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ORIGINAL ARTICLE

Native Thai Speakers' Acquisition of English Word Stress Patterns

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Abstract The influence of syllabic structure, lexical class and stress patterns of known words on the acquisition of the English stress system was investigated in ten native Thai speakers. All participants were adult learners of English with an average length of residence in the US of 1.4 years. They were asked to produce and give perceptual judgments on 40 English non-words of varying syllabic structures in noun and verb sentence frames. Results of the production data suggested that syllables with a long vowel attracted stress more often than syllables containing a short vowel and nouns received initial stress more often than verbs. Additionally, regression analyses with the three factors as predictors suggested that Thai participants' pattern of stress assignment on non-words was significantly influenced by the stress patterns of phonologically similar real words. These results were compared and contrasted to those found in previous work with Spanish–English and Korean–English bilinguals.

Introduction

Languages differ not only in their inventory of speech segments (vowels and consonants) but also in their use of different suprasegmental features or prosodic systems such as tone, pitch-accent and stress to signal lexical contrasts. The phonetic properties used to distinguish vowels, consonants, and suprasegmental features also vary from language to language. These differences affect how adult listeners perceive and produce the phonetic qualities that are not represented in their native language (L1), thereby contributing to a detectable degree of foreign accent. A large number of studies have been conducted to examine the production

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and the perception of second language (L2) consonants and vowels by adult L2 learners over the past several decades (see, e.g., Lado, 1957; Richie, 1967; Michaels, 1974; Major, 1987; Flege, 1992; Flege, Munro & Mackay, 1995; Yamada, 1995; Munro, Flege, & Mackay, 1996; Flege, Mackay, & Meador, 1999; MacKay, Flege, Piske, & Schirru, 2001). Recently, however, there has been a growing interest in investigating the acquisition of word stress as part of the L2 prosodic system by adult L2 learners (see, e.g., Davis & Kelly, 1997; Arculili & Cupples, 2003, 2004; Guion, Harada, & Clark, 2004).

Sensitivity to the native language prosodic system begins early in life. Using a non-nutritive sucking technique, a study by Mehler et al. (1988) found that infants could distinguish between utterances in their native language (i.e., French) from those in another language (i.e., Russian) by 4 days of life. DeCasper, Lecanuet, Busnel, Granier-Deferre, & Maugeais, (1994) found that new-born infants preferred listening to the same story read to them in utero than to a new story. Using word segmentation tasks, Jusczyk and colleagues found that 7.5-months-old English-learning infants showed preference toward the dominant stress pattern of English (trochaic, or stress on the first syllable) in their segmentation of two syllable words from continuous English speech (Jusczyk & Aslin, 1995; Jusczyk, Houston, & Newsome, 1999). Interestingly, 9-month-old English-learning infants could also segment words in a foreign language having prosodic patterns similar to English, e.g., Dutch (Houston, Jusczyk, Kuijpers, Coolen, & Cutler, 2000). On the contrary, infants could not reliably segment words in a language with a prosodic system different from that of their native language. Polka and Sundara (2003), for example, found that 8 month-old English-learning infants could not segment French words from a French passage, nor could French-learning infants segment English words from an English passage.

From these studies, it appears that the learning of prosodic patterns of one's L1 emerges very early in childhood. An important question that one might reasonably ask, then, is whether and to what extent a different prosodic system can be acquired in adulthood. Earlier research (e.g., Guion et al., 2004; Guion, 2005) has shown that native speakers of a word level stress language (i.e., Spanish) and phrasal pitch accent language (i.e., Korean) could successfully learn certain aspects of the English word level stress system. The aim of the current paper is to investigate the acquisition of the English stress system by adult L2 learners whose native prosodic system is of a different type from that of English. Specifically, the knowledge of English stress patterns acquired by native speakers of Thai, a tone language, is investigated.

Previous studies on second language acquisition of English stress patterns

Three aspects of knowledge likely to influence the acquisition of English stress patterns among L2 learners are syllabic structure, statistical distribution of stress across the lexical classes of noun and verb, and stress patterns of phonologically similar words. Of these three factors, syllabic structure has been the most investigated.

In English, long vowels (e.g., [iɪ] in *beet*) tend to be stressed more often than short vowels (e.g., [ɪ] in *bit*). An investigation of the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995), for example, indicated that long vowels were roughly twice as likely to be stressed as short vowels (60% of long vowels vs. 35% of short vowels were stressed) (Guion, Clark, Harada, & Wayland, 2003). In addition, syllables with more coda consonants are more likely to receive stress than syllables with fewer or no coda consonants (Chomsky & Halle, 1968; Hayes, 1982). Both vowel length and number of coda consonants were found to affect stress placement on non-words for native English speakers in our previous research (Guion et al., 2003, 2004).

It appears, however, that knowledge of vowel length and coda consonant effects on stress are only partially learned by adult L2 learners of English (Erdmann, 1973; Mairs, 1989; Archibald, 1992, 1993; Guion et al., 2004) whose L1's stress system differed from that of English (e.g., German, Spanish, Polish). Instead, many of these studies reported evidence of a transfer of L1 stress patterns into English. Similarly, syllabic structures appeared to play only a small role in the acquisition of English stress patterns by native speakers of languages whose prosodic systems differ from that of English. For example, Archibald (1997) found that the errors in English stress placement produced by native speakers of tone languages (i.e., Mandarin and Cantonese) and a pitch-accent language (i.e., Japanese) did not seem to be related to syllabic structures. In fact their errors did not have any readily discernable pattern.

The second aspect of knowledge that could be used to facilitate the acquisition of English stress system by English L2 learners is the distributional stress patterns of nouns and verbs. In English, bisyllabic nouns are more likely to have initial syllable stress while bisyllabic verbs are more likely to have final stress (Sereno, 1986; Kelly & Bock, 1988). Importantly, it has been shown that native English speakers were sensitive to this distributional property and that they demonstrated effects of this knowledge in experiments with non-words (Baker & Smith, 1976; Kelly & Bock 1988; Guion et al., 2003) and real words in an onset gating task (Arciuli & Cupples, 2004). Interestingly, L2 learners of English also exhibited knowledge of this distribution patterns. For example, when instructed to use bisyllabic English non-words with either initial or final stress in a sentence, L2 learners of English from a variety of first language backgrounds, having varying ages of acquisition (5–27 years) preferred to use non-words with final stress as verbs and those with initial stress as nouns (Davis & Kelly, 1997). Additionally, Arciuli and Cupples (2003, 2004) found an effect of the distributional patterns of stress across nouns and verbs in speeded grammatical classification and onset gating tasks with groups of non-native English speakers from a variety of language backgrounds. Typically stressed two-syllable nouns and typically stressed two-syllable verbs exhibited a processing advantage in the experimental tasks. In our previous studies (Guion et al., 2004; Guion, 2005), both early and late Spanish–English and early Korean–English bilinguals tended to produce bisyllabic non-words in a noun context with initial stress and in a verb context with final stress, whereas late Korean–English bilinguals did not. Similar effects were also found for stress preference in a perception task.

The third factor that has been shown to influence the acquisition of English stress system is the analogical extension of the stress patterns of phonologically similar known words. It has been found, for example, that both native and non-native speakers of English transferred stress patterns of a known word to the production of a new word, even in cases for which the analogical stress assignment ran counter to predictions made by syllabic structure or lexical class (Baker & Smith, 1976; Guion et al., 2003, 2004; Guion, 2005). The current study examined how and to what extent native Thai speakers who are learners of English relied on the three aspects of knowledge just discussed in the acquisition process of the English stress system.

Thai

Unlike English, Thai, the standard language of Thailand, is a tone language. Thai phonemically distinguishes five lexical tones, namely a low tone ([kʰàː] 'galanga, a kind of aromatic root often used in Thai cooking), a mid tone ([kʰaː] 'to be stuck or lodged in'), a high tone ([kʰáː] 'to engage in trade'), a falling tone ([kʰâː] 'I, servant'), and a rising tone ([kʰǎː] 'leg').

These five tones may be characterized in terms of pitch contour, pitch height, and voice quality. The characteristics of the five tones are schematically presented in Table 1 (Hudak, 1987).

The distribution of these lexical tones is conditioned by syllabic structure. All five tones may occur on syllables ending in a long vowel or a sonorant segment (i.e., m, n, ŋ, w, and j). On the other hand, only the low and the falling tones are allowed in syllables containing a long vowel followed by a non-sonorant segment (i.e., p, t, k), and only the low and the high tones are allowed in syllables containing a short vowel followed by a non-sonorant segment. Lexical tones assigned to English loan words in Thai are also subjected to similar constraints (Gandour 1979). Given the close relationship between syllabic structure, especially of vowel length, and lexical tones in Thai, one might reasonably assume that native Thai speakers will be sensitive to vowel duration in their production and perception of lexical stress in English. On the other hand, consonant clusters are not allowed in syllable-final position in Thai. Therefore, native Thai speakers' sensitivity to this aspect of syllabic structure and its affects on stress patterns may be reduced. Moreover, given that tone is a lexical property and thus has to be acquired item by item, it might be reasonable to assume that native Thai speakers will use similar approach when acquiring the English stress system. Consequently, they may be less likely to abstract stress patterns common across lexical classes of English nouns and verbs and will be more likely to store stress patterns of each individual lexical item being acquired. In turn, these stored stress patterns may be activated and analogically extended to new lexical items to be acquired.

The study

This study was conducted to investigate the question of whether a novel prosodic system could be learned after childhood. To this end, knowledge of the English prosodic system in native Thai speakers who learned English post-puberty was investigated. Participants recruited for this study were relatively inexperience learners of English. As such, the results of the study will shed light on factors influencing the early stages of the acquisition of English stress system by adult L2 learners. Specifically, knowledge of English stress patterns based on syllabic structure, lexical class and analogical extension of stress of known words to new words were investigated. Two experiments were conducted, one assessing production and the other perception of stress patterns. The perception task required only preference judgments, and thus placed fewer demands on the processing system than the production task, which also required formation and production of a non-word. Therefore, it was hypothesized that the two experiments may reveal differential knowledge of stress patterns because of the difference in the nature of the tasks.

Table 1 Characteristics of Thai tones

Tone	Tone mark	Pitch contour	Pitch height	Voice quality
Mid	Unmarked	Level	Medium	Non-glottalized
Low	̀	Level	Low	Non-glottalized
Falling	̂	Contour	High to low	Glottalized (creaky)
High	́	Level	High	Glottalized
Rising	̌	Contour	Low to high	Non-glottalized

Experiment 1: effects of syllabic structure and lexical class in the production of lexical stress

Method

The method for this experiment as well as for the perception experiment (Experiment 2) is the same as that used in our previous research (Guion et al., 2003, 2004; Guion, 2005). The Materials and Procedure sections below provide a synopsis of the method used.

Participants

Ten (eight males, two females) adult native speakers of Thai were paid to participate in the experiment. None of the participants reported being diagnosed with any language or reading disorders and all passed a pure tone hearing screening in both ears from 500 to 4,000 Hz at octave intervals (re: 25 dB HL).

All participants spoke standard Thai as their first language and had lived in the US for an average of 1.4 year (ranges 1 month–7 years) at the time of testing. The age of acquisition[1] as determined by the age of first massive exposure to English when they moved to the US ranged from 14 to 37-years old (mean = 25.3 years). All participants reported using English on a daily basis at the time of the study. On average, they reported using English 63% of the time (ranges = 30%-80%) (see Table 2).

On a 9-point scale, the mean rating of their self-reported English proficiency in reading, writing, speaking, and listening were 6.2, 5.1, 5.7, and 6.2, respectively. In addition, a standardized test of English proficiency, the Test of Adolescent and Adult Language (TOAL), was administered to all participants. Two of the TOAL subtests, those focusing on listening vocabulary (TOAL1) and listening grammar (TOAL2), were administered.

Table 2 Information on the participants

Sex (F/M)	AOA[a]	LOR[b]	Age[c]	TOAL1[d]	TOAL2[e]	Educ.[f]	English use [g]
2/8	25.3	1.7	26.5	12.3	2.7	17.0	63%

[a] *AOA*, Mean age of English acquisition as defined by immersion in an English speaking environment (in years).

[b] *LOR*, Mean length of residence in the US. (in years).

[c] *Age*, Mean age at time of testing (in years).

[d] *TOAL1*, Mean score on subtest 1 of the Test of Adolescent and Adult Language-3 testing listening vocabulary (raw score out of 35 possible).

[e] *TOAL2*, Mean score on subtest 2 of the Test of Adolescent and Adult Language-3 testing listening grammar (raw score out of 35 possible).

[f] *Educ.*, Mean years of education. A high school degree was counted as 12 years, a Bachelor's degree as 16 years, a Master's Degree as 18 years, and a PhD was counted as 20 years. Partial years studying toward a degree were counted up to the maximum for that degree.

[g] *English use*, Mean self-reported estimated overall use of English in the participants' daily life currently.

[1] English is taught as a foreign language beginning in the fourth or fifth grade level in all public schools in Thailand. Therefore, all participants had studied English in a classroom setting for 10–12 years prior to coming to the US. However, most if not all English teachers, especially those at the primary school level are native Thai speakers who were trained in Thailand. Most of these teachers have very little exposure to English produced by native English speakers. As such, the instructional focus in the classroom is on grammar and reading comprehension rather than on pronunciation.

As shown in Table 2, their scores were well below the ceiling score of 35 and were much lower than those of Spanish and Korean bilinguals reported in Guion et al. (2004) and Guion (2005).

An additional proficiency measure that specifically tested the participants' ability to correctly place stress on real English words was also conducted. This test was described in detail in Guion et al. (2004). Briefly, the participants were asked to read 36 English words (see Appendix 1) and rate the confidence of their knowledge of the word's meaning and of their ability to pronounce the word on 5-point scales. Half the words followed the regular stress pattern of English and half did not. The words in the two halves did not differ in frequency of use. The words were coded for correct stress placement. Only words with a rating of 5 on both scales were considered in the analysis.

Table 3 presents the average proportion of correct stress placement of the two word types. Note that a stress placement on known English words with regular stress patterns was much higher than those with irregular stress patterns (90% vs. 72%). Moreover, these scores were lower than those obtained from late Korean–English bilinguals (98% vs. 95%) and Spanish–English bilinguals (98% vs. 96%) in earlier studies (Guion, et al., 2004; Guion, 2005).

Materials

The stimuli consisted of 40 two-syllable non-words presented as isolated stressed syllables. There were four types of non-words, each with a different syllabic structure (see Table 4).

The individual syllables making up the non-words were recorded by a native American English speaker. The same speaker also recorded the phrases "I'd like to" and "I'd like a". The final "to" and "a" were produced in a reduced form (i.e., [tə] and [ə]). The phrase "I'd like to __" will be referred to as the verb frame and the phrase "I'd like a __" will be referred to as the noun frame.

Table 3 Mean proportion of correct stress placements on known real English words

Words consistent with regular stress patterns	Words inconsistent with regular stress patterns
0.90	0.72

Table 4 The non-words used in experiments 1 and 2 (see Appendix 2 for equivalent English spellings for these non-words)

Type 1 CVV CVCC	Type 2 CV CVCC	Type 3 CV CVC	Type 4 CV CVVC
beɪ tɪst	dɛ kɪps	nɪ lɛt	nɪ liːt
tuːkɪps	nɪ gɛpt	dɛ sɪn	dɛ guːt
taɪ gɛpt	kɪ mɪnz	sɛ lɪn	bɪ teɪs
poʊ tɪst	sɛ tɪst	bɪ tɛs	bɪ toʊs
giːkɪps	bɪ bɛkt	sɛ gɛt	kɪ giːn
poʊ bɛkt	sɛ bɛkt	dɛ lɛt	sɛ liːt
tuːmɪnz	dɛ mɪnz	nɪ sɪn	nɪ guːt
taɪ mɪnz	nɪ kɪps	kɪ gɛt	kɪ teɪs
beɪ bɛkt	kɪ gɛpt	bɪ lɪn	dɛ toʊs
giːgɛpt	bɪ tɪst	kɪ tɛs	sɛ giːn

Procedure

The participants were asked to concatenate words of four syllabic structure types (see Table 4), presented as isolated, stressed syllables, into a single word and say it in a frame sentence. Each of the non-words was presented twice, once with the noun frame and once with the verb frame. Two pseudo-randomized, counterbalanced blocks were used, making a total of 80 trials. Each non-word was presented only once in each block. Half of the productions in each block were in the noun frame, half in the verb frame. There was a short distracter task between the two blocks. Participants were given some practice trials using non-test items before the first block.

Stimulus presentation was controlled by software on a personal computer and played over high-quality loud speakers in a sound attenuated room. For each trial, the participants were first presented with a frame sentence. Presentation of the frame was both aural and visual. After a 500-ms delay the two stressed, isolated syllables composing the non-word were presented with a 500-ms inter-stimulus interval. Presentation of non-words was aural only. Participants could replay the trial if they wished. After responding, they pushed a button to continue to the next trial. Responses were recorded on tape for later coding.

The participants were instructed to take the two syllables, keep them in the same order, and make a single word from them. They were instructed to produce all the sounds of the syllables they heard. Additionally, participants were asked to say the word in the carrier phrase that had just been presented. They were asked to say the carrier phrase in the same way they had heard it. If the final word in the frame ("to" or "a") was produced with stress during the practice block, the participant was stopped and corrected. All participants could easily produce the carrier phrase in the desired manner.

Coding and reliability

A trained phonetician listened to the taped responses of the non-words produced by all subjects. Some non-words were produced with segmental content different from that in the stimulus. If the substitution did not change the syllabic structure, the response was counted (e.g., [taɪmɪnz] as [taɪmɪnt]). However, if the substitution did change the syllabic structure (e.g., [sɛtɪst] as [seɪtɪst), the response was counted as missing. Approximately 39% of the responses were discarded because they did not reproduce the syllable pattern presented to the participant. This amount of errors was expected given the participants' low level of proficiency as indicated by their low-TOAL Test scores and their production accuracy of known English words reported above. The most common errors were the omission of the last consonant of the final consonant clusters and the substitution of a lax vowel by a tense vowel.

Non-words that were reproduced accurately (i.e., with the original syllable structures preserved) were coded for first syllable or second syllable stress by a trained phonetician and a native English speaker. Overall, the ratings of the two raters were significantly correlated (Pearson $r = 0.86$, $p = 0.0001$). Discrepancies were found in 32 out of the total 791 cases. The coding of these cases was resolved by a third native English speaker.

Statistical analysis

The scores from the production task were arcsine transformed to produce scores that were normally distributed and had a constant variance (see, e.g., Woods, Fletcher, & Hughes,

1986, p. 220). The transformed scores were then submitted to a repeated measures analysis of variance (ANOVA) with two factors: Syllabic Structure (4), and Lexical Class (2). The four levels for the factor Syllabic Structure are defined as the four non-word types in Table 4, and the two levels for the factor Lexical Class are word produced in a noun frame and word produced in a verb frame. For the subject (F1) and item (F2) analyses, repeated measures were used on Lexical Class since the same non-word was produced both in a noun frame and in a verb frame. For the subject analysis, repeated measures were also used on Syllabic Structure in order to compare the productions by a given participant across the four non-word types.

Results

Figure 1 presents the mean proportion of initial syllable stress for the four non-word types in two sentence frames (see Appendix 3 for data on individual participants). It is interesting to note that non-words produced in a noun frame were produced with initial syllable stress more often than those in a verb frame. Also a long vowel in the initial syllable (type 1) conditioned more initial syllable stress, whereas a long vowel in the final syllable (type 4) conditioned more final stress.

Results of the ANOVAs yielded a significant main effect of Syllabic Structure [$F1(3, 18) = 6.46,\ p = 0.004$], [$F2(3, 36) = 2.87,\ p = 0.05$]. The main effect of Lexical Class reached significance in the item analysis [$F2(1, 36) = 24.55,\ p = 0.000$] indicating that non-words were produced with significantly higher proportion of initial stress in the noun sentence frame than in the verb sentence frame. This effect was not, however, significant in the subject analysis [$F1(1, 6) = 1.2,\ p = 0.31$]. The interaction between the Syllabic Structure and Lexical Class was not significant in either analyses [$F1(3, 18) = 0.56,\ p = 0.65$], [$F2(3, 36) = 1.29,\ p = 0.29$]. For the subject analysis, post hoc pair wise comparison revealed that type 1 (CVVCVCC) syllabic structure obtained significantly higher (Bonferroni adjusted $p < 0.05$) proportion of initial stress than type 4 (CVCVVC). Additionally, post hoc

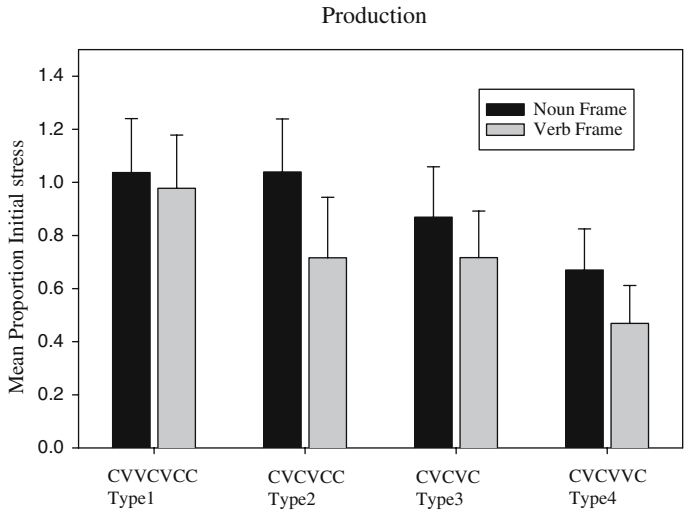

Fig. 1 Mean proportion and standard error of initial stress productions for the Thai speakers ($n = 10$). Four non-word types (ten items for each type) with different syllabic structures were produced in noun (*black bar*) and verb (*gray bar*) sentence frames

analyses for the item analysis revealed that type 1 (CVVCVCC) syllabic structure obtained significantly higher proportion of initial stress than type 2 (CVCVCC) syllabic structure (Bonferroni adjusted $p < 0.05$). These results indicate that a long vowel attracts stress in Thai participants' production of English non-words.

Experiment 2: effects of syllabic structure and lexical class in the perception of lexical stress

In this experiment, the same ten native Thai participants from experiment 1 participated. They were asked to report their preference for initial or final syllable stress on two syllable non-words (the same ones used in the previous experiment) that were aurally presented in noun and verb sentence frames. Similar to experiment 1, the effects of lexical class and syllabic structure on the four non-word stimulus types were investigated.

Materials

The same 40 non-words used in experiment 1, listed in Table 4, were produced with stress on the initial and final syllable in each of the carrier frames "I'd like a __" and "I'd like to __" making a total of 160 sentences. The "a" or "to" of each phrase was produced in a reduced manner. The same speaker used in experiment 1 produced these sentences.

Procedure

All participants were run on experiment 2 after finishing experiment 1. Participants were asked to listen to the prerecorded phrases in pairs that varied only in the stress placement on the non-word. In a given trial, the same sentence frame (noun or verb) was presented. They were instructed to listen to the two sentences and indicate, which one sounded the most like a real English sentence to them.

Each target non-word was presented in two trials, once in a noun frame and once in a verb frame. Two pseudo-randomized, counterbalanced blocks were used, making a total of 80 trials. Each non-word was presented only once in each block. Half of the productions in each block were in a noun frame, half in a verb frame. The order of initial or final syllable stress within a trial was also controlled. For a given non-word, the order of stress presentation remained constant for both the noun frame and verb frame trials. For each of the four non-word types, five of the non-words were presented with initial stress, then final stress. Conversely, the other five were presented with final stress, then initial stress. There was a break of a few minutes between the two blocks. Participants were given some practice trials using non-test items before the first block.

The stimuli were presented over high-quality headphones in a sound attenuated room. Participants adjusted the presentation volume to a comfortable level before testing began. For each trial, the participants were presented two sentences with a 1,500 ms inter-stimulus interval. They responded by indicating which sentence they preferred by pushing a button labeled "first" or "second". This brought up the next trial after a 2,000 ms delay. No repetition of the trial was allowed.

Statistical analysis

The same statistical design used for the production data was used for the perception data. Briefly, the scores from the perception task were arcsine transformed and then submitted to a mixed-design ANOVA with two factors: Syllabic Structure (4), and Lexical Class (2).

Results

The mean proportions of initial stress responses for each group are presented in Fig. 2 (see Appendix 4 for data on individual participants). Note that, unlike the production data, the effect that nouns tended to have more initial stress responses than verbs was not consistent across the four syllabic structure types. In addition, a long vowel in the initial syllable (type 1) did not condition more initial syllable stress, nor did a long vowel in the final syllable (type 4) condition more final stress.

The main effects of Syllabic Structure [$F1(3, 27) = 1.01,\ p = 0.40$], [$F2(3, 36) = 0.61,\ p = 0.61$]; Lexical Class [$F1(1, 9) = 0.00,\ p = 0.99$], [$F2(1, 36) = 0.34,\ p = 0.56$] and Syllabic Structure × Lexical Class [$F1(3, 27) = 1, 2,\ p = 0.34$], [$F2(3, 36) = 0.40,\ p = 0.75$] were all non-significant. This indicates that Thai participants' perception of English stress patterns was based neither on syllabic structure or lexical class of the words. These results were different from those found in their production in experiment 1.

Regression analyses

In this section, the results of two (binary) logistic regression analyses designed to investigate the effects of lexical class, syllabic structure, and the influence of phonologically similar real words on stress placement are presented. These analyses provide additional information to the ANOVAs presented above, as the effect of phonologically similar words is factored in, allowing for an assessment of its unique predictive power on stress placement.

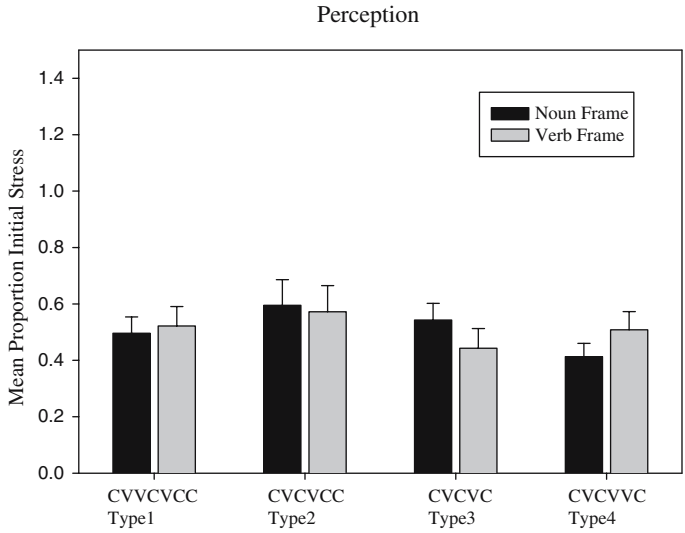

Fig. 2 Mean proportion and standard error of initial stress preference for Thai participants ($n = 10$). Four non-word types (ten items for each type) with different syllabic structures were presented in noun (*black bar*) and verb (*gray bar*) sentence frames

Dependent variables

The dependent variables used in the analyses were the results from experiments 1 and 2 just reported. The individual data points were used and were thus binary (i.e., initial or final stress). A separate regression was performed on the production and perception results.

Independent variables

Three independent variables were used as predictors for each analysis: Syllabic Structure, Lexical Class, and Phonological Similarity.

Syllabic structure

The first predictor variable was the stress placement predicted by the distribution of stress across different syllable types. As previously mentioned, in English, long vowels seem to be the strongest attractors of stress, followed by coda consonant clusters, followed by a singleton coda consonant. Therefore, it was predicted that if the non-word has a syllable with a long vowel, it is stressed. If there is no long vowel, a syllable with a coda cluster is stressed. If there is no such syllable, the syllable with a single coda consonant is stressed. As such, initial stress was predicted for non-word type 1 and final stress was predicted for non-word types 2–4.

Lexical class

The second predictor variable was based on the statistical distribution of main stress between nouns and verbs. Nouns were predicted to have initial main stress and verbs were predicted to have final main stress.

Phonological similarity

The third predictor variable was based on the stress placement of a phonologically similar real words obtained from each participant for each of the non-word in a word similarity task that each participant performed. Since it is likely that different participants would consider different words to be phonologically similar to the non-words, this task was administered to empirically determine phonologically similar words for each of the participants individually.

The method for the word similarity task is identical to the one used in our previous research (Guion et al., 2003, 2004; Guion, 2005). In brief, the participants heard the same 40 non-words used in experiments 1 and 2 in a single randomized block and presented as isolated syllables. A 10 s interval followed the presentation, in which time the participants were asked to list any phonologically similar words they thought of. This task was proven rather challenging for some of the participants due, no doubt, to their relatively low-English proficiency. Nonetheless, they were able to perform the task and, on the average, were able to provide on the average 22 phonologically similar real (Thai and English) words to the 40 non-words presented. The majority (over 90%) of the real words provided had obvious segmental similarities to the target non-words, indicating that the participants were basing their responses on phonological similarities (and not, e.g., semantic associations).

A trained phonetician listened to all real words provided and coded them as having either initial or final stress. However, due to a lack of systematic correspondences between Thai

tones and stress, all Thai words provided were discarded. The placement of stress of the English words provided was determined by the perceived location of main stress in the word as the participant actually produced it. Only the stress for words with more than one syllable was recorded. Most words were disyllabic but two (i.e., obsolete, statistics) were longer. In these cases, the stress was transcribed as initial syllable stress for stress on the second syllable (e.g., statistics) and as final syllable stress for stress on the last syllable (e.g. obsolete). On average, 13 words per participants were coded and included in the regression analysis.

Regression results

Production Data

A binary logistic regression analysis was performed on stress placement of the non-words produced in experiment 1 with three predictor variables: Syllabic Structure, Lexical Class, and Phonological Similarity. After deletion of 636 (79.5%) cases with missing values on Phonological Similarity, 165 (20.6%) cases from nine participants were available for analysis. A test of the full model with all three predictors against a constant-only model was statistically reliable, [$\chi^2(3) = 13.33,\ p < 0.004$], indicating that the predictors, as a set, reliably distinguished between initial and final stress on the production data with a fair model fit (Nagelkerke $R^2 = 0.10$). Overall classification was moderately good. On the basis of the three predictor variables, correct classification rates were 67.4 % for initial and 60.5% for final stress, with an overall success rate of 64.2%.

Table 5 shows the contribution of the individual predictors to the model by giving the Wald statistic (in terms of z-ratio) and the odds ratio, which estimate the strength of the prediction. As shown in this table, Phonological Similarity was the only predictor that made a significant contribution to the model with a relatively high odds ratio of 3.2, suggesting a high probability that non-words produced by native Thai participants would have similar stress patterns as those of the accorded real words with similar phonological structure. (see Appendix 5 for data on individual participants)

Perception data

Similar to production data, a binary logistic regression analysis was performed on preference of stress placement on the non-words in the perception task (experiment 2) with Syllabic

Table 5 Results from logistic regression analyses with the production results from experiment 1 as the dependent variable and three predictor variables: Syllabic Structure, Lexical Class, and Phonological Similarity

Predictor variables	B(SE)	Wald (z-ratio) (df = 1)	Odds ratio
Native english group			
Phonological similarity	1.2 (0.33)	12.55 ($p = 0.000$)	3.2
Lexical class	0.17 (0.33)	0.27 ($p = 0.60$)	1.2
Syllabic structure	0.01 (0.45)	0.00 ($p = 0.99$)	1.0
Constant	−2.2 (1.1)	3.9 ($p = 0.05$)	0.12

Note: B is the logistic coefficient or "logit" representing the log of the odds for an event occurring for a case when the value of an independent variable increases by 1. The Wald statistic (z-ratio) determines the significance of the effect. The odds ratio ($Exp(B)$) represents the odds of an event occurring for a case when the value of an independent variable increases by 1. The lower 95% confidence interval for the odds ratio was above 1 for all significant effects reported

Structure, Lexical Class, and Phonological Similarity as predictors. After deletion of cases with missing values (= 504 cases), 296 (37%) cases were available for analysis. A test of the full model with all three predictors against a constant-only model was statistically unreliable [$\chi^2(3) = 4.34$, $p < 0.23$], indicating that the predictors, as a set, did not reliably distinguish between initial and final stress on the perception. Moreover, the model fit was rather poor [Nagelkerke $R^2 = 0.02$]. Overall classification was fair. On the basis of the three predictor variables, correct classification rates were 47.8% for initial and 60.8% for final stress, with an overall success rate of 54.7%. As shown in Table 6, Phonological Similarity was the only predictor that significantly contributed to the model with an odds ratio of 1.6 (see Appendix 6 for data on individual participants).

Discussion and conclusion

This current study is one in a series of experiments conducted to examine the relative influence of three aspects of knowledge, namely syllabic structure, lexical class, and stress patterns of phonologically similar known words, that might have influenced the acquisition process of the English stress system by adult L2 learners whose native prosodic systems differed from that of English. All three factors have been shown to significantly and independently influence stress assignment patterns on non-words among native English speakers, and early Korean–English and Spanish–English bilinguals. However, syllabic structure played a reduced role for late Spanish–English bilinguals and both syllabic structure and lexical class played a reduced role for late Korean–English bilinguals, while stress patterns of phonologically similar known words was a good predictor of stress for both late bilingual groups (Guion et al., 2003, 2004; Guion, 2005). Based on these results, we argued that some aspects of a new prosodic system differing from that of one's native system can be learned, albeit imperfectly, through adulthood, and that one's native prosodic system exerts a strong influence in the acquisition process, especially among adult learners. We found that late Korean–English bilinguals did not rely on lexical class in their production and perception of lexical stress in English. This might have been due to the fact that prosodic prominence in Korean is defined at the phrase level rather than at the lexical or word level as in English. Early exposure to prosodic contrast at phrasal level may have reduced Korean–English bilinguals' sensitivity to prosodic prominence realized at word level. Evidence of the influence of L1 prosodic system was also found among late Spanish–English bilinguals. In contrast to native English speakers and early Spanish–English bilinguals, late Spanish–English bilinguals preferred first syllable stress both in their production and perception. This may have been due to the transfer of knowledge of the distribution pattern in which penultimate stress is the most common in Spanish lexicon.

Table 6 Results from logistic regression analyses with the perception results from experiment 2 as the dependent variable with three predictor variables: Syllabic Structure, Lexical Class, and Phonological Similarity

Predictor Variables	*B* (SE)	Wald (*z*-ratio) (df = 1)	Odds ratio
Native english group			
Phonological similarity	0.51 (0.25)	4.21 ($p = 0.04$)	1.7
Lexical class	0.06 (0.24)	0.06 ($p = 0.81$)	1.1
Syllabic structure	−0.14 (0.28)	0.27 ($p = 0.61$)	0.87
Constant	−0.53 (0.35)	2.26 ($p = 0.13$)	0.59

In this study, the acquisition of the English stress system by native Thai speakers was examined. The results from the *production* experiment (experiment 1) indicated that, like late Spanish–English bilinguals, this group of L2 learners possesses some knowledge of patterns of stress placement based on lexical class. More importantly, they seem to possess native-like knowledge of the relationship between syllabic structure and stress pattern placement. In their production of the English non-words, a syllable with a long vowel attracted stress more often than those with a short vowel or coda consonant(s). As mentioned, this may have been due to a relationship that exists between vowel length and lexical tone distribution in Thai. Number of coda consonants, on the other hand, did not appear to influence stress assignment, possibly due to the non-existent relationship between number of coda consonants and lexical tone distribution in Thai.

The results from the *perception* experiment (experiment 2), on the other hand, suggested that neither lexical class nor syllabic structure influenced their preferred patterns of stress assignment. Discrepancies between these two experiments might have stemmed from a difference in relative degree of demand placed on the processing system by the two tasks. A relatively stronger processing demand placed on the participant in the production task may have perhaps forced them to access those aspects of knowledge stored in the lexicon.

In the binary logistic regression analyses, together with lexical class and syllabic structure, stress patterns of phonologically similar known words were added as another predictor variable. The analyses revealed that, both in their production and perception of new words, native Thai speakers relied heavily on the stress patterns of already known words and not on syllabic structure or lexical class. Given the fact that only a subset of non-words produced in experiment 1 (i.e., only non-words, for which phonologically similar real words were available) were analyzed in the regression analysis, these results should be taken as complimentary as opposed to contradictory to those found in the ANOVAs performed on the production data. That is, it would be more reasonable to conclude that native Thai speakers' acquisition of lexical stress was influenced to a certain extent by syllabic structure (i.e., long vowel) and lexical class and to a large extent by knowledge of stress patterns of phonologically similar known words.

The extension of stress patterns from known real word to the non-words was also a strong predictor for stress placement among late Korean–English and Spanish–English bilinguals in our earlier work (Guion et al., 2004, Guion, 2005). The results from the late learners in these studies, combined with the results from the late Thai–English bilinguals in this study, suggest that late learners of English may rely more heavily on word-by-word learning of stress patterns and are less likely to abstract generalities about stress placement by syllabic structure and lexical class. Such an interpretation would be in agreement with earlier studies on the acquisition of English stress patterns by syllabic structure, which reported incomplete to no apparent knowledge of these stress patterns (Erdmann, 1973; Mairs, 1989; Archibald, 1992, 1993, 1997). However, such an interpretation would run counter to the findings by Kelly and Block (1988) and Arcuili and Cupples (2003, 2004), in which late learners demonstrated knowledge of English stress patterns based on the lexical classes noun and verb. In these studies, many of the participants were from stress-language backgrounds. Perhaps the effects reported in these studies were due primarily to these speakers. It may be that when participants from a tone language backgrounds only, as was the case here with the Thai participants, are considered, little evidence for the acquisition of stress patterns by syllabic structure and lexical class will be found in future research.

In conclusion, results of this study and the others in the series strongly suggest that aspects of knowledge influencing the assignment of stress patterns in English can be acquired by

adult L2 learners to a varying degree of success depending on such factors as differences between English and the learners' L1 prosodic system, age of acquisition and perhaps English proficiency.

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Appendix 1

Words read by the Thai participants in the frame sentence "I said __ this time" to determine accuracy in stress placement on real English words

Lexical class	Syllabic structure with stress predicted by rule	Consistent with stress rules	Inconsistent with stress rules
Noun	ˈσ CVCC	Agent	Percent
Noun	ˈσ CVCC	Aspect	Descent
Noun	σˈ CVV(C)	Machine	Pillow
Noun	σˈ CVV(C)	Prestige	Window
Noun	ˈσ CVC	Basket	Hotel
Noun	ˈσ CVC	Habit	Giraffe
Noun	σˈ CVV(C)V(C)	Potato	Medium
Noun	σˈ CVC CV(C)	Agenda	Calendar
Noun	ˈσ CV CV(C)	Origin	Eleven
Noun	ˈσ CV CV(C)	Numeral	Banana
Noun	ˈσσ CVV(C)	Hurricane	Spaghetti
Noun	ˈσσ CVV(C)	Magazine	Kangaroo
Verb	σˈ CVV(C)	Behave	Borrow
Verb	σˈ CVV(C)	Maintain	Rotate
Verb	ˈσ CVC	Cancel	Begin
Verb	ˈσ CVC	Manage	Possess
Verb	ˈσ CVC	Indicate	Introduce
Verb	ˈσσ CVV(C)	Compensate	Entertain

Appendix 2

Equivalent English spellings for the non-words used in the study (Table 4)

Type 1 CVV CVCC	Type 2 CV CVCC	Type 3 CV CVC	Type 4 CV CVVC
bay tist	de kips	ni let	ni leet
too kips	ni gept	de sin	de goot
tai gept	ki minz	se lin	bi tase
poe tist	se tist	bi tes	bi tose
gee kips	bi bekt	se get	ki geen
poe bekt	se bekt	de let	se leet
too minz	de minz	ni sin	ni goot
tai minz	ni kips	ki get	ki tase
bay bekt	ki gept	bi lin	de tose
gee gept	bi tist	ki tes	se geen

Appendix 3

This table shows mean (arcsine transformed) proportion of initial stress as produced by each participant for each of the four syllable structures for both the noun and the verb frame sentence obtained from experiment 1. The highest proportion possible is 1.57. It indicates that all non-words were produced with an initial stress by the participant. The lowest proportion of 0.00 indicates that all non-words were produced with final stress. Dashed lines indicate missing data.

Subject	Noun frame				Verb frame			
	Type 1 (CVVCVCC)	Type 2 (CVCVCC)	Type 3 (CVCVC)	Type 4 (CVCVVC)	Type 1 (CVVCVCC)	Type 2 (CVCVCC)	Type 3 (CVCVC)	Type 4 (CVCVVC)
1	1.57	1.57	1.57	1.57	1.57	0.73	1.10	1.10
2	–	1.57	0.85	0.73	1.57	0.52	1.57	0.79
3	0.46	0.14	0.46	0.22	0.52	0.34	0.25	0.00
4	1.57	1.04	1.08	0.89	0.17	0.00	0.13	0.00
5	0.64	0.34	0.13	0.22	0.29	0.14	0.20	0.11
6	1.57	1.57	–	–	1.57	–	–	–
7	0.39	0.10	0.00	0.17	0.41	0.00	0.22	0.11
8	0.52	0.93	1.08	0.52	1.57	1.57	1.12	0.46
9	1.57	1.57	1.10	1.10	1.57	1.57	0.93	0.93
10	–	1.57	1.57	0.59	0.52	1.57	0.93	0.73

From this table, one observes the influence of both Syllabic Structure and Lexical Class on the stress pattern of non-words produced by most of the participants. Participant 1, for example, appears to prefer first syllable stress for both nouns and verbs. However, s/he slightly preferred final stress over initial stress for type 2 syllabic structure for verbs. Participant 2 preferred initial stress for both nouns and verbs except when the second syllable contains a long vowel (i.e., type 4 syllabic structure). Participant 4 (S4) exhibited a preference for initial stress for nouns except when the second syllable contains a long vowel (Type 4 syllabic structure). However, s/he preferred final stress for verbs regardless of syllabic structure. The influence of Syllabic Structure and Lexical class is also apparent in S8, S9, and S10 data. On the other hand, some participants (e.g., S3, S5, and S7) preferred final stress while others (e.g., S6) preferred initial stress regardless of syllabic structure or lexical class. It was not obvious at present, which aspect of the participant's language background accounted for these individual variations. It was rather obvious that participant's length of residence in the US is not a strong predictor of their performance. For example, S3 has the shortest amount of residence in the US, while S7 has the longest amount, yet both participants exhibited similar pattern of stress preference. It is of note, however, that both reported similar percentage of English use (80 and 70%, respectively) and similar level of English proficiency in speaking, reading, writing, and listening. On the other hand, S1 who reported similar amount of English use (i.e., 80%) had the opposite pattern of stress preference from those of S3 and S7. Thus, individual differences in stress assignment among second language learners remain to be accounted for.

Appendix 4

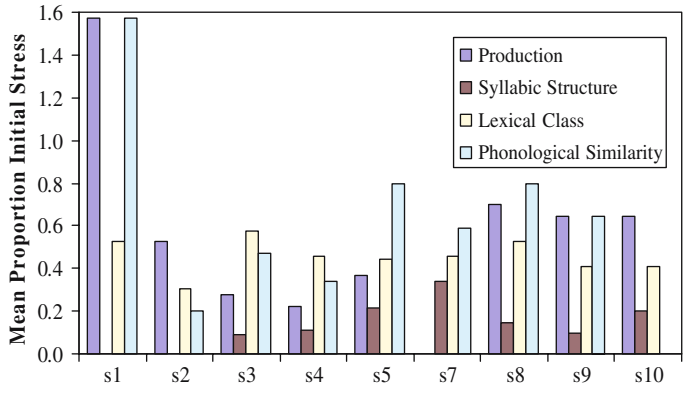
This table shows mean proportion of initial stress as preferred by each of the Thai participants when they listened to non-words produced as a noun or as a verb in experiment 2. Unlike

Appendix 3, the effects of either Syllabic Structure or Lexical Class were less apparent in this table. Overall, participants appeared to prefer final stress over initial stress. However, in some cases, both initial and final stresses were equally preferred for no apparent reason. For example, for Participant 1, initial and final stresses were equally preferred for non-words of types 2 and 4 syllabic structures heard in the verb sentence frame when final stress should have been preferred according to Syllabic Structure and Lexical Class. Similar to Appendix 3, individual variation was observed but could not be easily explained by any of the participant's language background information.

Subject	Noun frame				Verb frame			
	Type1 (CVVCVCC)	Type 2 (CVCVCC)	Type 3 (CVCVC)	Type 4 (CVCVVC)	Type1 (CVVCVCC)	Type 2 (CVCVCC)	Type 3 (CVCVC)	Type 4 (CVCVVC)
1.00	0.52	0.64	0.20	0.64	0.64	0.78	0.10	0.78
2.00	0.30	0.41	0.52	0.30	0.41	0.10	0.41	0.64
3.00	0.52	0.30	0.41	0.41	0.41	0.52	0.41	0.20
4.00	0.78	1.12	0.64	0.41	0.10	0.41	0.20	0.64
5.00	0.41	0.64	0.64	0.41	0.52	0.78	0.78	0.52
6.00	0.41	0.78	0.78	0.20	0.52	0.30	0.52	0.30
7.00	0.20	0.20	0.41	0.30	0.64	0.52	0.30	0.20
8.00	0.52	0.52	0.78	0.52	0.41	0.41	0.78	0.64
9.00	0.78	0.41	0.64	0.64	0.64	0.78	0.52	0.52
10.00	0.52	0.93	0.41	0.30	0.93	1.12	0.41	0.64

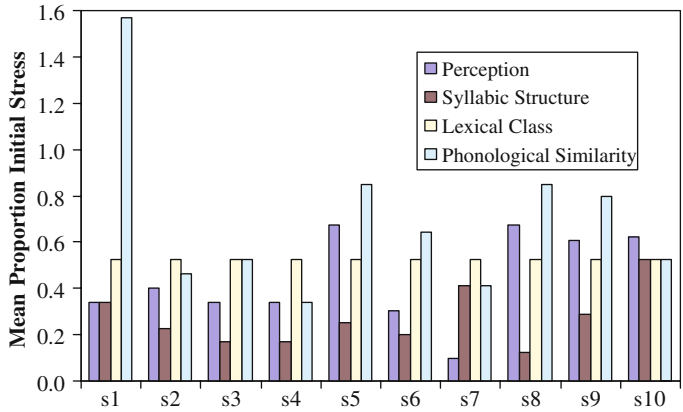
Appendix 5

This figure shows data entered into the logistic regression analyses (see Regression analyses Section), which include mean (arcsine transformed) proportion of initial stress produced by each Thai participant averaged across all four syllable types, proportion of initial stress as predicted by Syllabic Structure and Lexical Class as well as proportion of phonologically similar words produced with initial stress. Failure to accurately produce target non-words of type 1 (CVVCVCC) syllabic structure was responsible for the missing data in S1 and S2. The S6 was not able to produce any target non-words accurately. On the other hand, all target non-words produced by S7 had stress on the second syllable and failure to provide phonologically similar real words to the target non-words was responsible for the missing data in S10. From this figure, one can see that, with the exception of Participant 2 (S2), proportion of initial stress produced by every participant (first bar) were equal to or less than proportion of initial stress of phonologically similar words (fourth bar) provided by the participant suggesting a strong correlation between the stress pattern produced by the participant and that of a familiar word. This figure also shows that a correlation between proportion of initial stress as predicted by Syllabic Structure (second bar) and Lexical Class (third bar) and the actual proportion of initial stress produced by the participant was relatively less strong. These results are in agreement with those obtained from the logistic regression analysis reported in the text.



Appendix 6

This figure shows mean proportion of initial stress obtained from each participant from the perception experiment (Experiment 2), mean proportion of initial stress of phonologically similar words provided by the participant as well as mean proportion of initial stress as predicted by Syllabic Structure and Lexical Class of the non-words heard in the experiment. Similar to Appendix 5, this figure illustrates that, with the exception of Participant 10 (S10), mean proportion of initial stress of phonologically similar words were higher than mean proportion of initial stress as preferred by the participant. This result suggests that the stress pattern of a phonologically similar word related strongly to the preferred stress pattern of a non-word as judged by the participant. Results of the logistic regression analysis are consistent with these observations.



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