Support for metrical stress theory in stress acquisition

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Abstract

This study provides a detailed analysis of stress errors in English-speaking children's word productions to determine whether the patterns of errors are consistent with the theoretical notions of metrical phonology. Children (aged 22–34 months) produced three-syllable novel and real words which varied according to metrical pattern. Results revealed three general stages in stress acquisition and support for metrical parameters, such as quantity-sensitivity, extrametricality, and main stress. Findings are compared with a recent analysis of stress development in Dutch-speaking children, based on a parametric metrical framework.

Keywords: stress errors, metrical phonology, acquisition, English, Dutch

Introduction

Most linguistic theories make use of a system of principles and parameters, a system of representation, and a system of rules or constraints to account for various aspects of phonological phenomena. Which system one chooses is of utmost importance, because this will influence the interpretation of phonetic facts. The linguistic theory that is the focus of investigation is metrical phonology, a sub-branch of non-linear phonology that deals with stress and rhythm. This theory has been used to describe the stress systems of a wide variety of the world's languages (Hayes, 1981, 1995), but has only been minimally applied to children's speech. There are a number of recent studies, however, which point to the importance of metrical theory in the analysis of children's stress errors (Archibald, 1995; Fikkert, 1994; Hochberg, 1988).

An earlier paper showed that English-speaking children produce greater numbers of stress errors on exceptional stress forms, supporting a systematic pattern of stress acquisition (Kehoe, 1997). This paper provides an in-depth analysis of the same children's stress errors in three-syllable words, to seek further evidence for metrical theory. In particular, it compares findings of the present study with findings from a Dutch study, which documented distinct stages in stress acquisition and support for metrical parameters (Fikkert, 1994). In the first part of this paper I highlight the main features of metrical phonology that will be useful in the analysis of children's...
stress errors, and then focus on those studies which have pursued a metrical framework in the interpretation of children’s rhythmic patterns.

**Metrical phonology**

Stress is found in a large number of languages in the world, but languages vary in rich and diverse ways in terms of which syllables in a word receive stress. Metrical phonology captures the uniformity between stress systems by positing a small inventory of parameters. Differences between stress systems are derived by choosing particular settings for each parameter. A brief description of the main parameters in metrical theory is provided below:

1. **Foot-headedness.** The core feature within a metrical framework is a unit called a foot, which is typically composed of a stressed and an unstressed syllable. Terms from traditional metrics are often employed in the labelling of foot-types: an iambic foot has the head syllable (i.e. stressed syllable) on the right and a trochaic foot has the head syllable on the left.

2. **Quantity-sensitivity.** Quantity sensitivity refers to whether stress assignment is sensitive to the internal structure of a syllable. For example, syllables may be light (e.g. CV) or heavy, that is, contain a long vowel or additional consonant (e.g. CVV or CVC). When stress is assigned to a syllable which is heavy, the stress system is quantity-sensitive. When stress assignment is unconcerned with syllable structure, the stress system is quantity-insensitive.

3. **Directionality of stress parsing.** Another component of the stress system is the direction in which stress is assigned. Feet may be constructed from left to right or from right to left.

4. **Extrametricality.** Extrametricality designates a specific prosodic constituent (e.g. segment or syllable) as invisible for the purposes of stress assignment. The most common case is that the final syllable of a word is extrametrical.

5. **Main stress.** Main stress refers to the increased prominence of one stress-foot with respect to another stress-foot. Typically, the right-most or left-most stressed syllable in a word receives main stress with the exception of extrametrical syllables. In recent accounts, word stress is achieved using labelling rules, End Rule Left/Right (Hayes, 1995; Prince, 1983).

The present analysis is based on Hayes’ (1995) metrical stress theory which employs bracketed grid format. In this theory Hayes posits a restricted inventory of foot-types, which combine the parameters of headedness and quantity-sensitivity. His inventory includes three main foot-types, shown in (1).

(1)  

(a) syllabic trochee  
possible feet  
\[
\begin{align*}
\text{foot} & : \sigma \sigma, \sigma, \\
\text{possible feet} & : (X_\sigma), (X_\sigma) \\
\end{align*}
\]

(b) moraic trochee  
possible feet  
\[
\begin{align*}
\text{foot} & : \sigma, \sigma, \\
\text{possible feet} & : (X_\sigma), (X_\sigma) \\
\end{align*}
\]

(c) iamb  
possible feet  
\[
\begin{align*}
\text{foot} & : \sigma, \sigma, \\
\text{possible feet} & : (X_\sigma), (X_\sigma) \\
\end{align*}
\]

where /σ/ = any syllable; /_/_ = heavy syllable; and /_/_ = light syllable.

This inventory captures the empirical observation that trochaic feet can be
both quantity-sensitive and quantity-insensitive, whereas iambic feet are typically quantity-sensitive.

**Support for metrical theory in stress acquisition**

In 1990, Dresher and Kaye published an influential article on the learnability of stress, based on a parameter-setting model. After reviewing several learning theories they advocated a deterministic learning strategy (no back-tracking) which takes advantage of robust and appropriate cues in the linguistic environment. At the time they published their model there were no developmental studies of stress directly related to parameter-setting. However, they hypothesized that if such a model were plausible then one should observe well-defined stages of stress acquisition and points in development where children become aware, for example, that stress is related to quantity, and that stress is computed from the right side of the word. They also hypothesized that the setting of parameters which depend on the prior setting of other parameters should occur late in the acquisition process. For example, the setting of main word stress, which depends upon foot-level parameters, should be one of the last parameters to be set.

Dresher and Kaye’s (1990) model was directly adopted by Fikkert (1994) in her longitudinal study of Dutch children’s stress. (For application to second-language learning, see Archibald, 1993.) From the analysis of prosodic processes such as truncation and stress, Fikkert documented four distinct stages in the development of stress. In her model, stress errors result from a variety of factors, including mapping to a metrical template and the setting of parameters, such as quantity-sensitivity and main stress. Some examples of these errors are discussed below.

At stage 1, children circumscribe a trochaic foot from the right side of the adult target word and map this onto their own trochaic template. In the case of WS, ŠWS, and SWŠ words, children produce the stressed syllable at the end of the word; in the case of SW and WSW words, children produce a bisyllabic SW unit. (Throughout the paper, S refers to stressed syllable, and W refers to unstressed syllable. Primary stress is indicated by Š. Target lexical items appear in italics with primary and secondary stressed syllables denoted by upper-case lettering and unstressed syllables denoted by lower-case lettering.) At this initial stage of development, no stress errors occur. At stage 2, children produce their multisyllabic productions with a trochaic stress pattern, consistent with the mapping of segmental content from two syllables of the target form to a trochaic metrical template. Thus, disyllabic words with final stress (WS and SS words) are now produced with a trochaic stress pattern. Disyllabic productions of three-syllable words (e.g., ŠWS and SWŠ words) are also produced with trochaic stress. The crucial examples are productions of SWŠ words where the mapping of two syllables to a single template results in a trochaic metrical template. Thus, disyllabic words with final stress (WS and SS words) are now produced with a trochaic stress pattern. Disyllabic productions of three-syllable words (e.g., ŠWS and SWŠ words) are also produced with trochaic stress. The crucial examples are productions of SWŠ words where the mapping of two syllables to a single template results in a trochaic pattern, different from the target stress contour. Examples of stress errors in Robin’s productions of WS and SWŠ words at stage 2 of development are shown in (2). Phonetic transcription complies with the International Phonetic Association (IPA), with the exception of stress diacritics, where the American system of placing the diacritic above the stress-bearing vowel is employed.

(2) WS  \textit{giTAAR} /giˈt̚ər/ [ʃt̚ər] ‘guitar’ Robin  
\textit{giRAF} /giˈaf/ [ʃːaf] ‘giraffe’ Robin  
SWŠ  \textit{TEleFOON} /təˈlafon/ [tifɔːm] ‘telephone’ Robin
At stage 3, children produce both syllables in their productions with level stress. That is, they produce equal amounts of stress on each syllable. Fikkert’s formal account of this finding is that children’s prosodic templates have now expanded to two feet but, as yet, they have not acquired the main stress rule, which assigns greater prominence to one of the feet in the template. Therefore, both feet in the template receive equal stress. Examples of level stress forms in WS and SWŠ words are shown in (3).

(3) WS \textit{ballon} /balon/ [bændon] ‘balloon’ Robin
KASTEEL /kóstél/ [táştě:] ‘castle’ Robin

SWŠ \textit{microfoon} /mikrofon/ [mikafon] ‘microphone’ Robin
KROkoDIL /kròkodil/ [køkadI] ‘crocodile’ Robin

Finally, Fikkert noted that when children acquire the main stress parameter at the next stage of stress development (stage 4), they assign main stress to the right-most branching foot.\(^1\) In her corpus of words, most words received the correct target stress pattern, with the exception of SWŠ words, where the assignment of main stress to the right-most branching foot resulted in word-initial stress instead. Examples are shown in (4).

(4) \textit{KApiTEIN} /kàpipétIn/ [pápitIn] ‘captain’ Robin
TEleFOON /télafon/ [télafom] ‘telephone’ Robin
KROkoDIL /kròkodil/ [køkadi] ‘crocodile’ Robin

In order to explain this developmental sequence, Fikkert proposed that children start out with the following default parameters: foot-headedness [Left], directionality [Right-to-Left], and quantity-sensitivity [No]. The combination of foot-headedness [Left] and directionality [Right-to-Left] accounts for the finding that children initially produce SW words correctly, but truncate WS words to a strong form only (Allen and Hawkins, 1979, 1980; Echols and Newport, 1992; Schwartz and Goffman, 1995). According to Fikkert, right-headed feet can never be parsed if children start from the end of the word and search for the first stressed syllable. The evidence for the default setting of quantity-insensitivity comes from children’s trochaic forms at stage 2. Children produce bisyllabic words in which the final heavy syllable is unstressed (e.g. \textit{ballon}/balon/[pap3ml]). It is only at stage 3, when children become aware that words with the same number of syllables may have different stress patterns (a cue for quantity-sensitivity), that the quantity-sensitivity parameter is set to its marked value, [Yes]. At this time the parameters of headedness and directionality are then fixed to their default values and are no longer subject to change. Once foot-level parameters have been set, the child concentrates on main stress, thus confirming Dresher and Kaye’s prediction that the setting of parameters, which is dependent upon the setting of other parameters, occurs late in stress acquisition.

Because Dutch and English have similar rhythmic characteristics (both are trochaic languages), many of Fikkert’s predictions can be directly applied to the speech of English-speaking children. The aim of this study is to examine whether

\(^1\) Fikkert uses the obligatory branchingness parameter to account for the setting of main stress. This convention is more appropriate for tree formalism and has been largely superseded by the devices of extrametricality and End Rules in recent grid theories.
there is evidence for Fikkert’s stages of stress acquisition and support for metrical parameters in English-speaking children’s productions. That is, do English-speaking children pass through a stage of trochaic stress, level stress, and main-stress prominence in their development of prosodic structure? By analysing stress errors at different stages of development, empirical support for parameters such as foot-headedness, quantity-sensitivity, directionality, extrametricality, and main stress may be sought. This study focuses on three-syllable words rather than two-syllable words because they should offer a stronger test of a metrical framework. It also concentrates on children’s stress errors and not on other rhythmic processes (see Demuth and Fee, 1995; Fikkert, 1994; Kehoe and Stoel-Gammon, 1997, for studies which include analysis of truncation and epenthesis.) This study is based on the following metrical framework.

Metrical framework

The basic component of the English stress rule is a quantity-sensitive left-headed foot (moraic trochee) assigned from the right side of the word. In English nouns, final syllables are made extrametrical with the exception of those with long vowels, which 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. 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. Words that receive main stress on the final syllable must be marked as [-Extrametrical]. A metrical analysis of selected target words is shown in (5). 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. In SWŞ words an intermediate layer is shown, indicating the application of the alternating stress rule which assigns secondary stress.

(5) Metrical analysis of Target Stress Patterns

(a) SWW (e.g. Elephant)

\[
(X \\
(X .) \\
\langle \rangle \\
\epsilon \tilde{\epsilon} \tilde{\epsilon}
\]

End Rule Right
Moraic trochee, R→L
Extrametricality

(b) ŠWS (e.g. TELEPHONE)

\[
(X \\
(X .) \\
\langle X) \rangle \\
\langle (X) \rangle \\
\tilde{\epsilon} \tilde{\epsilon} \tilde{f}\;
\]

End Rule Right
Moraic trochee, R→L
Long vowel stress, Extrametricality
Method

The subjects were 18 English-speaking children, aged 22–34 months (six children at three separate age ranges: 22, 28, and 34 months). All children were within a 1-week interval of their age and received scores between the 20th and 80th percentile for their age range on the vocabulary section of the MacArthur Communicative Developmental Inventory: Toddlers (Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick and Reilly, 1991). Children were tested in two 45-min sessions separated by a 1-week interval. In each session they participated in semi-structured elicitation tasks in which they were encouraged either by an experimenter or a parent to produce multiple tokens of stimulus words. The stimulus words were 20 three-syllable novel and real words, consisting of four metrical patterns: SWS, SWŚ, SWW, and WSW. Novel words were tested to control for potential word familiarity effects that may influence rhythmic processes. The majority of novel words were imitated, whereas the real words included spontaneous and imitated productions. All sessions were videotaped using a camera situated in an adjacent test room. Each child wore a vest containing an electret microphone connected to an FM transmitter. The audio signal from the FM receiver was recorded onto the HiFi audio channel of a videotape simultaneously with the video signal.

The database consisted of 2117 productions of stimulus words collected from the 18 subjects. To be included in the database, tokens had to be produced: (1) in isolation or in phrase-final position; (2) with normal emotional level; and (3) as part of an utterance with falling intonation. To the extent possible, six productions of each real word and eight productions of each novel word were selected for each child. Tokens were then digitized and subject to acoustic and perceptual analysis (CSpeech Version 4.0; Milenkovic and Read, 1992). This procedure involved both perceptual judgement and inspection of the $F_0$ contour and time waveform to

2 The metrical analysis of KANgaROO may have two possibilities. It may be analysed as having two moraic trochees and an internal unparsable syllable, or the English stress rule may apply to give main stress to the final syllable and secondary stress may be provided by the alternating stress rule which is quantity-insensitive, thus allowing the internal weak syllable to be parsed within a foot. The second analysis was employed in this study.

3 The initial syllable of a WSW word, such as toMATo, is an unparsable syllable and does not have foot structure. This is different from earlier metrical approaches, including Fikkert’s, which parsed all syllables into feet and then employed destressing.
Metrical stress theory
determine stress placement. Tokens were coded according to whether there was perception of correct stress (i.e. correct primary stress placement), incorrect stress (placement of primary stress on incorrect syllable), or level stress (equal degrees of stress on two syllables). A subset of the data (15–20%) was re-examined for stress reliability. Inter and intra-judge agreement for primary stress placement based on perceptual coding was 81% and 83%, respectively. Intra-judge agreement based on acoustic-perceptual coding was 93%. A more detailed description of methodology can be found in Kehoe (1997).

Results
The following analysis of stress errors is organized according to target metrical pattern. To make the data compatible with Fikkert’s, incorrect and level stress forms and, where necessary, stress errors in truncated and non-truncated productions are separated out. Tables 1–4 include all production patterns in three-syllable words but the discussion focuses specifically on children’s stress errors. A small percentage of productions are not accounted for in Tables 1–4 due to the coding of unusual stress errors as ‘Other’.

Stress errors in ŠWS words
Table 1 shows the mean proportions of production patterns in novel and real ŠWS words. Observed patterns in ŠWS words (e.g. TáckeBO/tækbô/) were: rhythmically correct forms, that is, forms with the correct number of syllables and primary stress placement (e.g. [thækbo]); one-syllable truncations (e.g. [bx]); two-syllable truncations without stress shift (e.g. [thækbo]); level stress truncated and non-truncated forms (e.g. [gægrwô], [dáthô]); and incorrectly stressed truncated and non-truncated forms (e.g. [thækbo], [thækbo]).

Following Fikkert (1994), the ŠWS data were organized into three main groups of patterns: (1) truncated forms with S(W) pattern. This category includes both one- and two-syllable truncations; (2) truncated or non-truncated level stress forms; and (3) non-truncated forms with the correct rhythmic pattern. The truncated S(W) forms characterize Fikkert’s stages 1 and 2; the level stress forms characterize stage 3; and the non-truncated correct forms (i.e. ŠWS patterns) characterize stage 4. Developmental trends in these groups of production patterns for novel and real words are presented in Figure 1.

The findings show that truncated S(W) forms predominated in the youngest children’s productions with the exception of the real words which the older children also tended to truncate (see Kehoe and Stoel-Gammon, 1996, for discussion of segmental effects on truncation). Level stress forms were relatively infrequent as an error pattern, but occurred most often in the productions of the 28-month-old children. Correct ŠWS forms were present in the older children’s productions of novel words, but were less frequent in productions of real words due to the high proportion of truncations.

In general, the most important acoustic cues for determining placement of primary stress in this study were maximum \( F_0 \), \( F_0 \) contour (rise-fall), and amplitude. Duration was less useful, since all stimulus productions were phrase-final and, hence, both stressed and unstressed syllables in final position tended to be long.
Table 1. Mean proportions of production patterns in ŠWS words

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>N(^a)</th>
<th>Cor(^b)</th>
<th>S</th>
<th>SW</th>
<th>Lev</th>
<th>Incor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>12</td>
<td>0.29</td>
<td>0.05</td>
<td>0.44</td>
<td>0.12</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.30)(^c)</td>
<td>(0.15)</td>
<td>(0.36)</td>
<td>(0.14)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>28</td>
<td>12</td>
<td>0.48</td>
<td>0</td>
<td>0.04</td>
<td>0.14</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.40)</td>
<td></td>
<td>(0.11)</td>
<td>(0.15)</td>
<td>(0.35)</td>
</tr>
<tr>
<td>34</td>
<td>12</td>
<td>0.78</td>
<td>0</td>
<td>0.13</td>
<td>0.07</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.25)</td>
<td></td>
<td>(0.21)</td>
<td>(0.08)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Real</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>22</td>
<td>17</td>
<td>0.17</td>
<td>0.05</td>
<td>0.46</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.28)</td>
<td>(0.14)</td>
<td>(0.40)</td>
<td>(0.17)</td>
<td>(0.25)</td>
</tr>
<tr>
<td>28</td>
<td>18</td>
<td>0.26</td>
<td>0</td>
<td>0.33</td>
<td>0.14</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.29)</td>
<td></td>
<td>(0.42)</td>
<td>(0.19)</td>
<td>(0.20)</td>
</tr>
<tr>
<td>34</td>
<td>18</td>
<td>0.27</td>
<td>0</td>
<td>0.51</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.31)</td>
<td></td>
<td>(0.40)</td>
<td>(0.14)</td>
<td>(0.09)</td>
</tr>
</tbody>
</table>

\(^a\)N = number of individual proportion scores.
\(^b\)Cor = correct rhythmic productions; S = one-syllable truncations; SW = two-syllable truncations; Lev = truncated and non-truncated forms with level stress; Incor = truncated and non-truncated forms with incorrect stress.
\(^c\)Standard deviations are indicated in parentheses.

Figure 1. Developmental trends in production patterns of ŠWS words.

Note that, apart from level stress forms, a proportion of the 22- and 28-month-old children’s productions were realized with incorrect stress. That is, children produced primary stress on the final syllable of their truncated and non-truncated productions, instead of on the initial syllable. 28-month-old children, in particular, displayed a high proportion of incorrect forms in their productions of novel ŠWS words. In part this was due to the unusual prosodic strategies of one child who displayed a strong tendency for word-final stress (Kehoe, 1996). A reanalysis of the data with the exclusion of this subject showed a decline in the proportion of incorrect stress from 0.27 to 0.17 in novel ŠWS words and from 0.11 to 0.04 in real ŠWS words. There were, however, three other 28-month-old children who shifted stress...
to the final syllable of novel ŠWS words, suggesting a tendency for word-final stress at this age.

In terms of individual word patterns the most salient stress error effect in ŠWS words was the high proportion of level and incorrect stress on the word CROcoDILE; 0.33 of the productions of CROcoDILE received stress errors. Examples of stress shift in CROcoDILE are shown in (6). All examples of error patterns from the present data 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). In the phonetic transcription a period between two vowels indicates a syllable break (e.g. [krákòdái.os]), and a space indicates a significant intraword pause (e.g. [tim[ti ti:i]). The placement of secondary stress should be interpreted more cautiously than that of primary stress.

(6) CROcoDILE /krákòdái/  
22f1 [hòkɡàu] (I)  
28f2 [pʰòkigàu] (I)  
28m3 [kʰòkigàu] (I)  
34f2 [pràtkìdái.a] (I)  
34m2 [krákòdái.os] (S)

Stress errors were less frequent in other ŠWS words and were present only in the youngest age groups of children (22 and 28 months). Some examples are shown in (7).

(7) TElePHONE /tèlafón/  
22f1 [påfó] (I)  
22f2 [tʰèlfó:] (S)  
22m1 [tùdådå:n] (S)  

DInoSAUR /dàmsòr/  
22f1 [påfó] (I)  
22f2 [tʰèlfó:] (S)  
28m3 [tigòbà:o] (I)  

TINkerBEL/ /tìnkəbêl/  
28f3 [tʰîngòbà:o] (I)  
28m3 [tigòbà:o] (I)  

TAckeBO /tækəbô/  
28f3 [tʰækəbô] (I)  
28m3 [tʰægòbô] (I)

Because the ŠWS words contain tense or long vowels word-finally, the incorrect stress errors may be consistent with children’s acquisition of quantity-sensitivity, combined at this stage with their non-acquisition of extrametricality. The tense vowel closest to the end of the word may attract stress at certain developmental times. The increased proportion of stress errors in CROcoDILE compared to other ŠWS words appears particularly related to quantity, because the final syllable of CROcoDILE is superheavy, consisting of a diphthong and a coda consonant. Even the older children, who made few errors on other ŠWS words, frequently shifted stress to the final syllable of CROcoDILE (see Wijnen, Krikhaar and Den Os, 1994, for similar observations in Dutch children).

5 Although TINkerBEL does not contain a tense vowel word-finally, it appeared to pattern in a similar way to other ŠWS words. Note that most children tend to diphthongize the final syllable, creating a long vowel in their own productions.
**Stress errors in SWW words**

Table 2 displays the mean proportions of production patterns in novel and real SWW words. Observed patterns in SWW words (e.g. Tānema/taːnəmə/) were: rhythmically correct forms (e.g. [tʰəməmə]; one-syllable truncations (e.g. [mæː]); two-syllable truncations with trochaic stress (e.g. [tʰəmə]; level stress truncated or non-truncated forms (e.g. [tʰəməmə], [dɪmː]; and incorrectly stressed truncated or non-truncated forms (e.g. [tʰənəmə], [tʰənæː;]).

In Fikkert’s analysis, SWW words were not subject to stress shift at any stage. The mapping of syllables to a single trochaic template resulted in SW forms at all stages of stress development. The English data were organized into two main groups of production patterns: (1) truncated SW forms; and (2) the correct rhythmic pattern (SWW forms). Developmental trends in these groups of patterns are presented in Figure 2.

In contrast to Fikkert’s findings, a variety of error patterns were present in productions of SWW words, including level and incorrect stress. Nevertheless, in accordance with Fikkert’s findings the predominant pattern was SW. In the real word condition all children produced a high proportion of SW patterns; in the novel word condition the 28-month-old children produced fewer truncated forms and higher numbers of incorrect stressed forms: 0.30 of their novel and 0.14 of their real word productions were subject to stress errors. The proportions of correct rhythmic productions tended to increase with age.

In terms of individual word patterns, stress errors were infrequent in productions of real SWW words, with the exception of Octopus where a much higher proportion of level and incorrect stress patterns was observed: 0.17 of the productions of

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>N</th>
<th>Cor</th>
<th>S</th>
<th>SW</th>
<th>Lev</th>
<th>Incor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Novel</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>12</td>
<td>0.32</td>
<td>0.13</td>
<td>0.43</td>
<td>0.07</td>
<td>0.02</td>
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<tr>
<td></td>
<td></td>
<td>(0.38)²</td>
<td>(0.30)</td>
<td>(0.34)</td>
<td>(0.12)</td>
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<td>(0.40)</td>
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<td>(0.07)</td>
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<td>(0.39)</td>
<td>(0.43)</td>
<td>(0.12)</td>
<td>(0.04)</td>
<td></td>
</tr>
</tbody>
</table>

*¹N = number of individual proportion scores.
²Cor = correct rhythmic productions; S = one-syllable truncations; SW = two-syllable truncations; Lev = truncated and non-truncated forms with level stress; Incor = truncated and non-truncated forms with incorrect stress.
³Standard deviations are indicated in parentheses.
Metrical stress theory

Figure 2. Developmental trends in production patterns of SWW words.

Octopus received stress errors compared to 0.05 in Elephant and 0.09 in Animal. Examples of stress errors in real and novel SWW words are shown in (8).

(8) Octopus /ɔktəpəs/ 22f2 [ɔː[pəpʊs] (I) 28f2 [ɔːkipʊs] (S) 28f3 [əʔəfʊs] (S)
     Animal /ənəməl/ 22m1 [ənɛmə] (I) 34f2 [ənimɔz] (I)
     Elephant /əlaːfənt/ 28f1 [əfɪt] (S) 28m3 [əfɛn] (S)
     BApika /bɛpəkɑ/ 28f3 [ɡɛk̩kɑ] (I) 28m3 [pʰɡikʰɑ] (I)
     Tanema /tənəmə/ 28f3 [tʰənə] (I) [tʰənəmə] (I)

One possible reason for the presence of stress errors in the English compared to the Dutch data is that the final unstressed syllable in some of the English SWW words is closed (e.g. Elephant; Octopus) or contains a syllabic element (e.g. Animal). In contrast, the final unstressed syllable in the Dutch SWW words contains a schwa vowel only. Although the final syllable in the novel English SWW words contains a schwa vowel only, these words were sometimes produced by the experimenter with prominence applied to the final syllable. For example, BApika was sometimes pronounced as [bɛpəkɑ] rather than [bɛpəkɑ]. Given the presence of vowel quality or closed syllable structure in the final syllable, the English-speaking children may have judged the metrical structure of SWW words as SWS and, thus, have been more likely to shift stress to the final syllable in the absence of having set the extrametricality parameter.
Stress errors in SWŚ words

Table 3 shows the mean proportions of production patterns in novel and real SWŚ words. Observed patterns in SWŚ words (e.g. BĒneSSEE/bēnasi/) were: rhythmically correct forms (e.g. [mēnāsēj]); one-syllable truncations (e.g. [biː]; two-syllable truncations with stress shift (e.g. [bēsēj]); two-syllable truncations without stress shift (e.g. [bēsēj]); truncated and non-truncated level stress forms (e.g. [bēbī], [bēndōsēj]); and incorrectly stressed non-truncated forms (e.g. [bēnasi]).

In Fikkert’s analysis, stress errors in SWŚ words occur at three separate stages, corresponding to stages 2, 3, and 4 of stress development. First, the mapping of segmental content from the two stressed syllables of the target to a single trochaic template results in truncated forms with incorrect stress. Second, the mapping of segmental material to two trochaic templates, without the main stress parameter being set, results in truncated or non-truncated forms with level stress. Finally, the acquisition of the main stress parameter results in incorrect stress to non-truncated forms of SWŚ productions. The English data were organized into three main groups of errors patterns: (1) truncated forms with S(W) pattern; (2) truncated or non-truncated level stress forms; and (3) non-truncated forms with initial main stress. Developmental trends in these patterns are presented in Figure 3.

The results supported Fikkert’s stages of stress development in SWŚ words. Truncated forms with stress shift (i.e. SW forms) were most prevalent in the younger children’s productions (22-month-old children), suggesting that these children were around stage 2 of stress acquisition. They also produced a large number of one-syllable truncations, consistent with Fikkert’s stage 1 of stress acquisition (see Table 3). Examples of two-syllable forms with stress shift are shown in (9).

Table 3. Mean proportions of production patterns in SWŚ words

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>N*</th>
<th>Cořb</th>
<th>S</th>
<th>SW</th>
<th>WS</th>
<th>Lev</th>
<th>SWŚ</th>
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<tbody>
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<td></td>
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<tr>
<td>22</td>
<td>12</td>
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<td>0.25</td>
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<td>0.12</td>
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<tr>
<td></td>
<td></td>
<td>(0.23)c</td>
<td>(0.32)</td>
<td>(0.28)</td>
<td>(0.25)</td>
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<td>(0.14)</td>
</tr>
<tr>
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<td>0.26</td>
<td>0.10</td>
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<tr>
<td></td>
<td></td>
<td>(0.27)</td>
<td>(0.21)</td>
<td>(0.16)</td>
<td>(0.11)</td>
<td>(0.12)</td>
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<tr>
<td>34</td>
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<td>0.14</td>
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<td>(0.25)</td>
<td>(0.26)</td>
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<tr>
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<td></td>
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<td>(0.22)</td>
<td>(0.33)</td>
<td>(0.15)</td>
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<td>(0.13)</td>
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<tr>
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<td>(0.11)</td>
<td>(0.22)</td>
<td>(0.15)</td>
<td>(0.37)</td>
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</tr>
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</table>

* N = number of individual proportion scores.
* Coř = correct rhythmic productions; S = one-syllable truncations; SW = two-syllable truncations; WS = two-syllable truncations without stress shift; Lev = truncated and non-truncated forms with level stress; SWŚ = non-truncated forms with stress shift.
* Standard deviations are indicated in parentheses.
Figure 3. Developmental trends in production patterns of SW$S$ words.

(9) **KANgaROO** /kæŋgərʊ:/  
    22f1 [wáwò] (I)  
    22m3 [kæŋwʊ] (I)

**CHIMpanZEE** /tʃɪmˈpænzə:/  
    22f1 [nɪrɪ:] (I)  
    22f3 [tʃɪˈnɪ:] (I)

**BEneSSEE** /bɛnəsɪː/  
    22f3 [bɛsːi] (I)  
    22m3 [bɛsiː] (I)

**DOpaTOO** /dɔpətʊː:/  
    22f3 [dádʊ] (I)  
    22m2 [bátʰʊ] (I)

Truncated and non-truncated forms with level stress were most frequent in the 28-month-old children’s productions, suggesting that these children were around stage 3 of stress acquisition. Examples are shown in (10).

(10) **KANgaROO** /kæŋgərʊ:/  
    28f1 [kæŋɡəwʊ.ə] (S)  
    28m3 [kʰɪɡrʊ] (S)

**CHIMpanZEE** /tʃɪmˈpænzə:/  
    28f1 [zɪpəzɪ] (I)  
    28f1 [tʃɪmˈfɪzɪ] (S)

**BEneSSEE** /bɛnəsɪː/  
    28f3 [bɛsːi] (I)  
    28m1 [jɛsːɪ] (I)

**DOpaTOO** /dɔpətʊː:/  
    28m1 [jɑpʰʊ] (I)  
    28m3 [tɑbə dú] (I)

Non-truncated forms with incorrect stress were most prevalent in the older children’s productions, suggesting that these children were at stage 4 of stress acquisition. Examples are presented in (11).

(11) **KANgaROO** /kæŋgərʊ:/  
    34f2 [tʰɛndzərʊ] (S)  
    [tʰɛdʒərəl] (S)
Nevertheless, there were two findings that were not consistent with Fikkert’s analysis. First, truncated forms without stress shift (i.e. WS forms) were frequently attested in the data. They were almost as frequent as SW forms in the 22-month-old productions and were also present in the older children’s speech (see Table 3). Examples are shown in (12).

These forms do not appear to be an artifact of imitated speech, because they were observed in spontaneous and imitated productions. Nor are they unique to the current set of children, because other researchers have documented similar patterns in children’s productions of SWS words (Wijnen et al., 1994). These forms are also not consistent with Fikkert’s template mapping account of stress errors, because if two-syllable trochaic forms result from mapping to a single trochaic template, two-syllable iambic-like forms presumably result from mapping to an iambic template. However, having access to both a trochaic and an iambic template seems an unnecessary complication for the acquisition of stress. Alternatively, these forms may reflect mapping to an expanded prosodic template (i.e. a two-feet template) which has already set the main stress parameter to its marked setting. Thus, these forms may represent a more advanced stage of stress development, than the two-syllable trochaic forms. However, it is unlikely that the 22-month-old children, who appear to be operating around stage 1 to 2 of stress acquisition, should also be operating at the later stages of stress acquisition.

The second finding that was not consistent with Fikkert’s analysis was that, in addition to the level stress forms, 28-month-old children displayed a high proportion

6 Productions of the word CHIMpazEE are complicated by the two alternative pronunciations of this word in American English: one with primary stress on the medial syllable and the other with primary stress on the final syllable. Some of the children’s productions also contained stress shift to the medial syllable. This pattern may either be a correct production or it may represent quantity-related stress shift due to the heavy medial syllable. The latter possibility was considered the most likely because all parents of children used the SWS pronunciation, and the only pronunciation children heard during the recording session was SWS. Nevertheless, it cannot be ruled out that exposure to the alternative pronunciation may be responsible for some of the ‘stress errors’ in CHIMpazEE.
of rhythmically correct forms—that is, non-truncated productions with the correct target stress pattern. In the novel word condition, 0.43 of the 28-month-old productions were rhythmically correct, in comparison to 0.10 of the 22-month-old and 0.23 of the 34-month-old productions (see Table 3). A similar trend was observed in the real word condition. In view of the greater tendency of 28-month-old children to display stress errors, the high degree of accuracy with SWS words is striking.

(13) KANgaROO /kæŋɡərʊ:/ 28f1 [kæŋɡərubuː] (I)
28f3 [kʰɛŋɡərwuː] (S)

CHIMPanZEE /tʃɪmpənzɪː:/ 28f1 [nɪɲɛnzɪː] (S)
28f3 [tʰɪmsɪː] (I)

BEneSSEE /bɛnəsɪː:/ 28f3 [vɛnəsi] (I)
28ml [θɛnəsis] (I)

DOpaTOO /dɔpəˈtuː/:
28m1 [təpəˈtuː] (I)
28m3 [dəpəˈtuː] (I)

The most likely explanation for both of these findings is that they reflect the same trends that were observed in SWS and SWW words, suggesting that children pass through a stage of final syllable stress due to quantity-sensitivity and failure to apply extrametricality. The fact that the 28-month-old children displayed the highest proportion of rhythmically correct forms in SWS words, and also displayed the greatest tendency to shift stress in SWS words and in some SWW words, is consistent with this hypothesis. The WS forms, rather than reflecting mapping to a single template, may reflect mapping to two templates, with final-syllable main stress resulting from failure to apply extrametricality and application of the main stress rule.

On the other hand, the occurrence of forms with final stress may simply also point to the lexicalization or memorization of stress. Children as young as 22 months appear to have the phonetic skills to produce word-final stress, and may produce marked forms in their spontaneous and imitated productions a certain proportion of the time.

The pattern observed in 34-month-old children—that is, incorrect stress in non-truncated productions of SWS words, is consistent with their eventual acquisition of final-syllable extrametricality. Subjects in this age group shifted stress less frequently to the final syllable of SWS and SWW words, also consistent with their procurement of extrametricality.

Stress errors in WSW words

Table 4 shows the mean proportions of productions patterns in novel and real WSW words. Observed patterns in WSW words (e.g. taKEdo/takēdo/) were: rhythmically correct forms (e.g. [dʌktʰɛdɔ]; one-syllable truncations (e.g. [dʌː]; two-syllable truncations with trochaic stress (e.g. [tʰɛdə]; truncations with level stress (e.g. [ɡɛdə]); non-truncated forms with initial or level stress (e.g. [tʰɛɡə], [ɡɑkʰɛjə]) and incorrectly stressed truncated and non-truncated forms (e.g. [tʰɛdə], [tʰɛdə]).

In Fikkert’s analysis, stress errors in WSW words occur at stage 3 when children’s prosodic templates expand to include two feet but the main stress parameter has not been set. The result is level stress on non-truncated productions (i.e. SSW forms). Prior to stage 3, children’s productions consist of truncated SW forms, consistent
with the mapping of two syllables from the target form to a single trochaic template. Following Fikkert, the data were organized according to the categories: (1) truncated SW forms; (2) non-truncated level stress forms; and (3) correct rhythmic forms. The proportions of production patterns across age are shown in Figure 4.

Of all the stress patterns examined, results with WSW words revealed the most robust developmental trends. The youngest age group produced the highest proportion of truncated forms and the lowest proportion of correct rhythmic forms; the reverse was true of the oldest age group. In light of Fikkert’s stages the 22- and 28-month-old children are around stage 2 in their rhythmic development of WSW words, because the majority of their productions are truncated; the 34-month-old children are probably at stage 3–4 because they produce both level stress and correct production patterns.

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**Table 4. Mean proportions of production patterns in WSW words**

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>N&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Cor&lt;sup&gt;b&lt;/sup&gt;</th>
<th>S</th>
<th>SW</th>
<th>SS</th>
<th>SSW</th>
<th>Incor</th>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>12</td>
<td>0.23 (0.36)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0</td>
<td>0.38 (0.40)</td>
<td>0.07 (0.17)</td>
<td>0.07 (0.11)</td>
<td>0.11 (0.29)</td>
</tr>
<tr>
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<td>0</td>
<td>0.22 (0.33)</td>
<td>0.01 (0.04)</td>
<td>0.10 (0.18)</td>
<td>0.08 (0.16)</td>
</tr>
<tr>
<td>Real</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.06 (0.20)</td>
<td>0.11 (0.24)</td>
<td>0.63 (0.32)</td>
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<td>0.05 (0.12)</td>
<td>0.08 (0.21)</td>
</tr>
<tr>
<td>28</td>
<td>18</td>
<td>0.23 (0.38)</td>
<td>0</td>
<td>0.50 (0.41)</td>
<td>0.12 (0.21)</td>
<td>0.05 (0.14)</td>
<td>0.10 (0.25)</td>
</tr>
<tr>
<td>34</td>
<td>18</td>
<td>0.55 (0.43)</td>
<td>0</td>
<td>0.35 (0.43)</td>
<td>0.02 (0.05)</td>
<td>0.07 (0.15)</td>
<td>0.01 (0.04)</td>
</tr>
</tbody>
</table>

<sup>a</sup>N = number of individual proportion scores.

<sup>b</sup>Cor = correct rhythmic productions; S = one-syllable truncations; SW = two-syllable truncations; SS = truncations with level stress; SSW = non-truncated forms with initial or level stress; Incor = truncated or non-truncated forms with incorrect stress.

<sup>c</sup>Standard deviations are indicated in parentheses.

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**Figure 4. Developmental trends in production patterns of WSW words.**
rhythmic forms. Nevertheless, level stress non-truncated patterns were relatively rare in the data overall, and other types of stress errors were also present. For example, 28-month-old children produced approximately 20% of productions with ‘unexpected’ stress shift patterns. Examples of these are presented below.

There were two main types of error patterns not observed in Fikkert’s data. Truncated forms were often produced with level stress rather than a trochaic pattern.

There were also truncated and non-truncated forms with final stress.

The presence of truncated forms with level or incorrect stress is quite unexpected because truncations of WSW words fit neatly into a trochaic template. If children are biased to produce trochaic forms in their productions, as has been suggested (Allen and Hawkins, 1979, 1980; Wijnen et al., 1994), it is surprising that they deviate from this pattern. These stress errors may again reflect the trends present in the SWS and SWW words, suggesting that children pass through a stage of final syllable stress, either due to awareness of quantity-sensitivity, lack of extrametricality, or due to a combination of these factors. Children may perceive the final syllable of WSW words as having some degree of stress due to the full vowel quality of the final vowel in some words (as in poTAto, toMAto, or taKEdo), or due to cues such as aspiration which occur in ‘unnatural’ pronunciations of these words. For example, parents occasionally pronounced poTAto as [patʰɛtʰo] rather than [patʰejo], offering ambiguous cues as to foot structure. On the other hand, such stress errors may simply be examples of random stress effects, or reflect children’s phonetic immaturity. Children’s inability to reduce unstressed syllables, in general, may create the effect of prominence on the final syllable of WSW words.

The type of stress error observed by Fikkert (i.e. SSW forms) was observed mainly in the productions of the older children, which is not surprising since the majority of the younger children’s productions was truncated. It represented less than 10% of the productions of 34-month-old children, in contrast to 50–60% of productions, which were produced with the correct target stress pattern (see Table 4).

In addition to SSW forms, initial stressed non-truncated forms were present, suggesting that children may experiment with the main stress rule, and on some occasions assign stress to the incorrect syllable. Examples of level and initial stressed non-truncated forms are shown in (16).
Discussion

A detailed analysis of stress errors in English-speaking children’s word productions revealed evidence for stages in stress development, and support for metrical parameters, thereby corroborating Fikkert’s analysis with Dutch-speaking children. There were, however, a number of inconsistencies between Fikkert’s and the present findings. Before I compare the outcomes of these two studies, I consider factors which may have contributed to differences between the Dutch and English data.

One of the most important differences between Fikkert’s and the present study was that this study was based on cross-sectional data whereas Fikkert’s was based on longitudinal data. Cross-sectional testing may not have captured children at the exact stages of development in which stress errors occur. This possibility cannot be discounted because, even in Fikkert’s study, not all children displayed all forms of stress errors, and when they did occur they were often restricted to a narrow period of recording time. Second, Fikkert’s study was based on spontaneous productions, whereas the present study included both spontaneous and imitated productions. Some of the unusual stress pattern effects may have resulted from the use of unfamiliar and/or imitated lexical items. Several studies have shown that unfamiliar words tend to be associated with greater numbers of stress errors than familiar words (Hochberg, 1988; Klein, 1984; Kehoe, 1997). Third, differences between the two studies may have resulted from language-specific differences in the word shapes of English and Dutch. For example, unstressed final syllables in English often contain full vowels or coda consonants (e.g. toMAto, Elephant) whereas unstressed final syllables in Dutch are generally schwa-final. Even slight differences in the linguistic features of the input may influence the strategies of children acquiring stress. Finally, methodological factors related to stress transcription may be responsible for different results. In this study, stress was transcribed using acoustic-perceptual analysis, whereas in Fikkert’s study perceptual analysis was employed.

Despite the disparate methodologies between the two studies, general tendencies in stress pattern development were documented which were analogous to Fikkert’s stages of stress development. The present findings revealed three main stages of stress development:

1. *Trochaic constraint stage*: the productions of the 22-month-old children characterized this period of development. They exhibited a high proportion of one-
and two-syllable truncations consistent with mapping to a single trochaic template. These forms are typical of Fikkert’s stages 1 and 2 of stress development. However, in addition to producing trochaic forms, the younger children produced two-syllable forms with final stress for SWS and SWŠ words, indicating that a trochaic template cannot fully explain stress patterns in early prosodic development (see Kehoe and Stoel-Gammon, 1997).

2. **Experimental stage:** the productions of the 28-month-old children characterized this period of development. They exhibited a high proportion of level and incorrect stress forms, often shifting stress to the final syllable. Stress patterns were consistent with a metrical representation that had already expanded beyond a single foot and with the exploration of many aspects of stress learning such as extrametricality, quantity-sensitivity, and main stress. This period is similar to Fikkert’s stage 3 of stress development.

3. **Consistent stress pattern stage:** the productions of the 34-month-old children characterized this period of development. Children’s metrical representation for this corpus of words appeared reasonably adult-like. They made few errors of stress, except with extreme quantity situations (e.g. CHoDILE) and with SWŠ words. Errors on SWŠ words may now occur because children have established the extrametricality rule and are overgeneralizing it. This period is analogous to Fikkert’s stage 4 of stress development.

Level stress forms indicative of Fikkert’s stage 3 of stress development were not frequently observed in the English data. Incidentally, Pollock, Brammer, and Hagerman (1993), who also examined stress errors in English-speaking children, did not find a high proportion of level stress forms. In my own experience level stress is a relatively precarious perceptual category, and is subject to low reliability among transcribers. Thus, the different findings between the two studies—the increased prevalence of incorrect forms in the present data and level stress forms in Fikkert’s data—may stem from methodological factors in stress transcription. One transcription system may have been biased to perceive differences in stress, whereas the other may have been biased to perceive similarities in stress. However, if these findings do reflect real differences between Dutch- and English-speaking children, the implication is that English-speaking children acquire the ability to apply main stress earlier than Dutch-speaking children. What leads to this precocity is difficult to ascertain, but may reflect peculiarities of the stress systems of Dutch and English.

The results suggest that the parameters of metrical theory do play a role in children’s stress development. A summary of evidence for metrical parameters is provided below:

**Foot-type and directionality of parsing**

The majority of error patterns were consistent with a trochaic stress foot parsed from right to left. In the case of foot type, two-syllable truncations were predominantly trochaic in form, and non-truncated productions of SWS and SWŠ words were consistent with a prosodic representation containing one bisyllabic bimoraic foot and one monosyllabic bimoraic foot, possible foot-types in a moraic trochaic system, e.g. (X .) (X). Independent forms of evidence such as pause between the second and third syllable of non-truncated productions of SWS words, present in a number of children’s productions (e.g. [tʰi pi dʒi] for CHIMpanZEE) supports this
metrical representation. Interestingly, there was one child in this study who appeared to operate with an iambic template, suggesting that children may experiment with foot-type at certain developmental periods (Kehoe, 1996).

In the case of directionality of parsing, evidence came from truncation patterns showing that children’s earliest truncations consisted of the stressed syllable or SW unit on the right side of the word (Fikkert, 1994). For example, children produced forms such as [wu:] for *KANgaROO* or [khád0] for *AvoCAdo* (see Kehoe and Stoel-Gammon, 1997). It was less easy to find evidence for directionality from children’s stress errors because the majority of words in the corpus contained initial stress, thus not allowing a clear test of left or right directionality. One possible source of evidence could be children’s non-truncated productions of WSW words, which in most cases were rhythmically correct. There were few stress errors of the type SWW or SWS, which might be expected if children apply a trochaic foot from the left side of the word rather than the right.

**Quantity-sensitivity**

Children displayed stress errors consistent with quantity-related factors. The youngest children in the study frequently shifted stress to final syllables that were heavy. Fikkert noted that Dutch-speaking children treat closed syllables as heavy. English-speaking children appeared to treat syllables with tense vowels or diphthongs as heavy. They treated some closed syllables as heavy (e.g. the final syllable in *OCtopus*) but not all (e.g. *Elephant*), suggesting that this was not the main cue for quantity.

**Extrametricality and main stress rule—End Rule Right**

The tendency of the 28-month-old children to shift stress to the final syllable is consistent with their lack of acquisition of extrametricality and with their use of the main stress rule, End Rule Right. The increased proportion of stress errors in SWSW compared to SWSW words in Kehoe’s (1994) study is also consistent with employment of End Rule Right (see Kehoe, 1997). The tendency of the 34-month-old children to produce word-initial rather than word-final stress in their productions of three-syllable words is consistent with their eventual acquisition of extrametricality and retainment of End Rule Right.

The nature of the data set, being cross-sectional rather than longitudinal, did not permit a detailed determination of default settings for parameters. If anything, the findings were most consistent with the following default settings: foot-headedness [Left], directionality of parsing [Right to Left], main stress [Right], and extrametricality [No]. The only parameter that appeared to be reset from its default position was extrametricality. These values are consistent with Fikkert’s findings with the exception of extrametricality, where Fikkert employs a different theoretical rationale. Archibald (1995), after re-analysing Spanish acquisition data, hypothesized that the default setting for extrametricality was [No], more in keeping with the present findings. The default setting for quantity-sensitivity is not indicated because the youngest children in this study already showed evidence of quantity-sensitivity. Fikkert’s results, which are based on even younger children, suggest that the default setting of quantity-sensitivity is [No].

It must be pointed out that, while many of the stress errors suggested the relevance of metrical parameters, some of the stress errors were less consistent with
metrical theory and appeared to reflect the influence of articulatory focus, motoric immaturity, or simply random factors (see Kehoe, 1997). Furthermore, one of the most striking aspects of the study was that children were extremely accurate in stress placement, and in the majority of productions did not produce stress errors. Thus, it must be conceded that a variety of factors, including lexicalization, play a part in early stress development. This need not obviate the role of rules (or parameters) since the presence of systematic patterns provides evidence that, when required, rule-based learning is employed.

Recently, linguistic theory has moved away from conceptualizing phonological processes in terms of rules but rather in terms of constraints that operate on output forms (McCarthy, 1995; McCarthy and Prince, 1993, 1995; Prince and Smolensky, 1993). The ordering of constraints forms the basis of a powerful new research programme, known as optimality theory. Given these new directions in linguistic theory, prosodic phenomena such as stress and truncation have received alternative explanations based on constraints (Benua, 1995; McCarthy, 1995; Pater, 1995; Pater and Paradis, 1996). A re-analysis of stress in terms of constraints does not render the present findings less significant, since the insights on which metrical phonology are based are directly translatable to constraint-based theory. Instead of rules or parameters that refer to foot size, foot-headedness, quantity-sensitivity, and main stress, constraints refer to these mechanisms (e.g. FtBin, RhType, Weight-to-Stress, Edgemost). Certain parameters do receive different treatments in optimality theory—for example, extrametricality and directionality of parsing—and it may well be that the handling of these aspects using constraints results in a superior analysis. (See Prince and Smolensky, 1993, for a discussion on how the extrametricality effect can be derived from constraints that apply to the form and alignment of prosodic structure.) Further research is necessary to determine whether constraint-based theory can account for the stress error patterns in the English data.

**Conclusion**

An in-depth analysis of stress errors in English-speaking children’s word productions revealed support for metrical theory. Findings showed general stages in stress development and stress errors consistent with the setting of metrical parameters. The results were in agreement with many aspects of Fikkert’s theory of stress acquisition, although there was no convincing support for all stages of stress acquisition, and there were stress errors in the data not present in Fikkert’s analysis. The disparities between the two studies may stem from differences in research methodology, or from differences in the linguistic characteristics of Dutch and English. The findings underscore the importance of an integrated approach to linguistic theory and acquisition data in phonological development.

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