English-Speaking Children's Knowledge of Stress Patterns*

Oh, Eunhae

차 례

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Ⅰ. Introduction

For many decades, researchers have attempted to understand how children acquire an adult-like phonological system and what changes occur in the mechanisms of phonological acquisition as their processing capability develops. Children's phonological knowledge is known to mature as children gain more experience, but what do infants start from as they begin to attend to the ambient language? Pierrehumbert(1994, 2003) emphasizes the contribution of lexicon or lexical feedbacks on the language acquisition.

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Specifically, the combination of 'bottom-up' learning from the adults' speech stream and generalization of patterns found in the lexicon has been suggested to initiate the development of phonological knowledge. The significant role of a lexicon in child phonology can be also found in an earlier study by Ferguson & Farwell (1975). They suggested that children construct phonological generalization from the input and gradually refine their phonological information represented in the emerging lexicons (see also, Beckman & Edwards, 2000; Bybee, 2001; Keating, 1988).

The notion of a child generalizing patterns and building on phonology emerging from the lexicon should be understood in the light of language specificity. There are generalizations that apply across all units and can be abstracted without reference to conceptual units (e.g., rhythm patterns), and generalizations that are made more specifically over bounded units (e.g., phonotactics, which references word boundaries). For example, Lindblom(1992) suggested phonemes emerging as a function of the acquisition of minimal pairs while Beckman and Edwards (2000) argued that the whole word-sized units bootstrap the language acquisition. Redford and Miikkulainen (2007) proposed that the notion depends on reference to syllable structure as well as word boundaries (Redford, 2007; Redford, 2008). Despite the distinction between patterns abstracted without reference to units and patterns that require a segmentation of the speech stream, and (sometimes) associations with meaning, the theoretical framework and the general notion of the current study is that phonology emerges from the lexicon during acquisition. Especially, the current study particularly focuses on children's acquisition of stress patterns in English on the basis of the emerging theoretical framework.

First, in order to better understand the aspects of the acquisition of lexical stress, factors influencing main stress placement in native English speakers should be accounted for. First, English is a quantity sensitive language, meaning that stress assignment follows in part from syllable weight. Stress placement in English is correlated with syllable weight. Heavy syllables, which have either long vowels or final consonant clusters, are more likely to have stress than light syllables (Hayes, 1995). The significant role of syllable weight found in infants can be explained in line with the heavy contribution of prominent syllable (i.e., those with long vowels, low vowels, high tones, or sonorant coda consonants) in adults' stress placement (Chomsky & Halle, 1968; Hayes, 1982). Guion and colleagues (Guion, Clark, Harada & Wayland, 2003) investigated factors affecting stress placement in English. On the assumption that speakers of English learn an association between heavy syllables and stress, they manipulated disyllable non-words that share similar stimulus structure but differ in vowel length or the number of coda consonants (e.g., CVV.CVCC vs. CV.CVCC, CV.CVC vs. CV.CVCC). The results of the stress placement of forty non-words produced by seventeen adult English speakers showed that syllables with long vowels, but not coda consonant clusters, were most likely to receive main stress. The indication was that English-speaking adults were sensitive to syllable weight, and especially to vowel length, when assigning stress to non-words.

In English, the most frequent type of foot structure is disyllabic with the first syllable receiving main stress (i.e., a trochee) (Culter, & Carter, 1987). As a result, early sensitivity to the specific prosodic characteristic has been observed in infants' bias toward trochaic stress pattern. For example, Jusczyk, Culter and Redanz (1993) found an emergence of the trochaic bias between 6 and 9 months of age in English-learning infants. In their study, 9 month-old infants particularly showed a stronger preference for English words with trochaic than iambic stress patterns even in the absence of segmental information (i.e, low-pass filtered). Also, Jusczyk, Houston, and Newsome (1999) conducted a headturn preference procedure on twenty four American infants who were 7.5 months old. They examined whether infants attend more closely to a trochaic than an iambic stress pattern and found that while the infants demonstrated the ability to segment trochaically stressed words, they missegmented iambically stressed words (e.g., 'guitar is' as 'taris').

Moreover, the emergence of trochaic preference in early age was found only when the infant's native language is prosodically trochaic. In Höhle, Bijeljac-Babic, Herold, Weissenborn, and Nazzi (2009), the effect of rhythmic properties of the native language was explored with German- and French-learning infants at 6 months. 24 German-learning and 24 French-learning infants listened to the same CVCV word stressed on either the first or the second syllable. The orientation times for each stimulus were recorded, using the headturn preference procedure. The results showed that a strong preference for trochaic sequences was found for German 6-month-olds, but not for French 6-month-olds. The authors argued that the SW sequence is likely to be acquired as the rhythmic unit for infants learning stress-timed language (see also, Houston, Jusczyk, Kuijpers, Coolen & Cutler, 2000 for German and Dutch). Similarly in Pons and Bosch (2010), Spanish-learning infants listened to CVC.CV and CV.CVC disyllabic non-words with main stress either on the first or second syllable, and the average looking times for the two structure types were compared. For CVC.CV words, infants looked significantly longer to the trochaically stressed words and iambic words, whereas CV.CVC words showed significantly longer looking times for iambically stressed words. The results were interpreted to suggest that infants who were exposed to Spanish (stress-timed language) make heavy use of lexical knowledge to determine stress, and particularly syllable weight is a significant factor affecting stress placement. Contrary to the universal 'trochaic bias' proposed by Allen and Hawkins (1979, 1980), the emergence of the trochaic bias in stress-based languages suggests that children abstract stress patterns from the familiar rhythmic structure of the lexicon.

An extensive literature on weak syllable deletion in 2-year-olds also suggests that young children acquire a strong-weak or trochaic stress pattern before they acquire a weak-strong or iambic stress pattern (Gerken, 1991; 1994; Kehoe, 2000; McGregor & Johnson, 1997; Schwartz & Goffman, 1995). Gerkin (1996) noted that it is not word-initial syllables but unfooted syllables that are susceptible to omission. In other words, syllables that did not conform to the S(trong)-W(eak) foot structure, as the second weak syllable in a SWWS pattern, are likely to be deleted in infant production. The preference for trochaic words is even more evident in older children. In Wood's (2006) study, 4 and 5 year-old pre-schoolers were asked to identify mispronounced disyllabic words that had been altered in terms of the location of main stress and vowel quality. The children were shown to have more difficulty indentifying the mispronounced words that had their metrical stress pattern reversed (i.e., strong-weak to weak-strong pattern) than words that were manipulated in other ways. The simplest explanation for the early acquisition and strong bias of trochaic patterns can be attributed to their prevalence in English: trochaically stressed words are much more common than iambically stressed words (Cutler & Carter, 1987). As noted earlier, however, a lexical frequency explanation for the early acquisition of trochaic stress does not imply that stress patterns remain tied to lexical items. Rather, the argument is that stress patterns are abstracted from the lexicon, just as other aspects of the phonology are (Beckman & Edwards, 2000; Ferguson & Farwell, 1975; Lindblom, 1992; Redford & Miikkulainen, 2007).

The second correlate to stress placement in adult English is lexical class. Disyllabic nouns in English are usually trochaically stressed, while disyllabic verbs are more often iambically stressed (Kelly & Bock, 1988). Adult native English speakers also appear to be sensitive to the lexical classes of noun and verb in assigning main stress. In Guion et al. (2003), participants were asked to produce non-words with varying syllable structure once in the noun phrase "I'd like a __" and once in the noun phrase "I'd like to __". The goal was to investigate whether native English speakers are more likely to assign main stress on the first syllable when produced in a noun phrase than a verb phrase. In accordance with the pattern that disyllabic nouns in English are more likely to have first syllable stress than disyllabic verbs (Chomsky & Halle 1968, Liberman & Prince, 1977; Kelly & Bock, 1988; Sereno, 1986; Sereno & Jongman, 1993), the results showed that the effect of lexical class was significant for all stimulus structures with nouns having more main stress on the first syllable than verbs. In Sereno and Jongman (1995), speakers' knowledge of the systematic relation between grammatical category and stress pattern was investigated. The authors presented disyllabic words that are frequently used as either noun or verb forms but do not exhibit changes in stress placement (e.g., answer, design). The goal was to discover whether speakers would produce any systematic acoustic differences between the two grammatical forms. Sixteen grammatically ambiguous disyllabic words were produced in both noun and verb contexts by 5 native English speakers. The results revealed that words with high frequency of occurrence as nouns were more likely to show longer duration and higher amplitude on the first syllable than those that were more frequent as verbs. The study suggested that grammatical information plays an important role in determining stress placement. Since the ability to abstract patterns related grammatical information (i.e. noun vs. verb) could only come from having acquired the relevant nouns and verbs and not from the trochaic pattern, investigating older children whose lexicons are large enough for robust lexical categories to have developed may provide insight into children's lexical achievements which is otherwise difficult to assess in early childhood.

The argument that children acquire an adult-like phonological system based on generalizations over the lexicon predicts that the acquisition of phonological knowledge will depend on the size of a child's vocabulary. Children with larger vocabulary are more likely to have encountered multiple items with uncommon stress patterns than children with smaller vocabulary. Several studies have argued that an increase in vocabulary size relates to the child's ability to make more robust phonological generalizations (Beckman, Munson & Edwards, 2007; Edwards, Beckman, & Munson, 2004; Vihman, 1996). Studies on the relationship between accuracy on non-word repetition and vocabulary size have also supported the effect of vocabulary acquisition on phonology (Frisch, Large & Pisoni, 2000; Gathercole, Hitch, Service, & Martin, 1997; Gathercole, Willis, Emslie & Baddeley, 1992). In Frisch, Large and Pisoni (2000), typically developing children were more likely to judge non-words with low-probability sequences to be word-like than children with specific language impairment (SLI), who generally have smaller vocabulary size. Similarly, Edwards, Beckman and Munson (2004) examined the association between the effect of sublexical sequence frequency and child's vocabulary size (measured by both Peabody Picture Vocabulary Test-III for receptive, Expressive Vocabulary Test for expressive vocabulary size) on repetition accuracy. The result revealed that both measures of vocabulary size were better predictors of production accuracy than age. After all, children need to be exposed to more vocabulary in order to build up a detailed phonetic representation and higher level of phonological sensitivity.

Ⅱ. The Current Study

There is ample evidence to suggest that when children reach school age they learn to command a wide variety of English stress patterns (Goffman, 2004). The developmental pattern in the acquisition of unstressed syllables can be explained by children's acquisition of more complex prosodic templates (Kehoe, 1999/2000). Children learn to assign stress in an adult-like manner, but what is not clear is whether children are sensitive to the different phonological and lexical factors that condition stress assignment in adult English. Most previous research has focused on infants' knowledge of prosodic and phonological properties of the native English and how this information is gained in the course of their speech development. The current study investigates the relatively less explored school-aged children whose realization of lexical stress is not yet fully developed but who have gained sensitivity to diverse lexical stress patterns. As knowledge of lexical class is likely to be employed in older children's production, investigating school-aged children allows more rigorous test on our hypothesis.

The overarching goal is to examine the effects and possible changes in the factors conditioning stress placement in school-aged children's speech. Specific hypotheses to be investigated are: (a) the association between syllable weight and stress acquired before association with lexical class; (b) the association between syllable weight and stress not dependent on segmentation of the speech stream, and thus not on vocabulary size; (c) the association between stress pattern and lexical items tied to lexicon, and thus a predicted relationship between vocabulary size and the abstraction. With vocabulary size shown to be a strong predictor of overall structural patterns of words, we might also predict that the acquisition of stress patterns would depend on the size of a child's vocabulary. Children with larger vocabularies are more likely to have encountered multiple items with uncommon stress patterns than children with smaller vocabularies. Furthermore, younger children with small lexicon might be expected to assign stress based on syllabic structure before assigning stress based on lexical class. Such a developmental sequence follows the assumption that children are provided with early and frequent evidence of the correlation between vowel length and stress, and that children must acquire a critical mass of lexical items before lexical classes can emerge (Li, Farakas & MacWhinney, 2004). Children are also likely to acquire the less frequent iambically stressed verbs later than the more frequently used monosyllabic verbs, and so may not have access to the generalization that disyllabic verbs are preferentially stressed on the second syllable until late middle-childhood or whenever children begin to acquire these less frequent verb forms.

To test the hypotheses, the current study examined preschool children's (approximately from 5 to 8 years old) production of two-syllable non-words. Although children's productive phonology appears adult-like by the age of 8 (Stoel-Gammon, 2011), preschool children still demonstrate significant acoustic differences from adults in lexical stress production (Ballard, Djaja, Arciuli, James & van Doorn, 2012). As the aim of the current study is to investigate changes in the factors influencing main stress placement in native English-speaking children as they age, we chose children in the period of early school age whose phonology is still being established. Adapting Guion et al.'s (2003) method, children were asked to blend two syllables into a single word with a tense/long vowel either in the first syllable or in the second syllable (i.e., CVV.CVC/CV.CVVC). First, to examine whether children have acquired prosodic frames for production, children's ability to blend the two syllables was observed. The prediction is that a trochaic bias coupled with knowledge about heavy syllables and stress will lead children to be able to produce CVV.CVC more readily than CV.CVVC. Moreover, as children' ability to blend two sounds into a single word emerges around 5 and 6 years old and completes around the age of 7 (according to Sutherland Phonological Awareness Test by Neilson, 2003), older children were expected to show better performance than younger children. With the successfully blended words, stress placement was coded as having main stress on either the first or second syllable. On the basis of the idea that the patterns are abstracted from the lexicon, tense/long vowels were expected to be the greatest attractors of stress. Finally, we collected children's vocabulary size to predict accurate production of uncommon lexical stress patterns. The Peabody Picture Vocabulary Test (PPVT-4; Dunn & Dunn, 2007) was used to measure children's receptive vocabulary and the raw scores were used to evaluate whether the effects of syllabic structure and lexical class on stress placement varied as a function of vocabulary size. Note, however, that children's PPVT score is used to provide a better look into what is abstracted in the acquired lexicon, but not necessarily how the abstractions are used in the production. The question of how the abstractions will be discussed in relation to children's judgments of where stress occurs (i.e., stress assignment).

Ⅲ. Methods

1. Participants

Four age groups (5, 6, 7, 8 years-old) of American-English speaking children participated in the production study. Each age group was comprised of 10 children and the children ranged in age from 63 months to

99 months (M = 81.73 months; SD = 10 months). All were native American-English speakers, and all were free of speech and hearing problems as determined by parental report and a pure-tone hearing screen. Expressive vocabulary was assessed for all children using the PPVT-4. Raw scores ranged from 99 to 194 (M = 139.42; SD = 16.61). Standardized scores ranged from 94 to 157 (M = 121.38; SD = 11.46).

Five American-English speaking listeners provided judgments of lexical stress. These listeners were all upper-division linguistics majors (3 females, 2 males) who had a clear understanding of lexical stress as a linguistic phenomenon.

2. Materials

Sixteen, two-syllable non-words with different syllabic structures varying in the placement of a tense or long vowel were created, referring to the subset of stimuli used in Guion, Clark, Harada, and Wayland (2003). In Guion et al (2003), the stimuli were designed to determine the effects of both vowel length and coda consonants on the placement of main stress. In the current study, only vowel length was manipulated to avoid too many stimuli which may make children too tired or frustrated to finish the task. Also, only vowel length was found to be the strongest contributor to stress placement in Guion et al. (2003). As shown in Table 1, two types of stimulus structure were used. CVV.CVC words have a long or tense vowel with no coda in the first syllable. The second stimulus type, CV.CVVC words, has a short vowel with no coda in the first syllable and a long vowel with a coda consonant in the second syllable.

A native-speaking female adult recorded each syllable of the two-syllable words in a frame sentence "Now I say _______" with pitch accent and stress. A total of 16 two-syllable non-words listed in Table 1 were recorded in DAT tape with a high quality microphone and were digitized at 22.05 kHz (16 bit). The prerecorded syllables were then removed from the frame sentences and normalized to 50% peak intensity. To ensure that children successfully blended the syllables into a non-word, the prerecorded two isolated syllables were prepared to be presented with an intervening 500 milliseconds inter-stimulus silence. Pilot work with shorter interstimulus intervals indicated that children would repeat the concatenated syllables with equal stress.

Table 1. Non-words speech stimuli varying in stimulus structure

CVV.CVC		CV.CVVC	
bei.let	bei.tes	bi.tous	de.teis
pou.let	pou.tes	de.tous	ki.gin
tai.lin	tai.sin	ki.teis	ni.lit
tu.lin	tu.sin	se.gin	se.lit

3. Procedure

Children were recorded in a child-friendly experiment room. For the production task, they all wore a baseball cap with a wireless microphone clipped on adjacent to their forehead. Participants adjusted the presentation volume to a comfortable level before the task began. To help the children prepare for listening to non-words, the experimenter would say that the two separate sounds the child will be listening to are “alien words”. Then, children were asked to blend the two isolated syllables into a single word so that it sounds more like an English word. Each participant was given some time to concatenate the two separate syllables into a single word before the testing began. For each trial, children heard the randomized prerecorded two syllables three times and then were presented with a noun or a verb frame sentence, "I'd like a __" or "I'd like to __". The noun and verb distinction was made to encode the effect of lexical class manipulation on children's stress placement. When the child successfully blended the syllables, there was a 500ms delay followed by the next two-syllable stimulus presented with a 500ms interstimulus interval. The recording is made onto a Marantz PMD660 Professional solid state recorder.

Children were allowed to listen to the stimuli twice, if needed. The experimenter repeated the trial when the two isolated syllables were not properly blended and produced with an audible gap. If the child was unable to concatenate the syllables into a single word after a couple of trials, the experimenter continued to the next trial.

4. Coding and analysis

The purpose of this analysis was to investigate whether the children show differences in the blending ability between CVV.CVC and CV.CVC words. Higher blending ability for CVV.CVC words is likely to indicate that children have acquired the relevant production frame that is sensitive to syllable weight.

The procedure resulted in 1280 words (40 children x 16 words x 2 frame sentences) for analysis. First, the first author listened to the taped responses that had been removed from the frame sentence and coded them as blended if the child successfully concatenated the two syllables into a word. These items were coded as blended (1) or not blended (0) depending on whether or not the item was successfully produced without inserting a pause between the first syllable and second syllable. Pauses were defined by visual inspection of the waveform associated with each item. Any silent interval intervening between a medial sonorant or fricative consonant and its adjacent vowels was identified as a pause. When the medial consonant was a stop, pauses were identified only when closure duration exceeded 100 milliseconds. This criteria was chosen because it corresponded to an audible boundary. Previous studies have also taken pauses longer than 100 milliseconds to indicate hesitancy between speech units (see Goldman-Eisler, 1958; Lounsbery, 1954).

In addition, responses with a change in the vowel length (e.g., 'dei.tous' for 'de.tous') or an insertion of consonants in the open syllable (e.g., 'des.tous' for 'de.tous') were considered to be unsuccessfully blended. In order to investigate whether children's blending capability can be explained with the predicted variables, logistic regression analyses were conducted. The independent variables included age, PPVT raw score for vocabulary size, stimulus structure (CVV.CVC/CV.CVVC) and lexical class (noun/verb).

Next, children's production of non-words was analyzed in order to examine the factors contributing to stress assignment. Lexical stress patterns were identified only for properly blended words that were also accurate renditions of the two syllables presented for blending. Once improperly blended or repeated tokens were excluded, there remained a total of 1280 items for analysis. These items were extracted from their frame sentences (i.e., "I'd like a___" and "I'd like to____") and presented in random order to the 5 native English-speaking listeners for stress judgments. All 5 listeners were experienced listeners who have worked at the phonetic lab as experimenters. Listeners identified main stress as occurring either on the first or second syllable. Listeners were also given the option of coding the item as having equal stress. Three out of 5 judges agreed on stress placement for 1014. Only items with high inter-listener agreement were included in the analyses on lexical stress.

In order to confirm that tokens with high inter-listener agreement were actually produced in a manner consistent with the main stress judgments, 20% of the tokens judged as iambically stressed and 20% of those judged as trochaically stressed were randomly selected for acoustic measurement. All of the tokens judged as equally stressed were also measured since there were relatively few of these. Duration, intensity, and mean F0 were recorded for the first and second vowels, and then expressed as ratios. One-way ANOVA tests on the ratios indicated that all 3 acoustic measures varied systematically with perceived main stress [duration, $F(2,196) = 13.319$, $p = 0.000$, $\eta p2 = 0.120$; intensity, $F(2,196) = 49.904$, $p = .000$, $\eta p2 = 0.337$; and F0, $F(2,196) = 66.489$, $p = 0.000$, $\eta p2 = 0.404$].

Once all blended items with indeterminant or equal lexical stress were excluded, there remained 974 items for analysis. Five out of forty children's productions were taken out of the analysis as they placed main stress only on the first or the second syllable throughout the entire task. The items were coded as either trochaically stressed (1) or iambically stressed (0). Because majority of the equal-stress responses were produced by younger (< 80 months) than older children, the assumption was that the equally stressed tokens were less properly blended and thus were perceived as unnatural speech sounds compared to those that were identified as iambically or trochaically stressed (Goffman, 2004).

Ⅳ. Results

The current study was designed to examine the effects of age on children's blending ability as well as on the factors determining the placement of main stress. Children's greater ability to blend two syllables into a single sound is taken as an indicator of high level of phonological awareness (Anthony, Lonigan, Burgess, Driscoll, Phillips, & Cantor, 2002) as well as the early acquisition of the production frame with regard to the association between syllable weight and stress. Based on the distributional effects of word frequency in English, the prediction was made that CVV.CVCwordswillshowhigherpercentage of fully blended non-words as well as greater number of main stress on the first syllable than CV.CVVCwords.The predictive strength of lexical class in children was expected to be smaller than that of stimulus structure. Knowledge of lexical class was expected to be employed after acquired large enough lexicons and abstracted stress patterns related to grammatical information (i.e., noun vs. verb). The independent contribution of these factors is assessed in a logistic regression analysis.

In logistic regression analyses, stimulus structure made a significant contribution to predicting stress assignment for children of different ages. Especially, the association between syllable weight and stress was shown to be acquired before the association with lexical class. Regardless of the vocabulary size, both stimulus structure and lexical class were significant predictors. In a separate analysis, children with lower PPVT scores showed a greater effect of stimulus structure and a smaller effect of lexical class than children with higher scores.

In this section, the results of children's blending ability are shown first. An analysis enumerates the effects of four variables, age, stimulus structure, lexical class and PPVT scores on main stress production. In the following analyses, the results of the lexical stress placement are presented with respective focuses on the effects of age and vocabulary size.

1. Blending Ability

Blending ability among all participants ranged from 31% blended to 100% blended. A first analysis investigated the extent to which age, vocabulary size, stimulus structure, and lexical class accounted for whether or not a given stimulus was blended to produce a word-like unit. To examine the magnitude of these four variables' contribution to the prediction of blending ability, binary logistic regression analyses were conducted. As expected, age and PPVT significantly correlates (Pearson's correlation coefficient = .592; p = .00), however the fact that both are significant indicates that they are individually accounting for a significant portion of variance. The highest odds ratio of stimuli structure (Exp (B) = 1.973) indicated that, regardless of age, the odds of a non-word being successfully blended were approximately 2 times greater if it was a CVVCVC than a CVCVVC word. Age-in-months showed a smaller yet significant effect, but the effect of lexical class was not significant. These results are shown in Table 2.

Table 2. Results from a binary logistic regression on blending ability.

(*p < .01)

Predictor variables	B(S.E.)	Wald (df=1)	Sig.	Odds Ratio (Exp(B))
Age in months	.075(.010)	60.470	*.000	1.078
Raw PPVT score	−.023(.006)	14.981	*.000	.977
Stimulus Structure	.680(.153)	19.712	*.000	1.973
Lexical Class	.011(.148)	.006	.941	1.011
Constant	−.995(.705)	1.993	.158	.370

Figure 1, as an illustration of Table 2, shows that blending ability increased with age and that children of all ages were better able to blend stimuli with CVV.CVC structures than stimuli with CV.CVVC structures. However, children younger than 70 months showed significantly lower probability of blended words than older children. Predicted probability was tied based on raw PPVT scores ranged from .83 to .94.

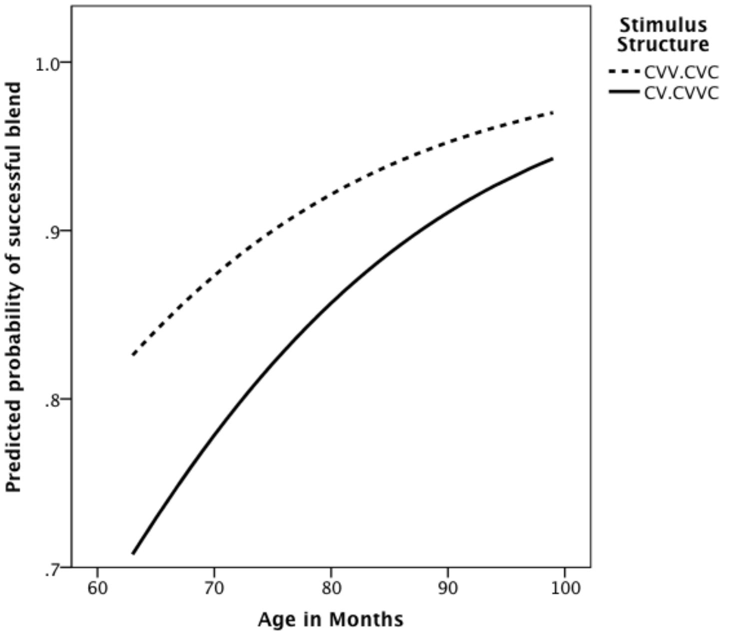

Figure 1. The effects of age and stimulus structure are shown (predicted probabilities derived from a model without PPVT scores or lexical class predictors).

As shown in Figure 1, blending ability increased with age, especially for the CV.CVVC non-words. However, there were also substantial differences in the range of blending ability for younger and older children.

Specifically, we find that blending ability ranged from 31% to 100% in the 5-year-old group (age range = 63 to 76 months), from 63% to 100% in the 6-year-old group (age range = 77 to 88 months), and from 78% to 100% in the 7-year-old group (age range = 89 to 99 months). The substantial differences in range of blending ability made me question whether the same model provided the best account of blending ability for all age groups. To answer this question, the subjects were split into 3, roughly equal, groups based on age. Children in the first group ranged in age from 63 months to 76 months (M = 70.7 months). Children in the second group ranged in age from 77 months to 88 months (M = 82.2 months), and those in the third group ranged in age from 89 months to 99 months (M = 92.9 months). Blending ability was then analyzed within each group as a function of the 4 factors of interest, including lexical class.

Results were that age in months was a significant predictor of blending ability within the youngest and oldest group of children (groups 1 and 3), but not for the group of children in between the youngest and oldest group (group 2). Stimulus structure and raw PPVT scores were significant predictors of blending ability in the younger groups of children (1 and 2), but not in the oldest group of children (group 3). Lexical class did not contribute to explaining any variance in blending ability for any of the age groups.

Comparisons among models based on log likelihood scores indicated that the best fit model with the fewest parameters included age in months, stimulus structure and raw PPVT scores for Group 1(youngest), stimulus structure and raw PPVT scores for Group 2(middle), and age in months and stimulus structure for Group 3(oldest). That is, even though stimulus structure was not a significant predictor of blending ability in Group 3(oldest), the model that excluded this factor was significantly poorer than the model that included it ($X^2(1) = 7.51$, $p < .01$). The results from these models are shown in Table 3.

Table 3. Results from the logistic regression of blending ability for each age group. (*p < .01)

Age Group	Predictor variables	B(S.E.)	Wald (df=1)	Sig	Odds ratio (Exp(B))
Group 1 (youngest)	Age-in-mos.	.135(.025)	29.350	*.000	1.144
	Raw PPVT score	-.037(.011)	11.623	*.001	.964
	Stimulus Structure	.728(.222)	10.747	*.001	2.070
	Lexical Class	-.070(.216)	.105	.746	.932
	Constant	-3.316(2.0)	2.674	.102	.036
Group 2 (middle)	Age-in-mos.	.075(.041)	3.270	.071	1.078
	Raw PPVT	-.032(.011)	8.796	*.003	.968
	Stimulus Structure	.664(.271)	6.004	*.014	1.943
	Lexical Class	.104(.263)	.155	.694	1.109
	Constant	.140(3.235)	.002	.965	1.150
Group 3 (oldest)	Age-in-mos.	-.138(.054)	6.512	*.011	.872
	Raw PPVT	.014(.011)	1.770	.183	1.015
	Stimulus Structure	.657(.356)	3.408	.065	1.928
	Lexical Class	-.058(.342)	.029	.864	.943
	Constant	13.221(4.67)	7.999	.005	551898

2. Lexical Stress Placement

The independent categorical variables of stimulus structure, lexical class and age in months were entered as predictors of the dependent variable of main stress placement. The individual contribution of each variable to the model was obtained using the binary logistic regression analysis as shown in Table 4.

Table 4. Results from a binary logistic regression on stress placement.

(*p < .01)

Predictor variables	B(S.E.)	Wald (df=1)	Sig.	Odds Ratio
Age in months	.016(.008)	3.416	.065	1.016
Raw PPVT score	.002(.005)	.168	.682	1.002
Stimulus Structure	.556(.121)	21.11	*.000	1.743
Lexical Class	.350(.121)	8.399	*.004	1.419
Constant	−1.637(.580)	7.956	.005	.195

A binary logistic regression analysis of lexical stress on all blended words produced by all speakers indicates that only stimulus structure and lexical class are significant predictors. That is, stimulus structure is likely to have the largest individual impact on the prediction of main stress being assigned to the first syllable(trochaic). The odds ratio(Exp (B)) of syllabic structure indicates that the odds of a non-word receiving main stress on the first syllable are 1.7 times greater if it was a CVV.CVC than a CV.CVVC word. The main effect of lexical class made a smaller yet significant contribution to the prediction of stress placement. The odds of a non-word receiving main stress on the first syllable were 1.4 times greater if it was produced in a noun than a verb frame. Although the main effect of age appears to play a relatively smaller role in predicting stress placement compared to the two independent factors, the effect of age is highly significant when raw PPVT is removed which suggests that the PPVT and age share some of the same variance due to a high correlation between the two factors. Although neither age nor PPVT was significant in the overall analysis, they met statistical significance individually if one was removed from the model. Thus, the data was split by age group and then by PPVT score group respectively. Also, age, stimulus structure and lexical class were shown to affect children's assignment of main stress but it is less clear whether these predictors account for the variable realization of lexical stress across all age groups.

First, binary logistic regression analysis was conducted for each age group. Based on the results for blending ability, the prediction was that stimulus structure would affect stress placement in all ages of children while the knowledge of lexical class would be employed later in older children's production. As shown in Table 5, only stimulus structure comes close to accounting for variability in the youngest group of children (Group 1). Raw PPVT scores, stimulus structure, and lexical class are all significant in the next youngest and the oldest groups (Group 2 and 3). The prediction that the effect of lexical class was more likely to be shown in older children than younger children was upheld.

Table 5. Results from the logistic regression of lexical stress placement for each age group. (*p < .01)

Age Group	Predictor Variables	B(S.E.)	Wald (df=1)	Sig.	Odds Ratio (Exp(B))
Group 1 (youngest)	Age-in-mos.	-.004(.027)	.019	.890	.996
	Raw PPVT	.011(.010)	1.18	.277	1.011
	Structure	-.362(.205)	3.12	.077	.696
	Lexical Class	-.172(.204)	.715	.398	.842
	Constant	-.708(1.98)	.127	.722	.493
Group 2 (middle)	Age-in-mos.	.024(.035)	.497	.481	1.025
	Raw PPVT	.024(.008)	8.31	*.004	1.024
	Structure	-.751(.216)	12.0	*.001	.472
	Lexical Class	-.454(.216)	4.41	*.036	.636
	Constant	-4.32(2.66)	2.63	.105	.013
Group 3 (oldest)	Age-in-mos.	.029(.036)	.634	.426	1.029
	Raw PPVT	-.020(.008)	6.37	*.012	.981
	Structure	-.570(.215)	7.02	*.008	.566
	Lexical Class	-.426(.216)	3.88	*.049	.653
	Constant	1.40(2.836)	.242	.623	4.031

Next, the data was split by PPVT score group (low, middle, high). Given that raw PPVT, but not age in months, is a significant predictor for the older groups, the question is whether the size of lexicon better account for the acquisition of stress pattern than age. On the assumption that phonological knowledge is abstracted from the lexicon, an additional question investigated was whether children with larger vocabularies would show different effects of the variables than children with smaller vocabularies. Although lexical development is generally correlated with chronological age, individual differences are likely to abound. Accordingly, children were divided into three groups based on their PPVT scores to predict stress placement from the syllabic structure and lexical class variables. The mean PPVT scores(standard deviation) for the low, middle and high groups were 123(7.43), 139(4.74), 159(12.43), respectively. The results are given in Table 6.

Table 6. Results from the logistic regression of lexical stress placement for each PPVT score group. (*p < .01)

PPVT Score Group	Predictor variables	B(S.E.)	Wald (df=1)	Sig.	Odds Ratio (Exp(B))
Low PPVT Group	Structure	.430(.206)	4.369	*.037	1.538
	Lexical Class	.269(.206)	1.706	.192	1.308
	Constant	.024(.179)	.017	.895	1.024
Middle PPVT Group	Structure	.488(.206)	5.638	*.018	1.629
	Lexical Class	.349(.206)	2.884	.089	1.418
	Constant	−.214(.18)	1.405	.236	.807
High PPVT Group	Structure	.740(.217)	11.666	*.001	2.096
	Lexical Class	.425(.217)	3.847	*.050	1.530
	Constant	−.072(.18)	.152	.697	.930

The results from the logistic regression across children in low and middle PPVT groups showed a significant main effect of stimulus structure. The increasing odds ratio of stimulus structure from the low to high PPVT groups (1.538 < 1.629 < 2.096) indicates its increasing contribution to the prediction of stress placement. The result also shows that only in the high PPVT group did lexical class become one of the primary predictors for stress placement. In other words, stress placement differs between words produced in a noun and a verb frame sentence only for children with large vocabulary size. The effect of lexical class, however, is only shown in words with CVV.CVC structure. As shown in Figure 2, children with high PPVT scores are much more likely to place main stress on the first syllable for CVV.CVC words in a noun frame. Although children show a strong preference for producing stress on tense or long vowels suggesting their early sensitivity to syllabic weight, the figure shows that knowledge of lexical class on stress placement also becomes distinctive for CVV.CVC words with increase in vocabulary size.

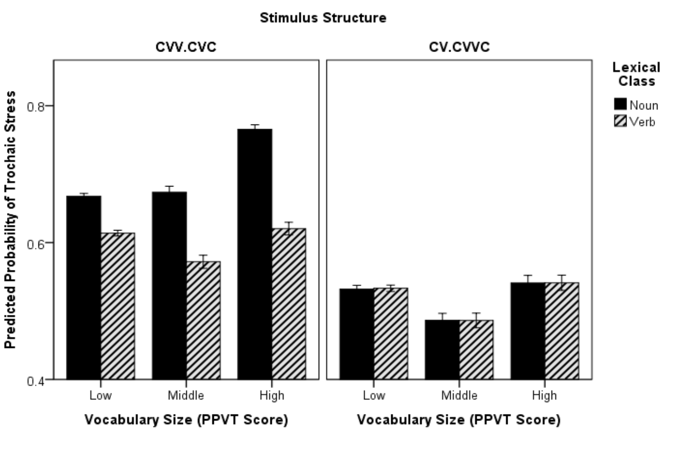

Figure 2. Predicted probability of trochaic stress for CVVCVC(left) and

CVCVVC(right) structure produced in a noun(solid black) and verb(striped) frame by low, middle, and high PPVT score groups.

Ⅴ. Discussion

Overall, the results reported in the current study indicate that children start to assign main stress to non-words on the basis of vowel length. Children were more likely to assign stress on syllables with long or tense vowels than syllables with short or lax vowels. Stimulus structure was shown to affect stress placement in all ages of children, while the knowledge of lexical class was employed later in older children's production. The result conforms to the prediction that children acquire the association between syllable weight and stress before the association with lexical class.

The effect of lexical class was greater in older children than younger children. Older children being able to associate syllable weight with stress indicates that they have gained knowledge about the distributional patterning of lexical class(noun/verb) across the stored lexical items. Still, the main effect of lexical class made a smaller contribution to the prediction of stress placement than stimulus structure (see Table 4) and this is where children differ substantially from adults in that adults were shown to rely more heavily on lexical class than stimulus structure when assigning main stress (Guion et al., 2003). The result indicates that stimulus structure not only takes precedence over but has stronger influence than lexical class in the course of children's development of phonological awareness. Children are known to develop abstract patterns from statistical regularities of lexical input (Aslin, Saffran and Newport, 1998; Saffran 2001), and thus, generalization may be first realized on the phonological level (i.e., stress distributions related to syllabic structure).

The difference in stress placement between words produced in a noun and a verb frame sentence differed only for children with a large vocabulary size. Specifically, the probability of a CVV.CVC non-word produced in a noun phrase receiving main stress on the first syllable increased with vocabulary size (see Table 6). Knowledge of the characteristic stress patterns of nouns and verbs goes beyond the effect of the exposure to frequent prosodic patterns in English. It requires an extensive experience with the distribution of stress across the two lexical categories and it can only be acquired with vocabulary growth. Thus, the relatively greater strength of contribution of lexical class in children with higher PPVT scores suggests that English monolingual children may need a larger lexicon to abstract the higher order stress patterns. Children may not be able to abstract patterns related grammatical information (i.e. noun vs. verb) until their lexicons are large enough for robust lexical categories to have developed.

With regard to children's blending ability, stimulus structure was shown to be the strongest predictor of the variables. The odds of a non-word being successfully blended were significantly greater if it was a CVV.CVC than a CV.CVVC word, whereas the effect of lexical class on blending ability was not significant. The independent contribution of stimulus structure may be viewed in terms of children's acquisition of prosodic frames and early acquisition of the association between syllable weight and stress. Note that children younger than 6 years old were not able to properly blend the two syllables. From the aspect of early form-meaning mappings in word learning and the relationships between comprehension and production, children may not blend syllables if the blended lexical entry is an abstract notion or if it is not stored in the mental lexicon (Plunkett, Sinha, Moller & Strandsby, 1992; Siskind, 1996; Yu, Ballard &

Aslin, 2005). Yu, Ballard and Aslin(2005) argued that the mapping of a phonological form to a conceptual representation is a big challenge that children encounter during word learning. Especially children in their earlier stage of language acquisition are likely to show greater difficulty in blending and producing non-words when no visual context is provided to facilitate the embodiment of word learning. The results on higher blending ability for CVV.CVC words than CV.CVVC words across all ages may be attributed to the fact that children acquire concrete nouns before verbs (Gentner, 1982) and two-syllable nouns are more likely to receive stress on the first syllable than verbs in English.

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Abstract

English-Speaking Children's Knowledge of Stress Patterns

Oh, Eunhae

The developmental patterns of stress placement was examined in a cross−sectional study of native English−speaking children aged 5, 6, 7 and 8 years old. A total of thirty five children produced two−syllabic nonwords of varying syllabic structures in both noun and verb contexts. Children's capability of combining two syllables and the proportion of first syllable stress responses were coded as a function of the developmental patterning of word stress. The results showed a significant effect of syllabic structure on children's stress placement. Lexical class was more likely to be employed in older children with larger vocabularies. The effects of age and lexicon size were discussed in relation to development of stress patterns.

Key Words: Lexical stress acquisition, stress assignment, syllable structure, lexical class, vocabulary size
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이름: 오 은 혜
소속: 협성대학교
주소: 445-805 경기도 화성시 봉담읍 수영로 61-16 한울 신창 비바 패밀리 아파트 112동 203호
이메일: gracey1980@yahoo.com