

Variability and Duration of Voice Onset Time in Childhood Apraxia of Speech in Korea: Results of the Spectrum Study

Junbeom Park¹ Haewon Byeon^{2,3*}

1 JUN Rehabilitation Medicine, Seoul, South Korea

*2 Dept. of Speech Language Pathology & Audiology, Nambu University,
Gwangju, South Korea*

*3 Speech-Language Pathology Center, Nambu University, Gwangju, South Korea,
byeon@nambu.ac.kr*

Abstract

Childhood apraxia of speech(CAS) is considered as an impairment of purposeful speech movements and is generally defined as a disorder of motor planning or motor programming. There have been a variety of studies about CAS and the diagnostic criteria were set up in English-speaking countries, but studies about diagnostic criteria of CAS for Korean speakers are needed. The purpose of the study was to examine voice onset time (VOT) and its variability in children with childhood apraxia of speech (CAS) compared to typically developing children. Twelve children with CAS aged 9-12 years old and 20 children who were age-matched participated in the study. This study measured VOT and variabilities of VOT during the production of /p' a/, /t' a/, /k' a/. For variability measures of VOT, each participant was asked to repeat speech tasks three times and the average value of the rates and its standard deviation were obtained. The verification of the hypotheses was tested by using T-test of the significance level of 0.05. The results showed that the variability of VOT in CAS group was more significantly higher than control group. But VOT of /p' a/, /t' a/, /k' a/ between the experimental group and the control group was not significantly different. The results suggested that variability of VOT might be more distinctive speech feature to children with CAS than the VOT. This study is meaningful because of two points; one is that it was conducted to fit the characteristics of Korea language while English cases are revitalized in the domestic situation, and the other is that it could be utilized as a resource for subsequent studies.

Keywords: *Childhood apraxia of speech, Voice Onset Time, Apraxia, Variability*

1. Introduction

Childhood Apraxia of Speech (CAS) is defined as a speech disorder with the characteristics of problems in phonological and articulatory output processes [1, 2]. Although articulation error of CAS is similar to articulation and phonological disorder, it is different in that the cause of the error stems from the damage of speech motor plan [3]. Especially, while Apraxia of Speech (AOS) which occurs during adulthood is mainly acquired symptoms caused by the damage of cerebral cortex, childhood Apraxia of Speech (CAS) are not necessarily caused by acquired brain damage, which presents difficulty of diagnosis [4]. Therefore, understanding speech characteristics of CAS is critical in the diagnosis of CAS.

According to American Speech-Language-Hearing Association, in clinical circumstances, vowel error, inconsistent variability error in word shadowing task and confusion of intonations are used in the diagnosis of Childhood Apraxia of Speech [2]. Nevertheless, so far there has been lack of CAS studies and standard of

* Corresponding author

diagnosis for Korean speakers. Unlike in English, as intonations are not outstanding in Korean, standard of diagnosis for English cannot be applied to Korean speakers. Therefore, to precisely diagnose CAS in Koreans, standards of diagnosis applying the characteristics of Korean are required.

Meanwhile, the importance of measuring Voice Onset Time (VOT) has been raised in many studies which investigated the speech characteristics of AOS. Studies on VOT of AOS have been conducted [5, 6], and the studies reported that VOT of AOS is slower than that of normal adults. On the contrary, a study on Americans [7] reported that VOT in voiceless plosives of AOS is faster than that of normal adults. Another study suggested that articulation error of AOS is a matter of production of perceptual errors in the voicing feature rather than VOT [8].

Recently, American Speech-Language-Hearing Association added variability of VOT to one of standards of diagnosis for CAS [2]. According to the new standard of diagnosis, inconsistent variability of articulation error is a typical core symptom of CAS [9]. Nevertheless, characteristics of variability of VOT have not been reported for Korean CAS yet.

This study investigated the characteristics of VOT and variability of VOT of Korean CAS using acoustic analysis and suggested basic material for diagnosis of CAS.

2. Methods

2.1 Subjects

This study analyzed 6 children with CAS at the age of 9 through 12 and 10 normal children with the same distribution of gender and age. CAS was diagnosed in a medical center and subjects were without problems in hearing and structure of oral cavity. Summary of standard for diagnosis of CAS defined by this study is as follows; first, there are errors in the imitation tasks of nonverbal language (e.g. movement of tongue); second, there is decrease in the coordination of articulation muscle in diadochokinetic tasks; third, there is decline in the imitation of daily motions; fourth, there are inappropriate pause in the sentence.

Normal children were selected as those without problems in hearing and structure of oral cavity and those over 30 percentile as the result of Korea National Health Screening Program for Infants and Children. Information on the subjects is presented in Table 1.

Table 1. Information on the Subjects

No	Age	Gender	Causes	Post onset time (year)
1	9 ; 1	male	Problems of metabolism	2
2	10 ; 1	male	Brain tumors	4
3	11 ; 8	male	Problems of metabolism	8
4	12 ; 10	female	Problems of metabolism	11

5	12 ; 11	female	Genetic problems	2
6	12 ; 11	male	Problems of metabolism	9
7	9 ; 1	male	Normal children	
8	9 ; 2	male	Normal children	
9	10 ; 3	male	Normal children	
10	10 ; 8	male	Normal children	
11	11 ; 10	male	Normal children	
12	11 ; 11	female	Normal children	
13	11 ; 11	male	Normal children	
14	12 ; 10	female	Normal children	
15	12 ; 11	female	Normal children	
16	12 ; 11	male	Normal children	

2.2.1. Check Words

In this study, /p*a/,/t*a/,/k*a/ were selected as check words because tense consonants are easier to be produced than aspirated consonants in children compared with adults [10].

To enhance the reliability of the study, place of recording, illumination and posture of the subjects were constituted in the same environment. Utterances of the subjects were recorded with IM-A830S microphone and the distance from the microphone and the mouth was maintained in 10cm.

2.2.2. VOT

VOT of collected utterance data was analyzed by using wave form of Praat (version 5.3.17) and spectrograph. Procedure of analysis was as follows; first, in the oscillogram of spectrograph, the point where vowel section was confirmed was selected. Then, referring to a preceding study [11], sections for VOT analysis were selected. At this time, the starting point of VOT was defined as the point where irregular wave began while the end of VOT was defined as the point where the wave of vowel appears when the first and second formant (F1, F2) began. Measured section of VOT is presented in Fig. 1.

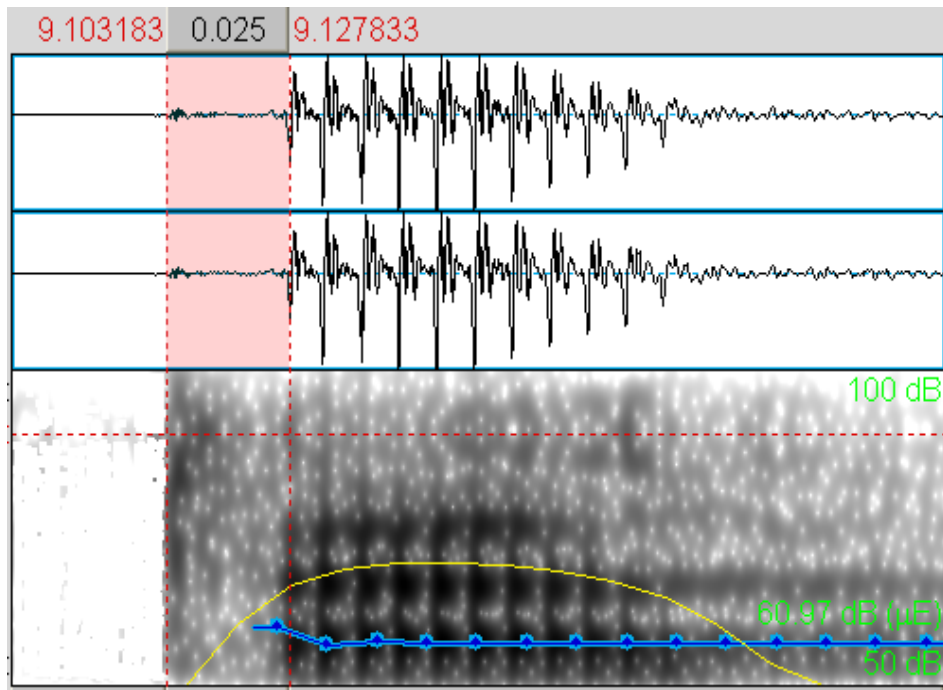


Figure 1. Measured Section of VOT is Presented

In some cases of children with CAS, it is difficult to identify the VOT section Fig. 2. In this case, by magnifying spectrogram and oscillogram, measurable VOT section was identified Fig.3.

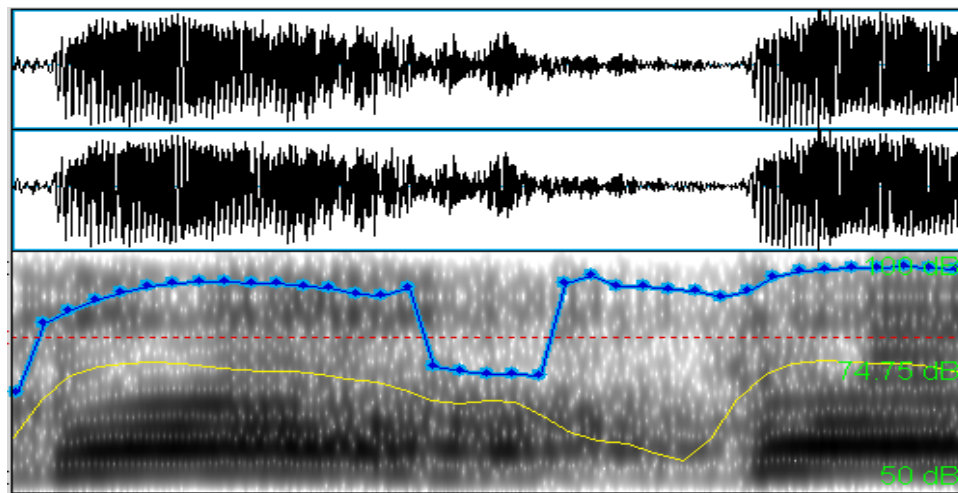


Figure 2. The Case that Difficult to Identify the VOT Section

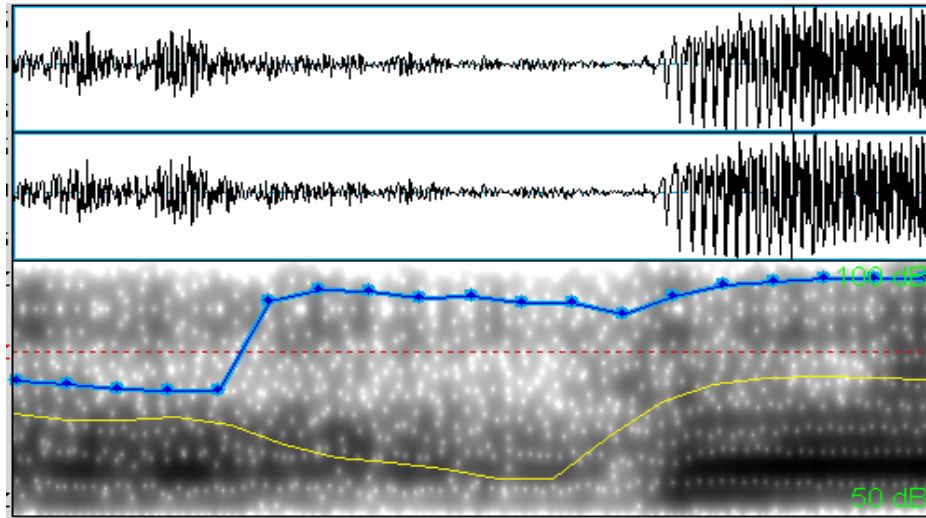


Figure 3. The Case that Magnifying Spectrogram and Oscillogram

2.3. Variability of VOT

Variability of VOT was calculated in standard deviation of the difference in performance after calculating each value of VOTs performed 3 times (Fig. 4). At this time, it was defined that the bigger the standard deviation, the greater the variability [12, 13].

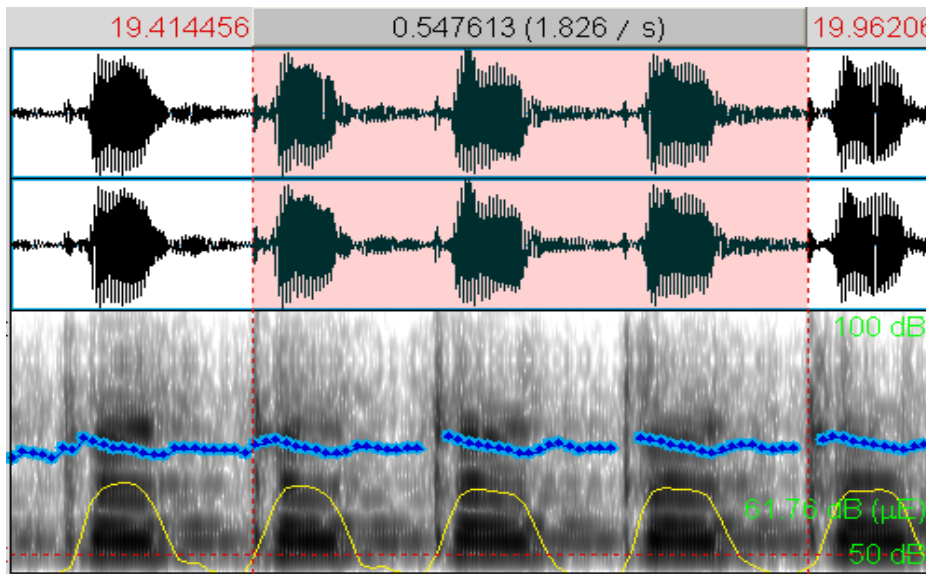


Figure 4. Calculation of Variability of VOT

2.4. Statistical Test

Mann-Whitney U test was used for the difference between average VOT and variability of VOT in children with CAS and normal children. Significance level was set less than 0.05 for both tests and all the analyses were conducted using SPSS version 21 (IBM Inc., Chicago, Illinois).

3. Results

3.1. VOT

Average values of VOT in children with CAS and normal children are presented in Table 2. As the result of Mann-Whitney U test, there was no significant difference in average VOT between children with CAS and normal children in the test words /p*a/, /t*a/, /k*a/.

Table 2. Average Values of VOT in Children with CAS and Normal Children

		N	Mean	SD	Min	Max	z	p
/p* a/	CAS	6	23.5	17.9	10	58	-.380	.713
	Normal	10	17.2	5.5	9	24		
/t* a/	CAS	6	18.5	8.4	11	34	-.382	.713
	Normal	10	21.3	9.9	11	37		
/k* a/	CAS	6	29.5	4.5	26	36	-.653	.562
	Normal	10	27.5	12.0	12	51		

3.2. VOT Variability

Values of VOT variability of children with CAS and normal children are presented in Table 3. As the result of Mann-Whitney U test, there was significant difference between children with CAS and normal children in the test words /p*a/, /t*a/, /k*a/. In /p*a/. VOT variability of children with CAS was 9.9ms, which was 5 times significantly higher than that of normal children with 2.1ms (p=0.016). In addition, VOT variability of children with CAS was around 2 times (p=0.008) significantly higher than that of normal children in /t*a/ and 2.5 times (p=0.003) significantly higher in /k*a/.

Table 3. Values of VOT Variability of Children with CAS and Normal Children

		N	Mean	SD	Min	Max	z	p
/p* a/	CAS	6	9.994	10.929	1.700	31.372	-2.388	.016
	Normal	10	2.115	1.447	.471	4.320		
/t* a/	CAS	5	4.197	1.362	2.5	5.715	-2.483	.008
	Normal	10	2.194	.807	1.247	3.859		
/k*	CAS	6	8.783	2.891	5.354	12	-2.824	.003

a/	Normal	10	3.349	2.110	.471	7.118
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4. Discussion

This study verified the difference of VOT and VOT variability between children with CAS and normal children using acoustic analysis. Major findings of this study are as follows;

First, there was no significant difference in average VOT between children with CAS and normal children in the test words /p*a/, /t*a/, /k*a/. In many studies, those with AOS had longer VOT than normal people and especially, in a study on adults with AOS, the difference of VOT length stood out [5, 6, 14]. And yet, as these preceding studies were conducted on adults with AOS, it is difficult to directly compare their results with that of this study. Therefore, there are two possible explanations for the fact that there was no difference in average VOT between children with CAS and normal children; first, characteristics of AOS caused by acquired brain damage such as aphasia are different from those of CAS caused by developmental problems. The studies that compared VOT of Koreans with AOS with that of normal adults reported that those with AOS had longer average VOT [5, 6]. Moreover, VOT of those with AOS was not only longer in all the plosives than normal adults [5] but was significantly longer than (those with) aphasia [14].

On the contrary, in this study, there was significant difference in VOT average between children with CAS and normal children in /p*a/, /t*a/, /k*a/. This result is in contrast to the VOT procrastination in preceding studies on AOS [5, 6, 14] and implies that VOT may not be a significant assessment factor for children with CAS. Especially, in a preceding study on the characteristics of plosives of those with AOS [4], the result that their VOT of speechless plosives did not have significant difference from that of normal adults supports this possibility. Second, it came from the phonetic characteristics of Korean that plosives are divided into aspirated consonants and tense one. In general, VOT of plosives in Korean is shorter in tense consonants than in aspirated ones [15, 16]. As this study tested plosive tense consonants ‘ /p*a, t*a, k*a/ ’ to measure VOT, they may be fundamentally different from /p Λ , t Λ , k Λ / which are studied in English-speaking countries.

Another finding of this study was that variability of VOT of children with CAS was significantly longer than that of normal children in /p*a/, /t*a/, /k*a/, which is similar to the result of a preceding study that those with AOS had longer variability of VOT than normal adults [17]. In addition, it was reported that children with CAS had higher variability of tongue movement in pronunciation process than normal children [3] and it is assumed that the finding of this study is the result of reflection of this characteristics of variability in the movements of articulatory organs.

This study has the strength that it identified the characteristics of variability of VOT for the diagnosis of Korean CAS. The limitations of this study are as follows; first, the study results cannot be generalized since number of subjects was not sufficient. Studies should be conducted on bigger number of children with CAS in the future studies. Second, there is a possibility that analysis was made on CAS with relatively less articulatory problems.

5. Conclusion

This study verified that there was a significant difference between children with CAS and normal children in variability of VOT rather than in average VOT. This result implies that it may be more effective to measure the variability of VOT in the diagnosis of Korean CAS rather than to measure average VOT.

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Authors



Junbeom Park, he received the MS degree in Speech Language Pathology from Hallym University. He is a speech language pathologist in JUN Rehabilitation Medicine, Seoul, Republic of Korea. His recent interests focus on childhood apraxia of speech and motor speech disorders.



Haewon Byeon, he received the DrSc degree in Biomedical Science from Ajou University School of Medicine. He is a professor in Department of Speech Language Pathology & Audiology and director of Speech Language Pathology Center in Nambu University, Gwangju, Republic of Korea. His recent interests focus on mild cognitive impairment and motor speech disorders.

