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4pSCb35. Speech rhythm in Korean: Experiments in speech cycling

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Korean has not been unanimously classified for rhythm class, and it lacks stress. Thus, it does not fit into views that rhythm rests on alternations of metrical strength. The goal was to examine what, if any, elements are used in Korean for rhythm purposes. It was hypothesized that the onsets of accentual phrases act as beats. The materials were 6 sentences; each was 9 syllables and three APs long. The number of syllables in each AP varied. Syllable composition also varied between CV and CVC. Native speakers repeated each sentence, fitting each repetition into beat intervals at three different metronome rates. Each AP was expressed as a ratio of the entire cycle. Two experiments were conducted. The first experiment suggests that speakers keep AP onsets in phase although syllable count and composition also affect phase. The results support our hypothesis that AP onsets operate similarly to stresses. The second experiment that used waltz rhythm showed that it is the only level of prominence, and no differentiation between the strength of these beats, such that it would produce waltz rhythm, is possible. The results suggest that Korean rhythm is not characterized by multiple levels of alternation between strong and weak constituents.

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1. INTRODUCTION

Rhythm is assumed to play an important role in organizing speech production, and leading to language acquisition and speech processing as well (among many, Cutler & Otake, T. 1994; Ramus, Nespor & Mehler, 1999). However, studies that have tried to find evidence for rhythm in the timing of particular prosodic constituents or in the durational variability of consonantal and vocalic intervals have not been successful (see Fletcher 2010 and Arvaniti 2012 for recent reviews). An alternative paradigm is *speech cycling*, which involves speakers repeating a phrase in time with periodic auditory stimuli (e.g. Cummins & Port 1998; Tajima & Port, 2003). Under these conditions speakers have been shown to keep metrically prominent elements, such as stressed-syllables in English and foot-initial syllables in Japanese *in stable phase*, where phase is the expression of the location of each such syllable with respect to a cycle defined by the onset of each successive phrase (cf. Cummins & Port, 1998; Tajima & Port, 2003).

Cycling, however, has been tested primarily with stress-timed English and Arabic and mora-timed Japanese (e.g. Cummins & Port, 1998 on English; Tajima & Port, 2003 on Japanese; Zawaydeh, Tajima & Kitahara on Arabic); on the other hand there is little cycling research on syllable-timed languages. Those that have been investigated are only Italian and Spanish briefly discussed in Cummins (2002). Cummins asked speakers of Italian and Spanish to produce phrases such as *munga la mucca* (Italian) and *busca la moto* (Spanish), while keeping to a waltz rhythm during each repetition cycle. He observed that most speakers could not do the task and concluded that this was due to the fact that Italian and Spanish are syllable-timed. It is not however clear what aspect of syllable-timing would make cycling impossible for the speakers. On the other hand, the materials used by Cummins provide some clues as to why the task was problematic: phrases like *munga la mucca* and *busca la moto* have each two stressed syllables, while the waltz rhythm the speakers were asked to adopt requires three beats; if stressed syllables acts as beats in Spanish and Italian, as they do in English, then the speakers difficulty had to do with the mismatch between the materials they were given and the rhythmic pattern they were asked to adopt. If so, then Cummins's results argue in favor of similarities between so-called syllable-timed languages like Spanish and Italian, on the one hand, and so-called stress-timed English, on the other, by highlighting the primary role of stress in both classes. His results further highlight the role of prosodic structure and of cross-linguistic differences in this regard: although stress plays the same part in English, Spanish and Italian, there is a difference between the former and the latter two in that in English it is possible to turn (some) unstressed syllables into stressed by providing a nonce vowel quality (cf. the indefinite article *a* being pronounced as a schwa in a phrase, but as [eɪ] if produced in isolation). In contrast, in Spanish and Italian this type of change is not possible. As a result, an English speaker can produce a phrase like *milk the cow* with waltz rhythm by giving to the word *the* a full vowel [mɪlk ðə kaʊ], while an Italian speaker cannot as readily do the same in *munga la mucca*.

An even more interesting problem with respect to cycling is presented by languages that do not have stress. One such language is Korean which has neither lexical stress nor a stress foot [Jun, 2005]. In addition, although the rhythm classification of Korean is not by any means settled, most studies conclude that it is syllable-timed (see Arvaniti, 2012, and references therein]. Given the structure of Korean and previous conclusions with respect to cycling, it would appear that cycling would be impossible in Korean. If that turned out not to be the case, however, the question that arises is what structure Korean speakers would use to create downbeats, and thus to successfully complete the cycling task. The aim of this study was to address these questions. Specifically, our aim was twofold. First, to examine whether Korean speakers can successfully produce speech under cycling. Second, to examine what prosodic element, if any, the speakers would use in lieu of stress. In particular, it was hypothesized that post-lexical prominences would act as beats playing the part stress plays in English. These post-lexical prominences were expected to be the initial syllables of Accentual Phrases (henceforth APs). Informally, APs can be described as a prosodic constituent that groups together Korean words and is intermediate between the prosodic word and phrase levels postulated for other languages (Jun, 2005). APs are marked by intonation, most typically a L(ow)H(igh)LH pattern that spreads through the AP (Jun 2005), and usually consist of 2 to 5 syllables in length (Kim, 2009). If our hypothesis is correct, what would determine the phase of specific syllables in cycling should be their position in an AP (first or other), not their order in the utterance. If, on the other hand, Korean is syllable-timed and syllables occur at strictly regular intervals, then cycling should reveal no regularities beyond those due to syllable count.

2. EXPERIMENT 1

2.1 Method

Participants

Five female and five male native speakers of Seoul Korean participated. Subjects were between 21 to 34 years of age, and were undergraduate or graduate students of the University of California, San Diego; all had some musical training but none was a professional musician. Undergraduates participated in the experiment in return for course credit; graduate students were compensated for their participation by being given a gift card of $15. None of them reported any history of a speaking or hearing impairment.

Materials

The materials consisted of short phrase that were all nine syllables and three APs long. The number of syllables in each AP varied following one of the three patterns shown in (a)-(c), allowing for syllables that had the same order in the phrase to be in different prosodic positions within an AP; e.g. σ3 is AP-final in the 3-3-3 pattern, but AP-initial in 2-4-3 and 2-2-5; likewise, σ7 is AP-initial in patterns 3-3-3 and 2-4-3, but AP-medial in 2-2-5. As noted, following standard assumptions in the use of the cycling paradigm, the hypothesis here was that AP-initial syllables would show comparable and stable phasing independently of their order in the phrase.

(a) 3-3-3: $[[\sigma_1\sigma_2\sigma_3]$ AP $[\sigma_4\sigma_5\sigma_6]$ AP $[\sigma_7\sigma_8\sigma_9]$ AP$]$ IP
(b) 2-4-3: $[[\sigma_1\sigma_2]$ AP $[\sigma_3\sigma_4\sigma_5\sigma_6]$ AP $[\sigma_7\sigma_8\sigma_9]$ AP$]$ IP
(c) 2-2-5: $[[\sigma_1\sigma_2]$ AP $[\sigma_3\sigma_4]$ AP $[\sigma_5\sigma_6\sigma_7\sigma_8\sigma_9]$ AP$]$ IP

Four phrases per pattern (3-3-3, 2-4-3, 2-2-5) were constructed; these differed in syntactic structure a feature that did not turn out to have any effect on the results and thus will not be discussed further here. In addition, to test the effect of syllable structure on phasing, one of the two phrases of each syntactic structure contained only CV syllables, the other mostly CVC. A sample of six phrases from the materials is shown in Table 1.

TABLE 1: Phrase Materials

Sentence Number	AP Pattern	Syllable Structure	Phrases
1	3-3-3	CV	[[norɛga]AP [nɔmuna]AP [nɨɾida]AP]IP ‘The song is too slow’
2	3-3-3	CVC	[[nambaŋdo]AP [matʃundɨt˺]AP [mannɨnda]AP]IP ‘The shirt also fits as if it is tailor-made’
3	2-4-3	CV	[[nado]AP [miɾudaga]AP [nɨdʒɔt’a]AP]IP ‘I was also late due to procrastination.’
4	2-4-3	CVC	[[naldo]AP [nuŋnukʰago]AP [mudɔpt’a]AP]IP ‘The weather is also humid and very hot’
5	2-2-5	CV	[[muɾi]AP [nɔmu]AP [midʒigɨnada]AP]IP ‘The water is too lukewarm’
6	2-2-5	CVC	[[mat’o]AP [mutʃɔk˺]AP [mandʒoksɨɾɔbt’a]AP]IP ‘The taste is also satisfying’

Procedures

In each trial, subjects were presented with one of the test phrases as a PowerPoint presentation on a computer screen. Subjects were asked to produce the phrase in time with a metronome which consisted of a single repeating tone. The metronome was set at 32, 36 and 40 beats per minute; thus, the interval between the beeps was 1900, 1700 and 1500 ms, respectively. Subjects started with the slowest tempo, then, produced the same phrase at successively faster tempi. No counterbalancing of tempi was attempted as it was clear from pilot data that the task would be sufficiently difficult without the added complication of tempi changing in different directions throughout the task. When the speakers completed producing a phrase with all three tempi, they moved on to the next phrase, starting again from the slowest tempo.

Subjects spent some time to get accustomed to the beep first. For each trial, they listened to the first four to six beeps, then, joined in to repeat the phrase. The subjects were asked to fit one phrase between two beeps and were also told that aligning the initial syllable or the last syllable of the phrase with a beep is acceptable. For this experiment, they were not required to follow a specific rhythmic pattern. Subjects produced the phrase as many times as they could without inserting breaths between repetitions. They were asked to stop when they needed to breathe. The number of repetitions within each breath varied between subjects from a minimum of 6 to a maximum of 24. On average, speakers produced 15 repetition per phrase and tempo; if a speaker produced fewer than 13 repetitions they were asked to repeat the task.

Measurements

Measurements were taken from 10 repetitions in the middle of each trial (where *trial* refers to the production of a phrase in time with the metronome set at a specific tempo). Initial and final repetitions were discarded to eliminate transient effects since subjects often produced a phrase with less stable rhythm at the beginning and end of a trial than in the middle; the number of discarded repetitions varied somewhat as the aim was to retain the middle 10 repetitions per trial. Since there were 10 speakers, 12 phrases, 3 tempi and 10 repetitions, a total of 3600 repetitions were collected (10 x 12 x 3 x 10 = 3600).

The measuring method used here is adapted from several earlier studies by Port and his colleagues (e.g. Cummins & Port, 1998; Tajima & Port, 2003). This method uses a relative measure of time instead of absolute measures such as milliseconds. The two relative measurements are *external phase* and *internal phase* as illustrated in Figure 1.

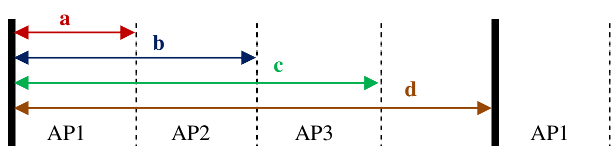


FIGURE 1: Definition of phases. Thick lines represent the beginning of each phrase repetition cycle; broken lines represent AP boundaries. In order to examine phasing, each AP was expressed as a ratio of a cycle, a/d, b/d, and c/d.

The external phase a/d and b/d expresses the timing of initial syllables of the second and third APs relative to the phrase repetition cycle. The phrase repetition cycle is the interval from the beginning of one phrase to the beginning of the next. Thus, the external phase of the second AP (AP2) is a/d, and this reflects both the relative duration of the first AP (AP1) and the stability of the onset of the second AP (AP2); the external phase of the third AP (AP3) is b/d and it reflects both the relative duration of AP2 and the stability of the onset of AP3. Last, the timing of the phrase boundary relative to the phrase repetition cycle, which is the timing of the AP3-final syllable, c/d, was measured. This measure reflects the relative duration of the phrase itself; (d), the phrase repetition cycle, is the sum of the phrase duration (c) and the pause inserted between repetitions of the phrase.

The vowel onset of the AP-initial syllable was chosen as an AP boundary marking point, since it is close to the P-center (among others, Fowler, 1979). Previous studies such as Cummins & Port (1998) used phrases the stressed syllables of which always started with a voiced stop (e.g. *buy Doug a beer*). For Korean, however, this was not an option for two reasons: first, Korean stops are always voiceless in phrase-initial positions, while Korean has a three-way stop distinction that does not fit the traditional IPA categories which rely on voicing and aspiration to categorize stops (Cho, Jun & Ladefoged, 2002). For this reasons, it was thought best to create natural-sounding phrases and use as AP-initial any sonorant consonants (nasals or liquids). Because of these differences with earlier cycling studies, the vowel-onsets of AP-initial syllable were marked instead of P-centers. This may have introduced some additional noise in the results but should not have materially altered them.

All measurements were taken from speech and not from the metronome beeps. The metronome was played to help speakers repeat a phrase regularly, and did not play a role in defining measuring points.

2.2 Experiment 1: Results

Speech Rate

The change in phase across different metronome rates was relatively small, suggesting that phasing was stable across tempi. Figure 2 shows the persistence of phase which suggests that speakers maintained the same rhythm across three different tempi. Figure 2 also demonstrates that the use of phases as measure of timing makes it possible to capture salient rhythmic properties of the repetitions. Stable rhythmic patterns across various metronome rates are revealed through persistence of phase across successive trials. Previous studies interpreted the relatively smaller changes in phases as indicating a quasi-discrete, stable rhythmic mode (Zawaydeh et al. 2002; Tajima, 1998). Because of the stability of the data across speech rates, speech rate was not used as a factor in subsequent analyses and data are pooled over speech rates (see below).

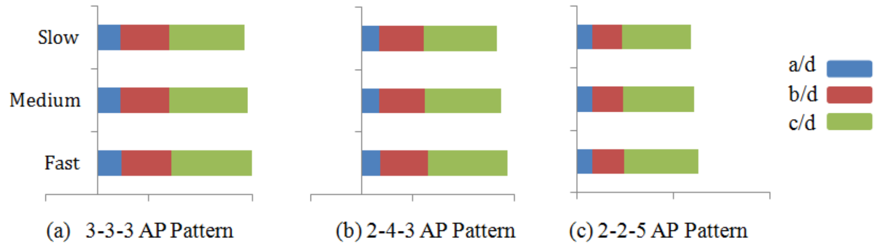
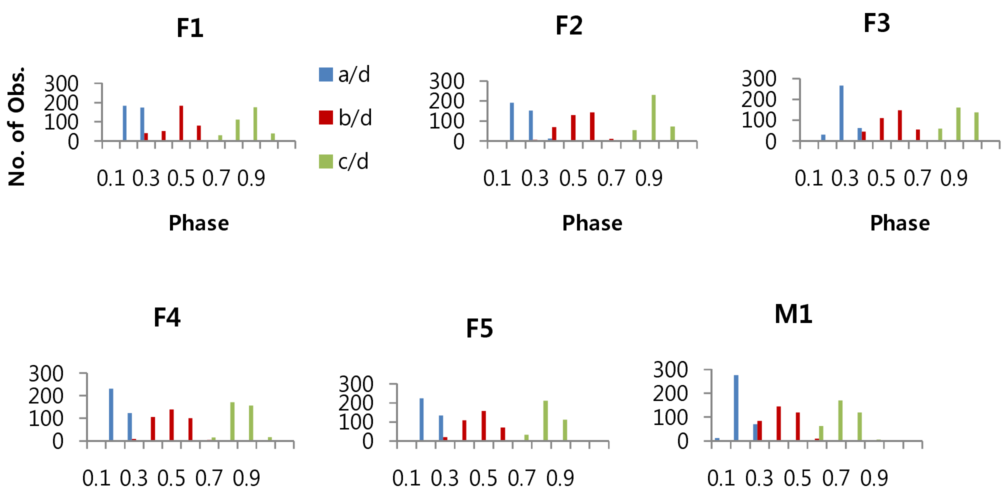


FIGURE 2. The mean values of phases, a/d, b/d and c/d, of each AP pattern for three different speech rates.

Phase histograms by speakers

To verify the hypothesis that AP-initial syllables would act as beats and occur at regular intervals, phase histograms separately for each speaker were examined. Figure 3 shows the distribution of phase for a/d (which represents the location of the AP2-initial syllable), b/d (which represents the location of the AP3-initial syllable) and c/d (which represents the duration of the entire phrase relative to the cycle). If AP-initial syllables act as downbeats in Korean, then their phases should show distributions with little or no overlap. As shown in Figure 3, this is the case for all speakers: they all had relatively similar histograms, reflecting the presence of minimal inter-speaker variation, while phases cluster into distinct groups and have narrow distributions.



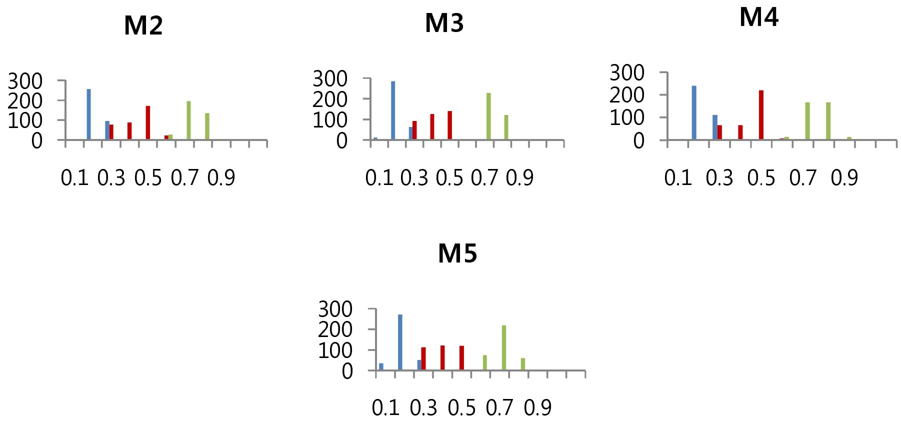


FIGURE 3. Histograms of phases measured by each speaker across phrases and speech rates.

Although the histograms shown above argue in favor of AP-initial syllables acting as downbeats in Korean and showing stable phasing, it is also worth considering if phasing showed any statistically significant effects of the number of syllables and the syllable structure of the phrases. To investigate these effects, ANOVAs were conducted with speaker as a random factor, phase as the dependent variable, and several independent variables (including speech rate and syntactic structure); here we focus on the two factors that significantly affected phase, namely syllable count (within AP) and syllable structure.

Syllable Count

As noted syllable count affected phase; see Figure 4. The phase a/d, which indicates the phasing of the initial syllable of AP2 in each phrase, differed between the 3-3-3 and the other two patterns, i.e. between the pattern in which AP2 started in the 4th syllable of the phrase and the two patterns in which AP2 started in the 3rd syllable of the phrase [$F(1,9) = 58.03$, $p < 0.001$]. Note, however, that the difference is smaller than would be anticipated by a model in which each syllable takes up the same amount of time. The same applies to the phase b/d, which indicates the phasing of the AP-initial syllable in AP3: in this case, it is 3-3-3 and 2-4-3 AP patterns that show the same phasing, while for 2-2-5 the value of the phase b/d is smaller suggesting that the AP3-initial syllable is produced significantly earlier in this case [$F(1,9) = 1238.8.03$, $p < 0.001$]. Like the results for a/d, however, these results are not compatible with the idea of each syllable taking up the same amount of time: if that were the case, one could expect the phase b/d for 2-2-5 (that is the phase that represents the position of the 5th syllable) to be even smaller compared to the ratios for 3-3-3 and 2-4-3 (both of which represent the position of the 7th syllable). Finally, the external phase of the entire phrase, c/d, showed no differences related to the AP syllable count, as every phrase had 9 syllables in total.

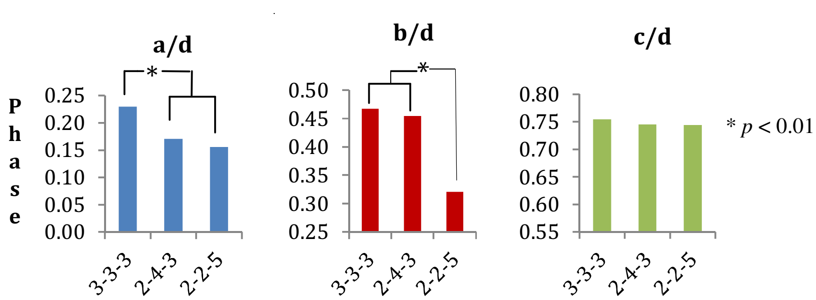
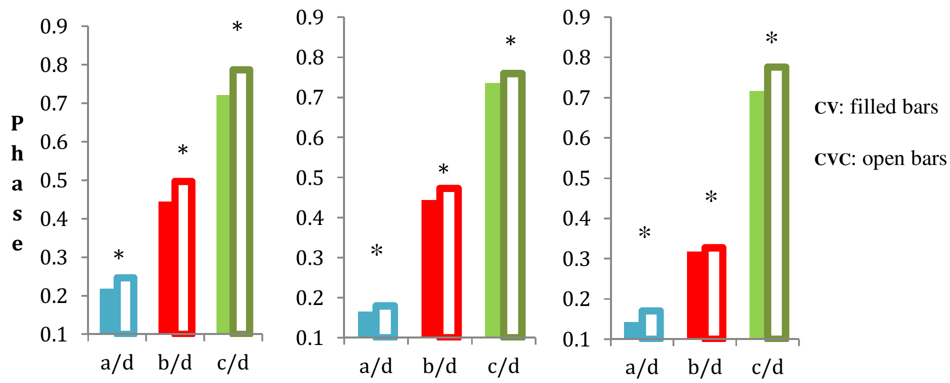


FIGURE 4. The mean phases, a/d, b/d and c/d, of each AP pattern across speech rates and speakers.

Syllable Structure

As noted above, syllable structure also had an effect on phase (see Figure 5). In all cases, AP-initial syllables were produced somewhat later in phrases that contained CVC syllables as compared to phrases with the same syllable count but only CV syllables. As shown in Figure 5, this applied to all AP patterns (3-3-3, 2-4-3 and 2-2-5) and to all ratios; (for a/d, $F(1, 9) = 110.38$, $p < 0.001$; for b/d, $F(1, 9) = 18.8$, $p < 0.01$; for c/d, $F(1, 9) = 72.54$, $p < 0.001$).



(a) 3-3-3 AP Pattern (b) 2-4-3 AP Pattern (c) 2-2-5 AP Pattern

FIGURE 5. The mean phases for each AP pattern depending on whether syllables were CV or CVC. (* p<0.01)

2.3 Experiment 1: Interim Discussion

The results suggest that speakers keep the onsets of APs in phase, clearly indicating that AP-initial syllables play the same part in Korean as stress does in English. This type of patterns can be interpreted as a post-lexical privileging of some syllables by virtue of their position in a particular phrase, and clearly shows that cycling is possible in a language that is by and large considered syllable-timed and is also known not to have lexical stress and foot structure. At the same time, the statistical analysis (of a type not undertaken in previous cycling studies) also suggests that phasing is not absolute and can be affected by both syllable count within each AP and by syllable structure. Interestingly, these two effects pull in opposite directions in that the effect of syllable count would seem to support a traditional syllable-timing understanding of the Korean results (with each syllable taking up the same amount of time), while the effect of syllable structure is fundamentally incompatible with that idea. If, on the other hand, the notion that the timing of a specific prosodic unit (the syllable or the foot) is controlled in production so as to remain of stable duration is replaced with the idea that the effects uncovered here represent incompressibility (Klatt 1976), then the data is not surprising: an AP with more segments or more syllables is likely to be longer than one with fewer segments or syllables respectively, because it is impossible for these segments or syllables to be produced without taking up any time at all. Thus the stability in phasing must be seen as being somewhat loose under all circumstances and possibly in all languages (a proposition that currently cannot be tested due to lack of statistical analysis of previous cycling results).

3. EXPERIMENT 2

3.1 Method

The second experiment followed the same method as Experiment 1 with one main difference: in Experiment 2, participants were asked to use a waltz rhythm while repeating phrases. They spent some time to get used to the waltz rhythm first; then in each trial, they listened to the waltz rhythm for a while, though during the task itself (i.e. when they were speaking) they listened only to the first beep of each cycle. Participants were asked to repeat the phrase reproducing the waltz rhythm as close as possible and to fit one phrase within the interval between beeps, aligning the onset of each phrase to a beep. Other procedures remained the same as in Experiment 1, except that 6 instead of 12 phrases were used. This decision was based on Experiment 1 which had shown that syntactic structure had no significant effect on results, while the use of 12 sentences made the task overlong and fatigued the participants.

Data were elicited from a different set of participants than those who took part in Experiment 1. Specifically, nine female native speakers of Seoul Korean took part in Experiment 2. They were in their early 20s and were undergraduates at the University of California, San Diego; none was a professional musician. They participated in the experiment in return for course credit. None of them had participated in a speech cycling experiment before. None reported any history of a speaking or hearing impairment. The recording of one speaker was of poor quality and was discarded; here data from five of the remaining eight speakers are presented.

3.2 Experiment 2: Results

The results of the second experiment corroborated those of the first. As the histograms in Figure 6 show, the speakers in Experiment 2 behaved similarly to each other and similarly to the speakers of Experiment 1 in that they showed narrow, non-overlapping distributions of phases, a/d, b/d and c/d. In addition, statistical analysis showed that there was no significant difference among speakers for a/d and b/d [for a/d, $F(4,2)=10.8$, n.s.; for b/d, $F(4, 2) = 9.3$, n.s.]; for c/d, some inter-speaker variation was found [$F(4, 5.9) = 91.2$, $p < 0.001$] presumably due to the fact that some speakers were faster talkers and thus took up less of the cycle with speech and had longer pauses at the end of each cycle. This result accords with the results regarding speech rates, which also showed no effect of speech rates for a/d and b/d [for a/d, $F(2, 8) < 1$; for b/d, $F(2,8) < 1$], but a significant effect for c/d [$F(2, 8) = 24.8$, $p < 0.001$]; as this suggests (see Figure 7a), at faster tempi the phrase overall took up more of the entire cycle than it did at slower tempi.

In addition, the results showed, as expected from Experiment 1, the effects of syllable count and syllable structure. Specifically, for a/d, there is small but significant effect of syllable count, such that AP2s starting on the third syllable were phased later than AP2s starting on the second syllable of the phrase [$F(1, 4) = 17.7$, $p < 0.05$]; the difference, as noted, was small (see Figure 7b). For b/d, there was also an effect of syllable count such that AP3s starting in the sixth syllable were phased later than those starting in the fourth syllable of the phrase [$F(1, 4) = 43.4$, $p < 0.01$]. The effect of syllable structure was less stable in this experiment compared to Experiment 1; a very small but significant difference was found for a/d [$F(1, 4) = 8.6$, $p < 0.05$] and c/d [$F(1, 4) = 69.4$, $p < 0.01$], but there was no significant effect of syllable structure on b/d [$F(1, 4) = 5.4$, n.s.] as shown in Figure 7c.

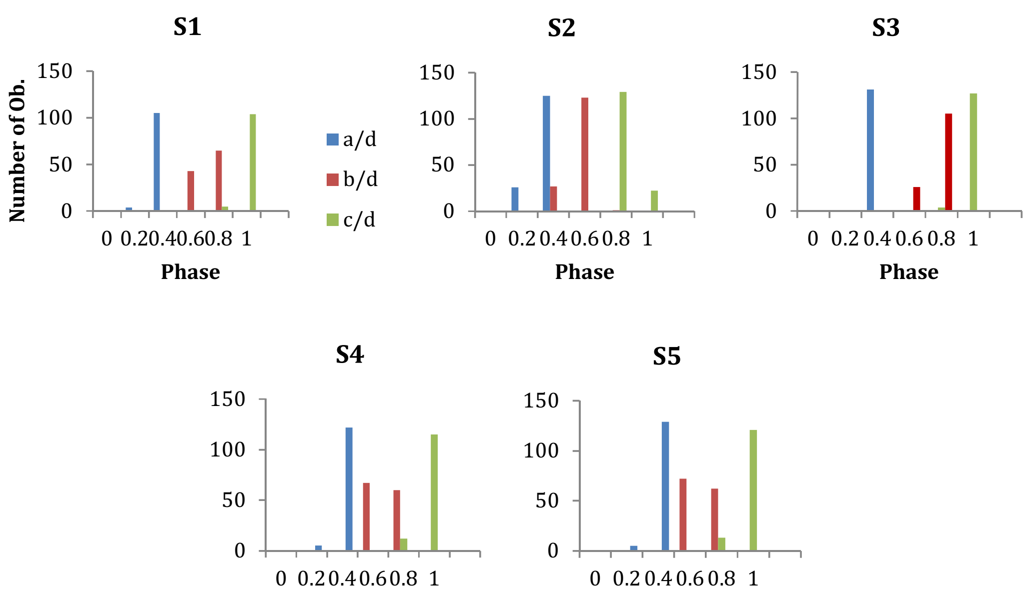
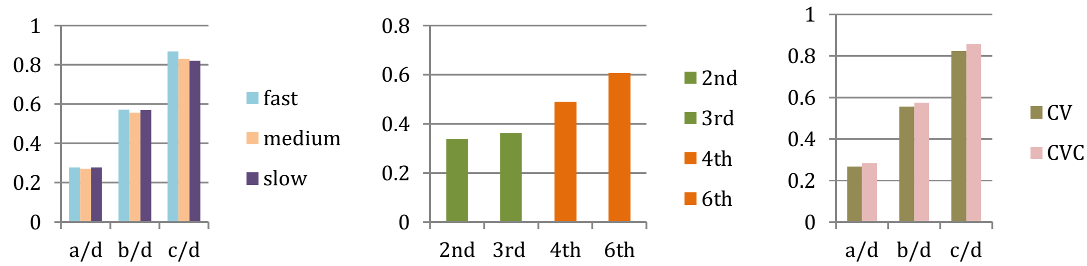


FIGURE 6. Histograms of phases measured by each speaker across phrases and speech rates.



(a) by speech rates (b) by AP-pattern (AP2-initial, AP3-initial) (c) by syllable structure

FIGURE 7. Mean phases a/d, b/d and c/d; results are presented separately for speech rate, AP-pattern and syllable structure.

4. DISCUSSION AND CONCLUSION

The results of the two experiments clearly show that Korean speakers can successfully complete a cycling task. In order to be able to do so, the speakers appear to utilize AP-initial syllables as downbeats, thereby assigning to these syllables the same role as English speakers assign to the stressed syllables. The results were even more regular in the second Experiment in which speakers were asked to use a waltz rhythm; although they often reported that they found this task difficult, and there were more of them who found it difficult than speakers who took part in Experiment 1, they were nevertheless able to use cycling and showed in fact smaller influences of the number of syllables in each AP and of syllable structure. In turn, this result lends credence to the idea of the developers of cycling that this task brings to the fore rhythmic behavior in speech production. In more general terms, these results have repercussions for our understanding of rhythm in that they show that speakers of a language said not to have stress or foot structure and typically classified as “syllable-timed” behave no differently from speakers of languages like English. The fact that the Korean speakers could accomplish their task by privileging specific syllables by virtue of their position alone could indicate that such privileging, which in some ways makes certain syllables stand out, may be a more general strategy in speech production independently of the prosodic structure or rhythmic classification of the language. More research with additional languages and with non-cycling speech in Korean is needed to answer this question.

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