less robust than in three-syllable words. The presence of exceptional forms in the lexicons of young children (e.g. AlliGAtor, HEliCOPter, and CAterPILLar are all exceptions to the English main stress rule) may complicate stress rule acquisition in productions of longer words.

Our findings confirmed previous reports that stress errors occur more frequently in imitated compared to spontaneous speech (Hochberg, 1988b; Klein, 1984). This is an intriguing result in view of the general tendency for phonological accuracy to be more frequently associated with imitation (Menn and Matthei, 1992). Instead, children achieved less accuracy in their stress pattern productions with imitation. This finding appears to reflect the influence of word familiarity. Words that are less familiar to children are more vulnerable to stress alterations than words that are familiar. Klein interpreted these results as evidence for the lexicalization of stress, but her claim was weakened by the limited selection of stress patterns in her study, in effect allowing no systematic evaluation of rule-related effects. As Hochberg (1988b) argued, stress errors in unfamiliar words may provide stronger evidence for a rule system because children are more likely to employ rule knowledge when the word is unfamiliar, but overcome this knowledge when the word is familiar and stress it correctly. In the present findings, systematic effects were observed across...
age group and stress pattern in the novel-word task, in which all words were unfamiliar, and similar effects were observed in the real-word task, in which words differed in degree of familiarity, suggesting that rule-based effects can indeed be found in imitated data.

The findings supported Klein's (1984) and Hochberg's (1988a) observations that stress errors may be associated with articulatory focus. The rhotacized vowel /ɔ/ in words such as *AlliGAtor* and *HEliCOpter* was often perceived as stressed, particularly in the productions of the 27- and 28-month-old children. This prominence effect appeared to be a by-product of articulatory effort, because it was phonetically different from other stress errors. An examination of stress errors in non-rhotacized dialects of English would be interesting because this type of stress error should not be present if it is a correlate of articulatory effort. In addition, one 28-month-old child frequently produced words such as *TElePHONE* and *Octopus* with medial syllable prominence (e.g. [tevɪfɔː], [hæbˈpʊs]). The unusual pattern of this stress error, and the fact that its phonetic realization was quite distinctive—characterized by high *F0* and amplitude but not duration—underscores the importance of considering phonetic-control as well as phonological factors in stress development.

Recently, Gillis *et al.* (1994a,b) have proposed that children acquire stress on the basis of analogy rather than by rule. Their approach, referred to as exemplar-based learning, assigns stress to novel items on the basis of similarity with stored items. Their findings with an artificial learner show a strong association of stress errors with metrical markedness and a tendency for stress errors to result in regularization of stress patterns. Although Gillis *et al.*'s findings challenge the rule-based conclusions of this study, they do not take into account the results of a more detailed metrical analysis. Since the representations and operations of metrical theory are not deemed necessary for exemplar-based learning, support for stages of stress development and metrical parameters contradict this approach to stress acquisition. A more detailed metrical analysis using the current data set is the focus of a companion study (Kehoe, 1996).

The analysis of stress pattern development has received such little attention in normally developing populations that its extension to clinical populations has not been fully explored. However, there is a growing body of literature showing that prosodic disturbances such as stress errors may be characteristic of the speech of subjects with specific language impairment (Piggott and Kessler Robb, 1994), hearing impairment (Miccio and Kehoe, 1996; Weiss, Carney and Leonard, 1985), and apraxia of speech (Kent and Rosenbeck, 1982; Odell, McNeil, Rosenbeck and Hunter, 1991). In particular, subjects with apraxia of speech are reported to have substantial problems with the accurate production of lexical stress, and the analysis of stress errors may serve as a useful tool in the differential diagnosis of this population (Odell *et al.*, 1991). Recent studies also show that manipulation of stress contrast may be employed in the remediation of such disorders as stuttering (Packman, Onslow, Richard and Van Doorn, 1996).

An example of a study which employs a metrical analysis in a clinical setting is Miccio and Kehoe (1996), who report on the high prevalence of stress errors in an adolescent boy with hearing impairment. In this subject, stress pattern acquisition was compounded by a fragile auditory system and a difficult stage of academic learning, when a large number of multisyllabic words were newly introduced. Despite the subject’s unusual speech patterns a metrical analysis revealed that his stress errors were neither aberrant nor unsystematic, but consistent with many features of
a metrical system, such as awareness of quantity-sensitivity and extrametricality. A metrical analysis, by guiding and facilitating the interpretation of stress patterns, may lead to greater insights into changes in the prosodic structure of speech that result from speech and language disturbances.

Conclusion

The findings reveal that English-speaking children between the ages of 22 and 34 months display a certain amount of systematicity in stress development. The proportions of stress errors varied significantly according to metrical pattern, with the greatest proportion of stress errors occurring in irregular stress patterns. The results indicate that stress errors occur more frequently in imitated speech, and that additional factors, apart from rule-related effects, may influence whether a syllable is perceived to be stressed.

Acknowledgements

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References


Appendix

Table A1. Percentages of spontaneous productions in real words across age and individual word

<table>
<thead>
<tr>
<th>Words</th>
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