말소리와 음성과학 제2권 제1호 (2010)
pp. 3~11

Intelligibility Improvement Benefit of Clear Speech and Korean Stops[1)]

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ABSTRACT

The present study confirmed the intelligibility improvement benefit of clear speech by investigating the intelligibility of Korean stops produced in different speaking styles: conversational, citation-form, and clear speech. This finding supports the Hypo- & Hyper-speech theory that speakers adjust vocal effort to accommodate hearers' speech perception difficulty. A progressive intelligibility improvement was found for the three speaking styles investigated: clear speech was more intelligible than citation-form speech citation-form speech was more intelligible than conversational speech and clear speech was also more intelligible than conversational speech. These findings suggest that the manipulations to elicit three distinct speaking styles in a laboratory setting were successful. Korean lenis stops showed the least intelligibility improvement among the three Korean stop types, and this result suggests that lenis stops should be more resistant to intelligibility enhancement efforts in clear speech than aspirated and fortis stops.

Keywords: Korean stops, clear speech,intelligibility benefit, speaking style

1. Introduction

The perceptual clear speech effect, that is, the intelligibility benefitof clear speech over conversational speech has been well established in numerous studies with various listener populations: normal-hearing listeners (Moon, 1991; Ferguson, 2004; Krause & Braida, 2004), hearingimpaired listeners (Picheny, Durlach, & Braida, 1985; Payton, Uchanski, & Braida, 1994; Ferguson & Kewley-Port, 2002), and listeners with limited experience in the test language (Bradlow & Bent, 2002; Bradlow & Alexander, 2007). Assuming that clear speechproduction aims to enhance access to acoustic cues in the speech signals and help listeners to access to the message, clear speech research has mostly examined the intelligibility benefit of clear speech with stimuli presented in a condition simulating degraded access to the speech signals, typically presented in noise (Payton, Uchanski, & Braida, 1994; Ferguson & Kewley-Port, 2002; Ferguson, 2004). The conversational and clear speech tokens are typically elicited in a laboratory setting with specific instructions, such as "read naturally as possible as you can as if you are talking to friends" or "read as carefully and clearly as you can". The majority of studies were conducted on English with a few exceptions (e.g., Smiljanic & Bradlow, 2005 in Croatian).

As a follow-up study of Kang & Guion (2008), the current study investigated the intelligibility benefit of clear speech in light of the perception of Korean stops. In the clear speech production experiments in Kang & Guion (2008) (hereafter "Experiment 1"), Korean stops were produced in conversational, citation-form, and clear speaking styles, and the three different speaking styles were tested for intelligibility of Korean stops[3)]. Based on the hypothesis of the Hypo- & Hyper-speech theory

1) Portions of this paper are based on the author's doctoral dissertation (Kang, 2009) and paper (Kang & Guion, 2008).

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Received: September 1, 2009.
Revisor received: January 23, 2010.
Accepted: January 27, 2010.

3) "Conversational" speech in Kang & Guion (2008) was elicited in a more casual and reduced manner compared with conversational speech in previous clear speech research. For this, a production task performed during a meaning-exploration job was used. See Kang & Guion (2008) for the details of the elicitation design.

(Lindblom, 1990) that speakers produce more “exaggerated” or “hyperarticulated”speech to accommodate hearers experiencing speech perception difficulty, Experiment 1 predicted that articulatory modifications aiming at intelligibility improvement include the enhancement of distinctiveness between phonological categories. The results of the experiments indicated that the acoustic distances between Korean stop contrasts were expanded in clear speech compared with conversational and citation-form speech. Perceptual experimentsin this paper aimto investigate whether this contrast enhancement in clear speech production would lead to improvement in the intelligibility of the stops. For this purpose, the recordings from Experiment 1 were submitted for the preparation of speech perception experiments in this study.

Unlike previous clear speech research, the novel speaking style manipulation in Experiment 1 was to elicit, along with citation-form and clear speech, “conversational speech”. This speaking style was intended to be more casual and reduced than citation-form speech, which has been labeled as conversational speech in other studies (see Kang and Guion, 2008 for details). Thus, another goal of the current study was to test whether the speaking style manipulations in Experiment 1 that attempted to elicit three distinct speaking styles were effective in terms of speech perception. The specific questions addressed in the current study were whether Korean stops produced in a clear speech style were more intelligible than those produced in a conversational style, and at the same time whether there was a difference in intelligibility between the conversational and citation-form speaking styles and between the citation-form and clear speaking styles. Thus, whether there was a progressive improvement in intelligibility across the speaking styles from conversational to citation-form and to clear speech was examined.

2. Intelligibility experiment

2.1 Participants

Eleven native speakers of Korean participated in the perception task. All of the eleven participants were female speakers and their length of staying in the U.S. ranged from 0.3 to 8 years (mean = 3.25 years). None of the listeners had participated in Experiment 1. All of the participants were speakers of the Seoul or Kyung-gi dialect of Korean and all were in the twenties in their age (mean = 23 years). The participants were all international students at the University of Oregonand reported that they used Korean in daily activities with their Korean friends or family members. None of the participants reported any history of language disorder or hearing problems.

2.2 Perception stimuli

The stimuliused for the syllable-in-noise perception task were taken from the recordings from Experiment 1. The initial syllable of the three test words, 탄탄하다 (/t^{h}an.t^{h}an.ha.ta/), 단단하다 (/tan.tan.ha.ta/), and 딴딴하다 (/t*an.t*an.ha.ta/) was excised and used for the preparation of the perception stimuli. Thus, three types of syllables, /t^{h}an/, /tan/, and /t*an/ were used as test stimuli in the current study. In Experiment 1, 11 younger speakers (six females and five males) produced the three test words twice for each of the three speaking styles (conversation, citation-form, and clear speech) and thus, 18 syllables (2 productions × 3 test words × 3 speaking styles) were submitted to the preparation of test syllables for each of the 11 speakers. Accordingly, 198 test syllables were prepared in total.

In order to equate amplitude over the test stimuli, speaking styles, and 11 speakers, the amplitude of all of the test syllables was normalized in terms of Root Mean Square (RMS) amplitude. Because most of the energy was distributed on the vowel /a/ and nasal /n/ portions and also because the boundary between the vowel and the nasal was hard to determine, the normalization process was performed to the combined amplitude of the vowel and nasal portion. In other words, the amplitude of the entire syllable, that is, stop + vowel + nasal was normalized to the combined amplitude level of the vowel + nasal portion. Each of the test syllables went through the following procedure. First, since the normalization level was set at 70 dB SPL, a sound pressure value in Pascal (p) equivalent to 70 dB sound pressure level (SPL) was obtained based on the following formula.

$$70\ \text{SPL (dB)} = 20 \log \frac{p}{p_0}$$

where p is a value in Pa, and p_0 is 0.00002 Pa

The obtained Pa value equivalent to 70 dB SPL was 0.063245.Then, the RMS amplitude of each of the test syllable was normalized to this Pascal value of 0.063245. To do this, the RMS amplitude level of the vowel and nasal portion was taken in Pascal, and the ratio of the amplitude of this vowel and nasal portion (in Pa) to 0.063245 Pa was obtained. Then, the obtained ratio was applied to the RMS amplitude of the entire test syllable. The ratio was less than 1 when the amplitude of the vowel and nasal portion (in Pa) was less than 0.063245 Pa (70 dB), and the ratio was greater than 1 when the amplitude of the vowel and nasal portion was greater than the reference level of 0.063245 Pa. In this way, the test syllables were normalized in

amplitude in a way that the average amplitude value over the entire syllable (that is, RMS amplitude of the entire syllable) is minimally affected by the varying amplitude structure over the three stop types[4].

As the next step in preparing the test stimuli, the normalized test syllables were then mixed with a multi-talker babble noise. First, the speech-like babble noise was created using the speech of six speakers.In order to produce multi-talker speech in a lab setting, six Korean speakers read a short Korean text simultaneously. Each speaker started to read at different times so that the readings of the six speakers have different phases in time. As a result, the readings were completely unintelligible (as judged by the author) and sounded like the "buzzing" noise produced when a large group of people talk simultaneously. The recordings were made in a sound-attenuated booth using a Shure B.G 5.1 condenser microphone and a Marantz digital recorder (PMD 670) at the sampling rate of 22,500 Hz. The six speakers were standing around the microphone approximately 2 feet away while they were reading.

After saving and storing the recordings in a wave file, two 30 second stretches of the recorded noise signal were randomly cut out and were mixed with each other to make a 12-talker babble noise (Ferguson and Kewley-Port, 2002; Ferguson, 2004). From this 30 second stretch of the noise file, a one second strechwithout an apparent pitch contour was excised and used as the source noise to make a masking noise. This process was used to ensure that the noise signals were not intelligible and thus, they only functioned as a background noise masking the test syllables.

For the last step of creating test stimuli, the multi-talker masking noise and the test syllables were mixed with each other. The mixing procedure was as follows. Each of the test syllables was mixed with the 1 second source noise. The length of the source noise was set by the duration of the test syllables. The test syllable was centered within the source noise with a head and tail stretch of 100 milliseconds (ms). This required the noise to be 200 milliseconds longer than the test syllable. So, for example, if the test syllable was 450 ms, the noise signal was edited to 650 ms from the beginning out of the entire 1000 ms duration. After each of the noise files was edited according to the duration of the test syllables, amplitude of each of the noise signals was rescaled in dB. The signal to noise ratio (S/N ratio) was chosen at -6 dB S/N after a series of pilot tests at 0, -1, -3, and -6 dB S/N. At -6 dB, the rate of correct response reached up to 85 to 90 % for the clear speech stimuli. The other S/N ratios showed a ceiling effect and thus, they were not selected. Through the mixing processes, a total of 198 stimuli was created (2 productions × 3 types of test syllable (t^han, tan, t*an) 3 speaking styles (conversational, citation-form, clear) × 11 speakers).

2.3 Procedure

The 198 test stimuli were presented in a random order across the 3 syllable types, 3 speaking styles, and 11 speakers. 11 speakers were all mixed considering a ceiling effect. Pilot tests returned a ceiling effect due to the salience of the role of F0 when the test stimuli were presented with a speaker blocked.During an informal talk with the experimenter, the author, the participants reported that they easily get familiarized with the idiosyncrasy of individual speakers' F0 range and were inclined to overly attend to F0 in identifying the /tan/ type from the other two syllable types. In other words, due to excessive F0 effect, the perception task was too easy to return reliable data with stimuli from an individual speaker. Additional pilot tests with greater S/N ratio did not resolve this problem. Accordingly, in order to alleviate the effect of F0 and get rid of the ceiling effect, the individual F0 idiosyncrasy was controlled by the speakers being all mixed.

The listeners participated in a forced-choice identification task. Three response categories of 탄 /t^han/, 단 /tan/, and 딴 /t*an/ were displayed on a computer screen in Korean orthography, and the participants were asked to choose one of these three choices when listening to the stimuli delivered binaurally through headphones (Sony MDR-7506). Each of the 198 test stimuli waspresented four times and thus, 792 responses were collectedfrom each of the 10 listeners. A small set of practice stimuli was provided before the main task to familiarize participants with the format of the task.The entire task took about 50 minutes including a practice session and it was conducted in the phonetics lab at the University of Oregon. The listeners who participated in the pilot tests were excluded from the participant pool of the current experiment.

2.4 Statistical design

For the dependent variable, the number of correct responses to each syllable type was entered. Because the question of interest

4) The fortis stop + vowel + nasal type, that is, /t*an/ type had the greatest ratio of vowel + nasal duration to the entire syllable duration compared with the aspirated or lenis stop vowel + nasal syllable (/t^han/ or /tan/) due to the shortest duration between stop release to the vowel onset.

was whether for each syllable type there was a difference in the level of intelligibility between the speaking styles, the number of correct responses was entered in a matrix of syllable type by speaking style. For each syllable type (/t^{h}an/, /tan/, and /t*an/), two test stimuli were created for each of the 11 speakers. In addition, each test stimulus was presented four times. So, for example, the /t^{h}an/ type had 88 instances in the entire stimulus set for each speaking style. The number of the correct responses for these 88 instances for each listener was entered as a data point for the dependent variable. Syllable type (/t^{h}an/, /tan/, and /t*an/) and speaking style (conversational, citation-form, and clear) were entered as independent variables and treated as repeated measures.

2.5 Results

A univariate repeated measures analysis conducted with factors, speaking style and syllable type returned significant main effects for speaking style [F(2, 20) = 34.368, p < .001] and syllable type [F(2, 20) = 12.016, p < 0.001]. The analysis also revealed an interaction of speaking style × syllable type [F(4, 40) = 9.4, p < 0.001]. These results indicate that the effect of speaking style varied depending on the syllable types.

Following the investigation of the overall effects of speaking style and syllable type on the intelligibility of the Korean stops, pairwise comparison tests were performed to compare two particular speaking styles (α-level was set at 0.016 for the three comparisons). The comparison between conversational and citation-form styles showed significant main effects for speaking style [F(1, 10) = 9.691, p = .011] and syllable type [F(2, 20) = 14.719, p < 0.001]. However, the interaction between these two factors was not significant (p = 0.384). For the comparison between citation-form and clear speech styles, significant main effects for speaking style [F(1, 10) = 24.9, p = .001] and syllable type [F(2, 20) = 14.105, p < 0.001] were found, in addition to a significant interaction between speaking style and syllable type [F(2, 20) = 14.459, p < 0.001]. Lastly, the same results were found for the comparison between conversational and clear styles. Significant main effects for speaking style [F(1, 10) = 58.075, p < .001], syllable type [F(2, 20) = 7.35, p = .004], and a significant interaction between speaking style and syllable type [F(2, 20) = 13.017, p < .001] were returned. These results indicate that there was a difference in the level of intelligibility for all of the three compared sets of speaking styles. In addition, the results indicate that the intelligibility difference between conversational and clear speech styles and also between citation-form and clear speech styles varied depending on syllable type. These results are presented in Table 1. The left-most column in Table 1 shows the intelligibility level averaged over the three syllable types for each speaking style, representing overall intelligibility differences between the speaking styles. The other three columns show the mean intelligibility level over the 11 listeners in a matrix of syllable type by speaking style.

Table 1. Mean percentage of correct response foreach syllable type and speaking style over 11 listeners. Numbers in the parentheses represent the mean correct responses over 11 listeners.

Mean over /tan/, /t^{h}an/, and /t*an/ types	/tan/	/t^{h}an/	/t*an/
Conversational			
77 % (67.7)	77 % (67.6)	83 % (72.8)	71 % (62.6)
Citation-form			
80 % (70.7)	80 % (70.5)	88 % (77.4)	73 % (64.2)
Clear speech			
89 % (77.9)	83 % (73.1)	94 % (82.5)	89 % (78)

Table 2. Results of paired-samples t-tests for each of the three syllable types between conversational - citation-form, conversational - clear speech, and citation-form – clear speech pairs. Asterisks (*) indicate significant differences in intelligibility between the two speaking styles investigated (α = 0.005). CV = conversational style, CF = citation-form style, and CS = clear speech style

	Pair	t	df	Sig. (2-tailed)
/tan/	CV – CF	-1.443	10	.180
	CV – CS	-4.353	10	.001*
	CF – CS	-1.219	10	.251
/t^{h}an/	CV – CF	-3.714	10	.004*
	CV – CS	-4.517	10	.001*
	CF – CS	-2.834	10	.018
/t*an/	CV – CF	-1.111	10	.292
	CV – CS	-8.863	10	.000*
	CF – CS	-7.864	10	.000*

The overall intelligibility over the three syllable types shown in Table 1 indicates intelligibility improvement for both citation-form and clear speech compared with conversational speech. However, the size of the overall intelligibility improvement varied. Clear speech showed greater improvement than citation-form speech. Citation-form speech showed a 3% increase in the mean correct response percentage from conversational speech, whereas clear speech showed a 12 % increase from conversational speech. At the same time, the

intelligibility improved progressively in the sequence of conversational,citation-form, and clear speech (see the left-most column of Table 1).

Next, in order to investigate the effect of speaking style for each of the three syllable types and thus to further investigate the interactions found between the speaking style and syllable type, paired-samples t-tests were performed.For each of the /t^{h}an/, /tan/, and /t*an/ syllable types, conversational and clear speech styles were paired and compared to each other. In addition, conversational and citation-form styles on the one hand, and citation-form and clear speech styles on the other hand, were compared in the same manner. In total, nine comparisons were made. Table 2 presents the results of the nine paired samples t-tests (α-level was adjusted to 0.005 for the nine comparisons).

When each of the syllable types was examined individually, clear speech and citation-form speech revealed further differences. Clear speech showed significant intelligibility improvements over conversational speech for all of the three syllable types (see the middle rows for each syllable type in Table 2).However, for citation-form speech, the /t^{h}an/ syllable type only showed significant improvement (p = 0.004) over conversational speech (see the top rows for each syllable type in Table 2). In addition, the effect of syllable type was greater on clear speech than on citation-form speech. In clear speech, the intelligibility improvement over conversational speech varied greatly depending on syllable type. The increase was greater for /t*an/ type, 18 % than those for /tan/ type, 6% and /t^{h}an/ type, 11% (compare the top-row conversational style and bottom-row clear speech style in Table 1). In contrast, the intelligibility improvement in citation-form speech over conversational speech had a less variation. The increase was 3%, 5%, and 2% for /tan/, /t^{h}an/, and /t*an/ types, respectively (see the top-row conversational style and middle-row citation-form style in Table 1. In fact, the improvement trend was significant only for the /t^{h}an/ types as shown in Table 2). These disproportionate improvements between the syllable types and the speaking styles were reflected in the interaction of speaking style and syllable type reported earlier.

The clear speech style showed intelligibility enhancement over citation-form style as well. The size of overall improvement was 9 % (See Table 1). As was the case for citation-form style over conversational style, the improvement was not present for all of the three syllable types. Only the /t*an/ type was significantly more intelligible in clear speech compared with citation-form speech (p < .001) (see the bottom row for each syllable type in Table 2).

To summarize, clear speech showed an intelligibility improvement over conversational speech for all of the three syllable types. Clear speech also showed a trend toward intelligibility improvement over citation-form speech, but only had a significant improvement for the /t*an/ type. Similarly, citation-form speech showed a general improvement over conversational speech, but had a significant improvement only for the /t^{h}an/ type. However, clear speech had a greater intelligibility improvement than citation-form speech over conversational speech for all three syllable types.

3. Discussion

The finding that Korean stops produced in the citation-form style were in general more intelligible than those in the conversational style relates to the work of Harnsberger, Wright, & Pisoni (2008). In Experiment 1, in an attempt to tackle the limit of other clear speech research dealing with only citation-form and clear speech, another speech mode named “conversational” speech was elicited. In order to minimize the degree of self monitoring commonly occurring in the text reading tasks, a meaning-explanation task was designed. The rationale for adding a more “hypoarticulated”speech style was to provide experimental data containing more distinctively hypoarticulated and hyperarticulated speech and thus to show more clearly the talkers’adaptive articulatory effort to listeners’ perceptual need.

Having a similar motivation of eliciting reduced, naturalistic speech in a laboratory setting closer to natural, conversational speech, Harnsberger et al. (2008) attempted to elicit three different speaking styles: reduced, citation, and hyperarticulated. To elicit a reduced speech style, speakers were prompted to perform a distracter task recalling multiple digits of number from short-term memory while reading sentences. The results of Harnsberger et al.’s (2008) work revealed overall success of eliciting three distinctive speech styles in a laboratory setting. The reduced and citation speech produced by 6 out of 12 speakers were impressionistically judged distinctive from each other by native listeners. The citation and hyperarticulated speech styles were also distinctive from each other.Their acoustic analyses revealed a limited difference between reduced and citation speech primarily on the durational properties for key words and sentences among other measures.

Even though Harnsberger et al. (2008) did not directly measure the intelligibility difference between the speaking styles they elicited, the findings from Experiment 1 and the current study are

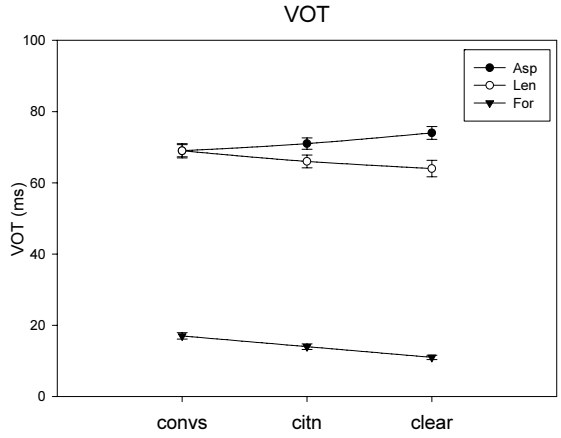
parallel to Harnsberger et al.'s (2008) findings. In Experiment1, conversational and citation-form speech were less distinctive from each other for the three acoustic measures investigated compared with the conversational and clear speech comparison (see Figures1 and 2). The results of the current study indicated that citation-form speech was less distinctive from conversational speech than clearspeech in its intelligibility.Similarly, in Harnsberger et al. (2008), the distinctiveness judgment score between the speaking styles revealed that the scores for reduced and citation-form speech were not as different as the scores for citation-form and hyperarticulated speech or reduced and hyperarticulated speech. Likewise, in Experiment 1, the percent correct response for the test syllables progressively improved over the three speaking styles (see Table 1). These findings suggest that the attempts in Experiment 1 to elicit speech signals residing on the hypo-speech and hyper-speech continuum (Lindblom, 1990) were successful.

In addition to the finding of the overall intelligibility improvements between the three speaking styles, the findings of the current experimentincluded a varying degree of intelligibility improvement across the three syllable types. The /t*an/ type had the greatest improvement of 16 % in clear speech over conversational speech, the /tan/ type had the least improvement of 6 %, and the /t^han/ type had the medium 11 % improvement (see Table 1).At the same time, when it comes to a comparison of citation-form speech with conversational speech, the /t^han/ type only had an improvement over citation-form speech. Similarly, only /t*an/ type had significant improvement for the comparison of clear speech with citation-form speech (see Table 2). Because the tokens of the three syllable types were presented to the listeners across the three syllable types (/t^han/, /tan/, and /t*an/), a discussion on thesevarying intelligibility improvements must be also made in light of the perception of the three-way manner contrasts of Korean stops.

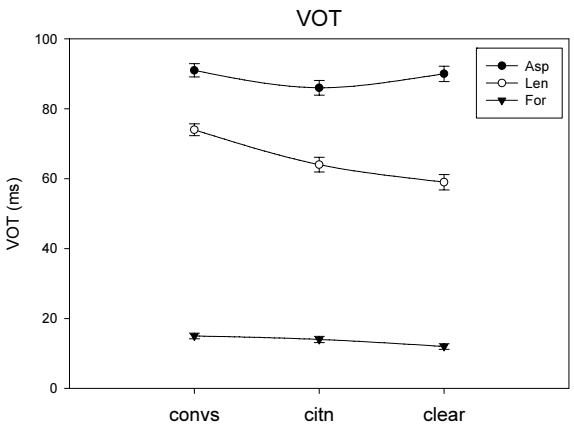
The significant improvement for the /t*an/ type in clear speech over citation-form speech may be related to the voice quality property for the /t*an/ type.The tense or creaky voice quality of the /t*an/ type enhanced in clear speech might contribute to the distinction from /tan/ and /t^han/ types, which are associated with breathy voicing quality. The results from investigation of acoustic-phonetic modifications in clear speech production in Kang & Guion (2008) support this explanation. As can be seen from Figure 1(b), the H1-H2 values for fortis stops greatly decreased in the clear speech style (indicating increased tense or creaky voicing), and this may explain the greatest intelligibility improvement of the /t*an/ type in clear speech over citation-form speech.

As for the /t^han/ type, the greater intelligibility compared with the /tan/ or /t*an/ type for all of the three speaking styles (ranging from 83 to 94% in Table 1) may be related to the acoustic characteristics associated with aspirated stops. With the highest F0 and the longest VOT values (see Figure 1(a) and (c)), perhaps the /t^han/ type was least confused with thelowest F0 /tan/ type and the shortest VOT /t*an/ type, and this might contribute to the highest intelligibility of the /t^han/ type among the three syllable types.

In contrast, regarding the intelligibility of the /tan/ type, the /tan/ type have a less distinctive VOT and F0 difference from the /t*an/ type compared with the /tan/-/t^han/ contrast, and this might give rise to the greater level of confusion forthe /tan/-/t*an/ distinction. In addition, the "tense" voice quality of the /t*an/ type was less salient for the tokens produced in the conversational and citation-form styles (see Figure 1(b)), and this might contribute, in conjunction with the less distinctive VOT and f0 difference, to the greater confusion with the /tan/ type. Lastly, the low F0 effect of the lenis /tan/ type on the distinction from the other two types might have been diminished by the between-speaker presentation of the test stimuli (6 female and 5 male speakers), and this may be related to the least intelligibility improvement of the /tan/ type. In fact, as can be seen Figure 1 (c), one of the reliable parameter that differentiate lenis stop from the other two types, "low F0" was not enhanced at all in clear speech. Instead, it shows a slight F0 increase in clear speech.



(a)



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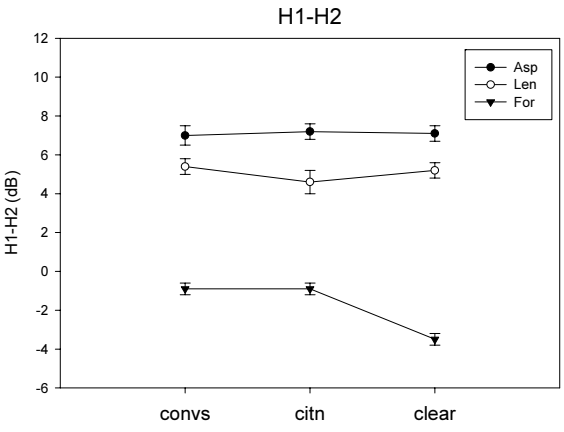

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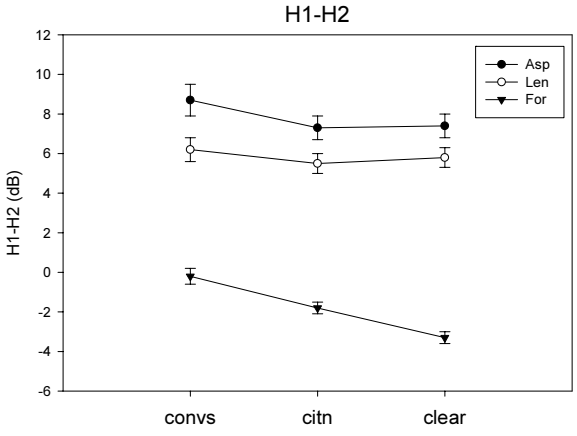

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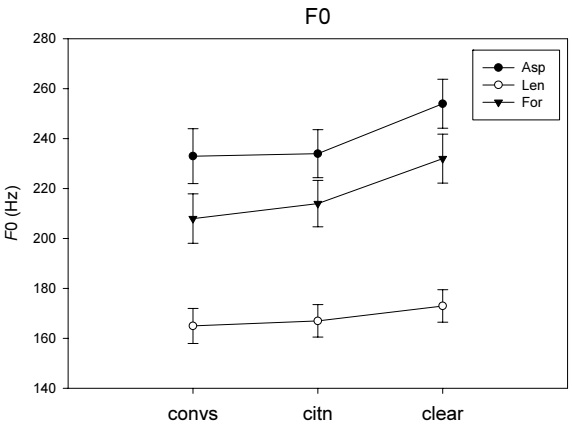
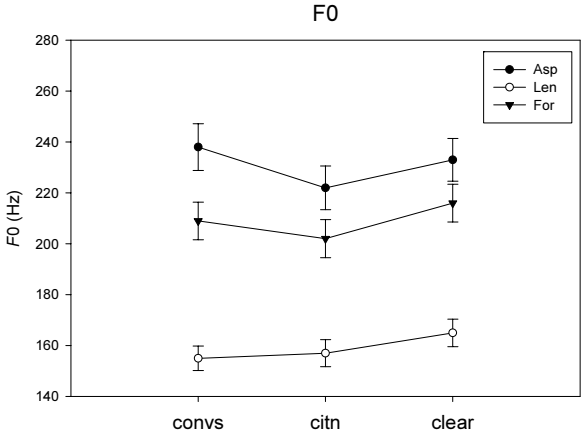


(c)



(c)

Figures 1 (left column: younger speakers) and 2 (right column: older speakers). Mean values with standard errors for the production of Korean stops (aspirated, lenis, fortis) in conversation, citation-form, and clear speech styles by the younger group (n=11) for three acoustic correlates [(a) VOT; (b) H1-H2; (c) F0] excerpted from Kang and Guion (2008).

4. Summary and conclusion

The primary finding of the current study that the clear speech showed intelligibility improvement over conversational speech and citation-form speech confirms the listener-orientation of clear speech, and the finding supports the Hypo- & Hyper-speech theory (Lindblom, 1990) that speakers adjust vocal effort to accommodate hearers' speech perception difficulty. Korean stops produced in the more careful, clear speech style were more intelligible than those produced in the more casual, conversational and citation-form speech styles. This finding is compatible with the findings of studies dealing with clear speech intelligibility over citation-form speech for syllables and vowels (Ferguson & Kewley-Port, 2002; Gagne et al., 2002), as well as with other studies that investigated the same question for sentences (Picheny et al., 1985; Uchanski et al., 1996; Krause & Braida, 2002; Smiljanic & Bradlow, 2005).

In addition to the intelligibility benefit of clear speech over citation-form speech, the current study showed that Korean stops produced in citation-form style were generally more intelligible than those produced in conversational style. Thus, intelligibility of the three distinct speaking styles improved progressively in the sequence of conversational, citation-form, and clear speech. These findings support, along with the acoustic-phonetic modifications found from Experiment 1 in Kang & Guion (2008), the gradation nature of phonetic process (Johnson et al, 1993) and the hypo- and hyper-speech continuum hypothesis (Lindblom, 1990).

Finally, the intelligibility improvement patterns compared between stop types suggested that the lenis type /tan/ should be more resistant to intelligibility improvement effort in clear speech to accommodate hearers' speech perception difficulty, compared with the aspirated /t^han/ and fortis /t*an/ types.

References

Bradlow, A. R. & Bent, T. (2002). "The clear speech effect for non-native listeners", *Journal of the Acoustical Society of America*, Vol. 112, pp. 272-284.

Ferguson, S. (2004). "Talker differences in clear and conversational speech: Vowel intelligibility for normal-hearing listeners", *Journal of the Acoustical Society of America*, Vol. 116, pp. 2365-2373.

Ferguson, S. (2004). "Talker differences in clear and conversational speech: Vowel intelligibility for normal-hearing listeners", *Journal of the Acoustical Society of America*, Vol. 116, pp. 2365-2373.

Ferguson, S. & Kewley-Port, D. (2002). "Vowel intelligibility in clear and conversational speech for normal-hearing and hearing-impaired listeners", *Journal of the Acoustical Society of America*, Vol. 112, pp. 259-271.

Gagne, J.-P., Rochette, A.-J. & Charest, M. (2002) "Auditory, visual, and audiovisual clear speech", *Speech Communication*, Vol. 37, pp. 213–230.

Harnsberger, J., Wright, R. & Pisoni, D. (2008). "A new method for eliciting three speaking styles in the laboratory", *Speech Communication*, Vol. 50, pp. 323-336.

Johnson, K., Flemming, E. & Wright, R. (1993). "The hyperspace effect: Phonetic targets are hyperarticulate", *Language*, Vol. 69, pp. 505-528.

Kang, K.-H. & Guion, S. G. (2008). "Clear speech production of Korean stops: Changing phonetic targets and enhancement strategies", *Journal of the Acoustical Society of America*. Vol. 124, pp. 3909-3917.

Kang, K.-H. (2009). *Clear speech production and perception of Korean stops and the sound change in Korean stops*, Unpublished Doctoral dissertation. University of Oregon.

Krause, J. & Braida, L. (2004). "Acoustic properties of naturally produced clear speech at normal speaking rates", *Journal of the Acoustical Society of America*, Vol. 115, pp. 362-378.

Lindblom, B. (1990). "Explaining phonetic variation: A sketch of the H and H theory", In W. J. Hard-castle and A. Marchal (Eds.), *Speech production and speech modeling* (pp. 403-439), Dordrecht, Netherlands: Kluwer Academic.

Moon, S.-J. (1991). *An acoustic and perceptual study of undershoot in clear and citation-form speech*, Doctoral dissertation. University of Texas at Austin.

Payton, K., Uchanski, R. & Braida, L. (1994). "Intelligibility of conversational and clear speech in noise and reverberation for listeners with normal and impaired hearing", *Journal of the Acoustical Society of America*, Vol. 95, pp. 1581-1592.

Picheny, M., Durlach, N. & Braida, L. (1985). "Speaking clearly for the hard of hearing I: Intelligibility differences between clear and conversational speech", *Journal of Speech and Hearing Research*, Vol. 28, pp. 96-103.

Smiljanic, R. & Bradlow, A. R. (2005). "Production and perception of clear speech in Croatian and English", *Journal of the Acoustical Society of America*, Vol. 118, pp. 1677-1688.

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