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Must "big" syllables carry stress in English?

Lulu Griffin & Anya Hogoboom*

Abstract. Two types of syllables with ambiguous stress-status are identified: open syllables with a full vowel adjacent to the primary stress (e.g. *no.tá.tion*) and closed syllables with a full vowel that occur non-adjacent to, but to the right of the primary stress syllable (e.g. *cá.ra.van*). Both syllable types have a full vowel but need not be heavy; the latter type also has a coda consonant. These two segmental properties of syllables were separated into two "big" syllable shapes, [Cæ] and [Cəs]. Two perception studies were run in which these syllables were given the prosodic characteristics of unstressed syllables and placed in syllable strings where a listener would expect a stressed syllable given the otherwise alternating pattern of the string. Listeners also heard truly alternating strings, and strings with initial or final stress lapse without a big syllable as part of the stress lapse. It was found that unstressed open syllables with full vowels were highly confusable with a truly alternating pattern, whereas unstressed closed syllables were not. As both ambiguously-stressed syllable shapes under consideration involve a full vowel, our full vowel study gives support for the hypothesis that such syllables may not be stressed, and are confusable with stressed syllables because of their vowel quality.

Keywords. full vowels; closed syllables; stress; English; perception

1. Introduction. This paper examines the relationship between segmental content and stress in English and whether or not this relationship can be separated. Unstressed, open, non-final syllables in English typically reduce to [ə] (Chomsky & Halle 1968), so the initial syllable of words like [noʊtéɪʃn̩] 'notation' and [veɪ.kéɪ.ʃn̩] 'vacation,' would generally be analyzed as bearing secondary stress (i.e. [nòʊtéɪʃn̩], [vèɪ.kéɪ.ʃn̩]), as their vowels are not reduced. Having a secondary stress on the initial syllable, however, results in a stress clash, which is dispreferred. Full vowels in closed syllables are also often taken to bear stress, for example, the final syllables of [káɹəvæn] ∼ [káɹəvæ̀n] 'caravan' and [máɪ.mə.sɛt] ∼ [máɪ.mə.sɛ̀t] 'marmoset.' In cases such as these, secondary stress would not cause a stress clash as the words have initial primary stress. However, given that English aligns its primary stress toward the right edge of the word (e.g., Prince 1983), it is surprising to find a secondary stress intervening between the primary stress and the end of the word. Two perception studies were undertaken to investigate whether segmental content may be distinct from stress, despite the strong tendency for full vowels and closed syllables to bear (some level of) stress.

We separate out these two types of "big" syllables[1] and investigate the perceptual salience of [Cæ] and [Cəs] syllables, testing whether they may be perceived as contributing to the rhythm of a word due to their segmental content alone.

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[1] Note that the syllables under discussion are not necessarily heavy: [æ] is a full vowel but not one that is taken to be bimoraic in English as it is not phonologically tense, and word-final CVC syllables behave as light (Liberman & Prince 1977). We therefore use the term "big" for the syllables under discussion.

We employ the methodology of Hogoboom (Lunden 2017, 2018, 2019) who used concatenated syllables in a series of perceptual experiments to test whether certain unstressed syllables could be perceived as sufficiently prominent to contribute to the perception of rhythm. She found that the additional phonetic duration of final syllables and the associated fuller (lower, backer) vowel quality of word-final [ə]s can contribute to the perception of a rhythmic alternation at the right-edge of a word, thus offering a possible explanation of why languages such as English allow adjacent unstressed syllables word-finally. Because listeners often perceived unstressed final syllables as contributing to the rhythm of a syllable string, Hogoboom proposes that the category of prosodically strong syllables encompasses not only stressed syllables but also unstressed word-final syllables. We seek to test whether syllables with full vowels and/or closed syllables should also be added to this group.

We find strong evidence that open syllables with a full vowel but that otherwise have the characteristics of unstressed syllables (lower intensity, shorter duration, etc.) are confusable with stressed syllables. We find weak to no evidence that unstressed closed syllables with a reduced vowel exhibit the same perceptual salience. We posit that full vowels may occur unstressed, and, when they do, their inherent "bigness" leads to ambiguity, and hence differing judgements on whether or not they are stressed (e.g. noʊtéɪʃn̩] ∼ [nòʊtéɪʃn̩], [kə́ɹəvæn] ∼ [kə́ɹəvæ̀n]).

The relevant background is further discussed in §2. The syllable content used in the perception studies was extracted from a production study which is presented in §3. The two perception studies are laid out in §4, first with an overview of the aspects common to both studies. The results of both studies are presented in §5 and discussed in §6. §7 concludes.

2. Background. It is either typical, or required, for unstressed vowels in non-final syllables to centralize in English. Vowels in non-final unstressed syllables are typically taken to reduce to [ə] but have also been proposed to be [ɨ] (Flemming & Johnson 2007). Full vowels, either those that are phonologically tense and therefore heavy (phonetically tense vowels, [ɔ], and [ɑ]) as well as those that are phonologically lax and light (phonetically lax vowels excepting [ɔ] and [ɑ]) are generally understood to occur only in syllables that bear primary or secondary stress (e.g., Chomsky & Halle 1968; Hammond 1999).[2] Some examples are given in (1).

(1) Full vowels in stressed syllables, [ə] in unstressed

a.	[bə.nǽ.nə]	'banana'
b.	[ə.mɛ́ɹ.ɹə.kə][3]	'America'
c.	[æ̀.lə.bǽ.mə]	'Alabama'

The two types of syllables being investigated here are those with a full vowel adjacent to the stressed syllable (e.g. [vo̲ʊ.kéɪ.ʃn̩] 'vocation', [ɹæ̲kún] 'raccoon') and final closed syllables with a full vowel which are not adjacent to the primary-stressed syllable (e.g. [mə́ɹ.zə.pæ̲n] 'marzipan,' [díp.lə.mæ̲t] 'diplomat'). In order to investigate the two properties involved, we separate these into open syllables with a full vowel [Cæ], and closed syllables with a reduced vowel [Cəs]. Final [CəC] syllables are less likely to reported as bearing secondary stress; for example Merriam-

[2] This is relaxed to some degree word-finally, where unstressed closed syllables may have full vowels (e.g. [æ̀.kə.dɛ́.mɪk] 'academic') and unstressed open syllables may host a limited set of full vowels: [i, u, o] (Hammond 1999; Lorber 2024 proposes adding [eɪ] and [ɔ]).

[3] The [ɹ] is shown parsed as an onset but in fact is ambisyllabic (or a covert geminate (Hammond 1997)), as primary stressed syllables in English are heavy and so the [ɹ] must also be a coda. The same is true of the [m] in 'Alabama' in (c) and the [m] in 'academic' in fn. 2.

Webster (2025) notates final closed syllables with a full vowel in words with antepenultimate stress as having secondary stress (e.g. [bú.mə.ɹæ̀ŋ] 'boomerang'), but not final closed syllables with a reduced vowel (e.g. [ɑ́k.tə.pəs] 'octopus,' [fɔ́ɹ.ʧə.nət] 'fortunate'). Closed syllables with a reduced vowel are nevertheless tested in order to tease apart the two aspects that could contribute to the perceptual salience of an unstressed closed syllable with a full vowel.

Hogoboom (Lunden 2017, 2018, 2019) has previously found that word-final syllables, which are subject to word-final lengthening and which have a less-reduced vowel, are perceptually salient and therefore confusable as being stressed. She concatenated five-syllable CV strings with generally alternating rhythm and then made some strings fully alternating (e.g. σ́σσ́σ́) and others have a stress lapse (e.g. σ́σσ́σσ). All stressed syllables had the characteristics of primary stress. Word-final syllables in stress lapse were either the same as the other unstressed syllables in the string, or, alternatively, had the characteristics of an unstressed word-final syllable (longer duration, less-reduced [ə]). Participants were asked for each syllable string whether it alternated in prominence throughout, or whether it failed to alternate throughout. She found that listeners regularly correctly categorized the baseline conditions, where ∼80% fully alternating strings were identified as such, whereas ∼20% final lapse strings with two adjacent equally-weak syllables were (incorrectly) identified as alternating. The test strings, which had a stress lapse but not a prominence lapse, were identified as alternating ∼60% of the time. Hogoboom therefore concludes that the inherently stronger properties of word-final syllables can lead to a perceptual repair of final stress lapse, which, she argues, motivates the acceptability of word-final stress lapse (relative to, say, word-initial stress lapse which is all but non-existent (Kager 2001)). Hogoboom (Lunden 2019) identifies two criteria that must be met for unstressed syllables to be analyzed as perceptually salient when using this methodology. The first is that syllable strings where such syllables are in a lapse position are statistically significantly more likely to be identified as alternating than lapse strings with two weak syllables. The second is that they are identified as fully alternating at least 50% of the time, thus reaching a threshold of confusability.

We modified this experimental paradigm to test whether an unstressed [Cæ] syllable, or unstressed [Cəs] syllable, placed in a position of initial or final stress lapse is more likely to be identified as being part of a fully alternating string compared to an unstressed [Cə] syllable in the same position. The following section reports on the production study that was undertaken in order to create the syllable strings used in the perception studies, which are then laid out in §4.

3. Production study. A production study was run in order to get natural pronunciations of target syllables, under different stress conditions that could subsequently be extracted, acoustically regularized, and concatenated into syllable strings.

3.1. PARTICIPANTS. Six native English speakers (female=4; male=1; non-binary=1; aged 18-21) participated, all of whom were undergraduate students at William & Mary who received participant credit.

3.2. STIMULI CREATION. Words with the target syllables needed for the two perception studies were identified. Stressed [Cɑ́] and unstressed [Cə] were used in both sets of syllable strings. Additionally, for the full vowel paradigm words with target stressed [Cǽ] syllables and secondarily-stressed [Cæ̀] syllables (that were later modified to have the characteristics of unstressed syllables) were identified. For the CVC paradigm, words with stressed [Cʌ́s] sequences and unstressed [Cəs] sequences (where the [s] might be in the following syllable of the target word) were identified.

Words in which the target syllable would be word-final were avoided, so that we did not have confounds of word-final lengthening, etc. Target syllables always had a voiced stop onset, and sets were created with each of [b], [d], and [g]. Target syllables might have an unwanted coda consonant that would need to be removed, in which case it was an obstruent, so as to be maximally separable. An example set for the full vowel paradigm is shown in Table 1 and one for the CVC paradigm is given in Table 2.

	stressed	unstressed
[æ]	æm.bǽ.sə.dɻ	mάɪ.kɹoʊ.bæ̀.lɪns
	'ambassador'	'microbalance'
central	bʎ́.ɾɻ.flɐ̀ɪ	sɐ́.bə.tɑʒ
	'butterfly	'sabotage'

Table 1. Set of target syllables for full vowel paradigm with [b] onset

	stressed	unstressed
CV	dʎ́.blˌ	ín.də.stri
	'double'	'industry'
CVC	dʎ́.ski	kə.lάɪ.də.skòʊp
	'dusky'	'kaleidoscope'

Table 2. Set of target syllables for CVC paradigm with [d] onset

3.3. STIMULI. The words were put into question and answer pairs, as in (2), adapted from Lunden (2017). Each participant read all 42 randomized question/answer pairs.

(2) Example question/answer pair for the word 'ambassador'
Which ambassador did the girl hug?
The girl hugged the ambassador that talked quietly.

3.4. PROCEDURE. Participants were instructed to read each question and answer pair as fluently and naturally as possible and asked to redo any answer sentence in which they paused or made a mistake. Subjects were recorded reading in a sound-attenuated booth while wearing a head-mounted Shure SM35 which was connected to a Tascam DR-100 Digital Voice Recorder.

One researcher subsequently listened to all the participants and identified the speaker with the clearest recording. All target syllables were then extracted from this speaker's recording. Target syllables were only extracted from the answer sentences.

4. Perception studies. All perception study participants took both the full vowel study and the CVC study. §4.2 has two further subsections, the first detailing full vowel study and then the CVC study. The procedure for both perception experiments is then given in 4.3.

4.1. PARTICIPANTS. Seventy native English speakers took both studies (female=46; male=22; non-binary=2; aged 18-25). Participants are undergraduate students at William & Mary and were recruited through student organization group chats and through the university's participant pool. Those recruited through the pool received participation credit.

4.2. STIMULI. Target syllables for each of the [b], [d], and [g] sets were extracted and concatenated into five-syllable strings. In both studies, the second and fourth positions always consisted of unstressed [Cə] syllables. As in Hogoboom's studies, only two levels of stress were used: stressed and unstressed. The vowels of the [Cə] unstressed syllables were adjusted to have a duration of 60 ms. The vowels of stressed [CÁ] syllables were standardized to 90 ms. For all syllable strings, pitch was adjusted to 185 Hz in stressed syllables and to 165 Hz in unstressed syllables. Intensity was near 60 dB in stressed syllables, and near 50 dB in unstressed syllables. Thus, truly stressed syllables consistently had higher pitch and intensity as well as longer duration.

4.2.1. FULL VOWEL STUDY. The 18 target syllables for the full vowel study were extracted. Stressed [Cǽ] syllables were standardized to have a vowel length of 130 ms. and unstressed [Cæ] syllables were standardized to 90 ms. These syllables, along with [CÁ] and [Cə], were concatenated into three different rhythmic patterns: fully alternating, initial lapse, and final lapse. Every string had one syllable with the full vowel [æ], which occurred in either initial or final position. The syllable strings with [b] onsets are shown in Table 3 and a sample waveform and spectrogram for the [g]-onset final lapse string with unstressed [æ] is shown in Figure 1, with blue representing the pitch and yellow representing the intensity. Unstressed [æ] in a lapse position is highlighted.

	[æ] in #σ	[æ] in σ#
fully alternating	bǽ.bə.bʌ́.bə.bʌ́	bʌ́.bə.bʌ́.bə.bǽ
initial lapse	bæ.bə.bʌ́.bə.bʌ́	bə.bə.bʌ́.bə.bǽ
final lapse	bǽ.bə.bʌ́.bə.bə	bʌ́.bə.bʌ́.bə.bæ

Table 3. Set of full vowel syllable strings with [b] onset

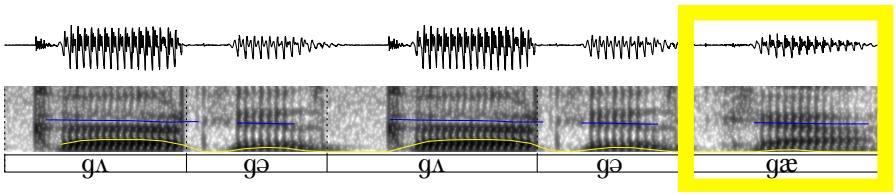

Figure 1. Example full vowel syllable string (full vowel in final lapse)

4.2.2. CVC STUDY. The 18 target syllables for the full vowel study were extracted. Stressed [Cʌ́s] syllables were standardized to have a vowel length of 80 ms. and a coda length of 80 ms. Unstressed [Cəs] syllables were standardized to 40 ms. for the vowel and 40 ms. for the coda. These syllables, along with [CÁ] and [Cə], were concatenated into three different rhythmic patterns: fully alternating, initial lapse, and final lapse. Two different types of CVC strings were made, which will be discussed separately, although the two types were intermingled in the study. The first type had one CVC syllable, occurring in either initial, third, or final position. A sample set of syllable strings, those with [d] onsets, are shown in Table 4. Unstressed CVC syllables in a lapse position are highlighted.

The second type of CVC syllable string had two CVC syllables in it, where one was stressed and the other unstressed. Like with 1-CVC strings, a CVC in the third (medial) position was always stressed. The set of 2-CVC syllable strings with [d]-onsets is shown in Table 5.

	#CVC	medial CVC	CVC#
fully alternating	dʌ́s.də.dʌ́.də.dʌ́	dʌ́.də.dʌ́s.də.dʌ́	dʌ́.də.dʌ́.də.dʌ́s
initial lapse	dəs.də.dʌ́.də.dʌ́	də.də.dʌ́s.də.dʌ́	də.də.dʌ́.də.dʌ́s
final lapse	dʌ́s.də.dʌ́.də.də	dʌ́.də.dʌ́s.də.də	dʌ́.də.dʌ́.də.dəs

Table 4. Set of 1-CVC syllable strings with [d] onset

	CVC in positions 1, 3	CVC in positions 1, 5	CVC in positions 3, 5
fully alternating	dʌ́s.də.dʌ́s.də.dʌ́	dʌ́s.də.dʌ́.də.dʌ́s	dʌ́.də.dʌ́s.də.dʌ́s
initial lapse	dəs.də.dʌ́s.də.dʌ́	dəs.də.dʌ́.də.dʌ́s	də.də.dʌ́s.də.dʌ́s
final lapse:	dʌ́s.də.dʌ́s.də.də	dʌ́s.də.dʌ́.də.dəs	dʌ́.də.dʌ́s.də.dəs

Table 5. Set of 2-CVC syllable strings with [d] onset

4.3. PROCEDURE. Both studies were set up as Multiple Forced Choice experiments in Praat (Boersma & Weenink 2023). Participants took the studies back-to-back (in alternating order) in a sound-attenuated booth wearing Sennheiser HD 280 pro headphones. The 18 syllable strings in the full vowel study were repeated 6 times, and the 54 syllable strings in the CVC study were repeated twice, so that each study had a total of 108 stimuli. The participants were instructed that they would hear strings of syllables that generally alternated between strong and weak throughout but that sometimes there were two weak syllables next to each other at the beginning or end of the string. They were asked to listen to each string and categorize it as alternating throughout or not.

An example was played of each basic string type: fully alternating, initial lapse, and final lapse, where the vowels were all [ʌ] (when stressed) or [ə] (when unstressed) and no codas were present. The three examples were described, respectively, as fully alternating, not alternating due to two weak syllables at the beginning, and not alternating due to two weak syllables at the end. Participants were told that the syllables in the strings in the actual study may sound more different from each other and that the question was always whether there was an alternation between strong and weak syllables throughout, regardless of the type of syllables in the string. The study's run-text read "Did the string alternate throughout?" with two choices, "yes" and "no."

5. Results.

5.1. FULL VOWEL STUDY. All syllable strings for the full vowel study had one syllable with [æ], either in initial or final position, either stressed or unstressed. When unstressed, it was part of a stress lapse. We want to compare the responses to the stress lapses in these test strings (those with unstressed [æ]) to the responses to the strings with stress lapses with two reduced vowels. The rate at which every type of syllable string was identified as "alternating throughout" is shown in Figure 2.

The gray bar shows the combined responses for both types of fully alternating strings– those with [æ] in the first syllable and those with [æ] in the last syllable, and we see that they were reliably perceived as "alternating throughout." The red bars show the percent of "alternating throughout" responses when there was a non-test stress lapse, broken out for whether the lapse was word-initial or word-final. We see that in these non-test lapse conditions, participants largely perceived the strings as "not alternating throughout." Lunden (2019) found very similar results for fully al-

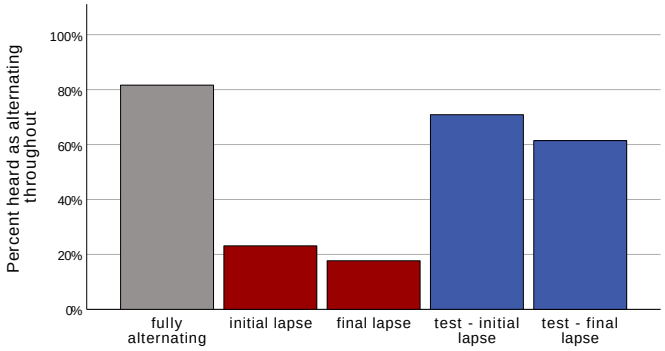

Figure 2. Percent "alternating throughout" responses for full vowel study

ternating strings (∼80% identified as "alternating") and non-test lapse strings (∼20% identified as "alternating") so the baseline cases are behaving as expected. The blue bars show results for the "test" conditions, in which there was an unstressed [æ] as part of the stress lapse, again broken out for initial vs. final position. In both test lapse conditions, we find participants identifying the strings as "alternating" as least 60% of the time.

A binary logistic regression was run in SPSS with dependent variable *response* and independent variables *rhythm* (three levels: fully alternating, initial lapse, final lapse) and *[æ]-position* (two levels: initial, final), and their interaction, with *subject* as a blocking factor, as given in Table 6.

	Wald χ^2	*df*	Sig
(intercept)	108.220	1	<0.001
rhythm	970.009	2	<0.001
[æ]-position	0.779	1	0.378
rhythm*[æ]-position	1005.063	2	<0.001
subject	446.055	69	<0.001

Table 6. Results of logistic regression with DV *response* for full vowel study

Post-hoc pairwise comparisons using Fisher's least significant difference adjustment were run for the interaction term *rhythm*[æ]-position*, and all significance levels reported come from these pairwise comparisons. Both test lapse strings were significantly less likely to be identified as "alternating throughout" than fully alternating strings ($p < 0.001$) but were significantly more likely to be identified as "alternating throughout" than non-test lapse strings ($p < 0.001$).

5.2. CVC STUDY. Half of the syllable strings in the CVC study had one CVC syllable, and the other half had two CVC syllables. While both types were run intermingled as part of the same study, they were found to behave differently and so the presentation of their results is separated into 1-CVC strings in §5.2.1 and 2-CVC strings in §5.2.2.

5.2.1. 1-CVC STRINGS. The responses to each string type, when there was one CVC syllable per string (in initial, medial, or final position of the five-syllable string) is shown in Figure 3.

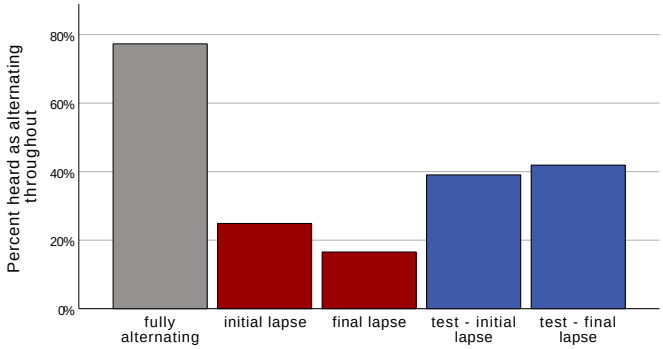

Figure 3. Percent "alternating throughout" responses for 1-CVC strings in CVC study

The gray bar represents all fully alternating strings, and so includes strings with the CVC in initial, medial, and final position, and we again see that they are reliably perceived as "alternating throughout." The non-test lapse conditions are shown in red and each combine two cases: those where the CVC is medial or where the CVC is on the non-lapse edge of the string. As in the results of the full vowel study, these baseline conditions behave as expected. The test lapse conditions, shown in blue, each show the results of a single string type: those in which an unstressed CVC was part of the stress lapse. Here we see more "alternating throughout" responses to the test lapse strings than to the non-test lapse strings, however, the test lapse strings are heard as "alternating throughout" $\sim$40% of the time, rather than the $>$60% we saw for the test lapse strings in the full vowel study.

A binary logistic regression was run in SPSS with dependent variable *response* and independent variables *rhythm* (three levels: fully alternating, initial lapse, final lapse), *CVC-initial* (two levels: initial CVC, no initial CVC), and *CVC-final* (two levels: final CVC, no final CVC), and the interactions *rhythm*CVC-initial* and *rhythm*CVC-final*, with *subject* as a blocking factor, as reported in Table 7.

	Wald χ^2	*df*	Sig
(intercept)	15.272	1	$<$0.001
rhythm	473.053	2	$<$0.001
CVC-initial	1.425	1	0.233
CVC-final	33.316	1	$<$0.001
rhythm*CVC-initial	22.978	2	$<$0.001
rhythm*CVC-final	29.043	2	$<$0.001
subject	226.959	69	$<$0.001

Table 7. Results of logistic regression with DV *response* for 1-CVC strings in CVC study

Post-hoc pairwise comparisons using Fisher's least significant difference adjustment were run for the two interaction terms and all significance levels reported come from these pairwise comparisons. As seen in the results of the full vowel study, test lapse strings were significantly less likely to be identified as "alternating throughout" than fully alternating strings ($p < 0.001$) but were significantly more likely to be identified as "alternating throughout" than non-test lapse strings

($p < 0.001$).

5.2.2. 2-CVC STRINGS. We now turn to the responses to the syllable strings that had two CVCs per string. The CVCs were either the first and third, first and fifth, or third and fifth syllables of the five-syllable strings. The percent of "alternating throughout" responses for each string type is shown in Figure 4.

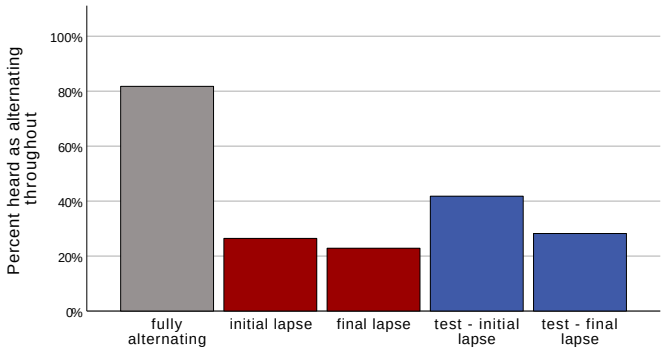

Figure 4. Percent "alternating throughout" responses for 2-CVC strings in CVC study

The gray bar again represents all fully alternating strings, of which there were three variations in the placement of CVC syllables, and we again see that they are reliably perceived as "alternating throughout." The non-test lapse conditions are shown in red. As seen previously, these baseline conditions behave as expected. The test lapse conditions, shown in blue, each combine the two cases where the unstressed CVC syllables were part of the stress lapse. Here we see minimal more "alternating throughout" responses to the test lapse strings than to the non-test lapse strings, particularly in the final lapse condition.

A binary logistic regression was run in SPSS with dependent variable *response* and independent variables *rhythm* (three levels: fully alternating, initial lapse, final lapse), *CVC-initial* (two levels: initial CVC, no initial CVC), and *CVC-final* (two levels: final CVC, no final CVC), and the interactions *rhythm*CVC-initial* and *rhythm*CVC-final*, with *subject* as a blocking factor, as reported in Table 8.

	Wald χ^2	*df*	Sig
(intercept)	4.605	1	0.032
rhythm	547.438	2	<0.001
CVC-initial	14.295	1	<0.001
CVC-final	0.340	1	0.560
rhythm*CVC-initial	16.702	2	<0.001
rhythm*CVC-final	4.775	2	0.092
subject	274.878	69	<0.001

Table 8. Results of logistic regression with DV *response* for 2-CVC strings in CVC study

Post-hoc pairwise comparisons using Fisher's least significant difference adjustment were run for the two interaction terms and all significance levels reported come from these pairwise comparisons. As seen in the results of 1-CVC strings, test lapse strings were significantly less likely to

be identified as "alternating throughout" than fully alternating strings ($p < 0.001$). With the 2-CVC strings, however, we see a notably different effect of an unstressed CVC in an initial lapse position, where it caused significantly more "alternating throughout" responses than non-test initial lapse strings ($p < 0.001$) and an unstressed CVC in a final lapse position, where it did not cause significantly more "alternating throughout" responses than non-test final lapse strings ($p = 0.099$).

6. Discussion. The two studies were set up to independently test the two aspects of the ambiguously-stressed syllables of interest: open syllables with a full vowel adjacent to the primary stressed syllable of the word (e.g. [ɹæ̱kún] 'raccoon') and closed syllables with a full vowel not adjacent to a stressed syllable (e.g. [mάɪ.zə.pæ̱n] 'marzipan'). Thus one perception study tested whether an unstressed full vowel might contribute to the rhythm of a syllable string just by virtue of being a full vowel, and the second perception study tested whether an unstressed CVC with a reduced vowel might do the same.

The results of both the full vowel study and the CVC study successfully replicated the baseline perceptions of fully alternating and non-test lapse strings found by Hogoboom (Lunden 2019). She proposed two criteria needed to be met in order for a specific type of unstressed syllable to count as prominent enough to contribute to an alternating rhythm. The first criterion is that the syllable strings with the test syllable in lapse position must be heard as "alternating throughout" statistically significantly more than syllable strings without a test syllable in the lapse position. This was found to be true for unstressed full vowels in both initial and final position, and it was also true of three of the four types of test strings in the CVC study. Unstressed CVC syllables in either an initial or final stress lapse in 1-CVC strings met this benchmark, as did unstressed syllables in initial lapse in 2-CVC strings. Unstressed CVC syllables in final lapse in 2-CVC strings, however, were not statistically significantly more likely to be perceived as "alternating throughout" than non-test final lapse strings. The second criterion is that the strings with the unstressed test syllable in lapse position need to be sufficiently confusable as "alternating (throughout)," with the threshold set at 50% "alternating (throughout)" responses. The responses to the relevant strings in the full vowel study clearly fulfill this second criterion as well, with over 60% "alternating throughout" responses. None of the rates of "alternating throughout" responses to the test strings in the CVC study meet this threshold, however, with ∼40% "alternating throughout" responses for the three types of syllable strings that met the first criterion.

Thus we find evidence that an unstressed full vowel is sufficiently confusable to contribute to the perception of a syllable string with a stress lapse as nevertheless having an alternating rhythm. We do not, however, find the same evidence that an unstressed CVC syllable can do the same. Because both types of syllables being considered here in fact have a full vowel, there is support for the conclusion that both an open syllable with a full vowel that is adjacent to the primary stressed syllable and a closed syllable with a full vowel to the right of the primary stressed syllable may in fact be analyzed as not stressed, but confusable with bearing stress, as they have a degree of inherent prominence due to the presence of a full vowel. We also see evidence that merely being closed does not increase a syllable's prominence.

There are several alternative explanations that might be put forward for the behavior of the full vowel test strings. One is that if full vowels always bear stress in English, then English listeners would hear any full vowel as stressed since it is a predictable property. In this case, however, we would expect that the test lapse strings would be as equally likely to be identified as "alternat-

ing throughout" as the truly fully alternating strings. Instead, we find that they are significantly less likely to be. Another alternative explanation might hinge on the fact that all stressed syllables in these strings bore the same level of stress, and that listeners might not give a "alternating throughout" response as reliably if some of the syllables bore a weak, secondary stress. If secondary stressed syllables in fact cause the same kind of confusability of whether or not a string is alternating, then perhaps the "unstressed" [æ] vowels were interpreted as having secondary stress. While the study undertaken here cannot offer evidence against this idea, Hogoboom has investigated the perception of syllable strings in which the stressed syllables were distinguished by two levels of stress, corresponding to primary and secondary (Lunden 2018 (Study 1)). She set up a perception study with five-syllable strings in which, like the fully alternating strings in the current studies, the first, medial, and final syllables bore stress, but which had two of the stressed syllables showing levels of duration, pitch, and intensity that were intermediate between the stronger (primary) stressed syllable and the unstressed syllables. Listeners in that study identified these fully alternating strings as "alternating throughout" more than 80% of the time, giving good evidence that secondary stress contributes to an alternating rhythm to the same degree that primary stress does.

One potential confound in the full vowel study is that in the test lapse strings, the stressed [ʌ́] vowels had the same duration as the unstressed [æ] vowels. The idea was that listeners would hear the longer duration of the stressed [ǽ] in other strings and so an unstressed [æ] would clearly fall short of the length of the stressed ones they had heard. However, because the durations used in the study reflected the fact that mid vowels are shorter than low vowels, there was not in fact a durational difference between the stressed and the unstressed test vowel in those strings, which could have helped contribute to the perception of an alternating rhythm.

Finally, if some full vowels in open syllables are not in fact stressed then there is an open theoretical question about why they do not reduce. (The same question does not occur with closed full vowel syllables, at least in word-final position, where they are known to occur stressless when adjacent to the main stress, e.g. [mæ̀.sə.ʧú.sɛ̱ts] 'Massachusetts.') In a word like *no̱tation*, the initial vowel might preserve its vowel quality from the root *no̱te*, but this analysis is not possible for *vo̱cation*, *ra̱ccoon*, etc. We leave this aspect of the analysis aside here, although acknowledge that if in fact full vowels can occur stressless then it is somewhat surprising that they do not do so more often.

7. Conclusion. Two perception studies were conducted in order to investigate whether unstressed full vowels and/or unstressed closed syllables can contribute to the perception of rhythmic alternation due to their bigger segmental content (compared to a typical unstressed [ə]). It was found that an [æ] that was given the acoustic properties of an unstressed syllable (apart from vowel quality) was rhythmically confusable with a stressed syllable ([Cǽ] or [Cʌ́]) in the same position. The same was not found for an unstressed [Cəs]. A full vowel, however, is a property of both types of syllables with an ambiguous stress-status that sparked the investigation: open syllables with a full vowel adjacent to the primary stress (e.g. *no̱.ta.tion*) where a secondary stress would cause a stress clash, and closed syllables with a full vowel that occur to the right of the primary stress syllable (e.g. *ca.ra.va̱n*), when the primary stress is expected to be the rightmost one in the word. Thus the full vowel study presented here offers evidence that segmental content can in fact be separated from the stress status of the syllable.

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