Non-native Speech Processing by Children with Phonological Disorders

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Non-native Speech Processing by Children with Phonological Disorders

임 동 선(이화여자대학교 언어병리학과)

< 요 약 >

본 연구의 목적은 말 처리 과정에 있어서 다양한 요인 중 하나인, 외국인의 억양을 이용하여 음운장애 아동의 어려움이 소리 개념(sound representation)에 있다는 가설을 뒷받침하는데 있다. 본 연구에서는 음운장애아동과 정상아동의 비원어민의 말, 즉 모국어가 다른 외국인의 말(non-native speech) 처리능력을 비교하였다. 총 55명의 3-8세 아동이 연구에 참여하였으며, 아동은 영어를 모국어로 사용하는 아동으로, 음운장애아동 20명, 정상아동 35명이였다. 본 연구에서는 첫째, 비원어민의 말과 원어민의 말, 즉 모국어가 같은 자국민의 말(native speech)의 수행능력을 두 그룹 간에 비교하였으며, 둘째, 비원어민의 말 수행능력에 있어서, 나이, 말, 언어 능력 중에서 어떠한 요인이 가장 영향을 미치는지를 살펴보았다. 문장(비원어민의 말과 원어민의 말)을 듣고, 문장의 마지막 단어를 그림에서 고르는 실험과제를 제시하였으며, 정확도와 반응속도로 아동의 수행능력을 분석하였다. 연구결과 첫째, 두 그룹 모두 비원어민의 말이 원어민의 말 보다 더 수행능력이 낮았다. 또한 반응속도를 분석한 결과, 음운장애가 없는 정상아동은 원어민의 말에서 통계적으로 유의미하게 빠른 속도를 보였으며, 음운장애 아동은 두 조건 모두에서 느린 반응 속도를 나타냈다. 마지막으로 말 처리과정을 가장 유의미 하게 영향을 미치는 요인은 연령으로 나타났으며, 원어민의 말의 정확도와 비원어민의 말의 반응속도가 비원어민의 말 처리과정의 정확도에 가장 유의미 하게 영향을 미쳤다. 본 연구결과, 음운장애아동은 말소리의 개념이 정상아동보다 더 불안정하다는 결론을 발견하였다.

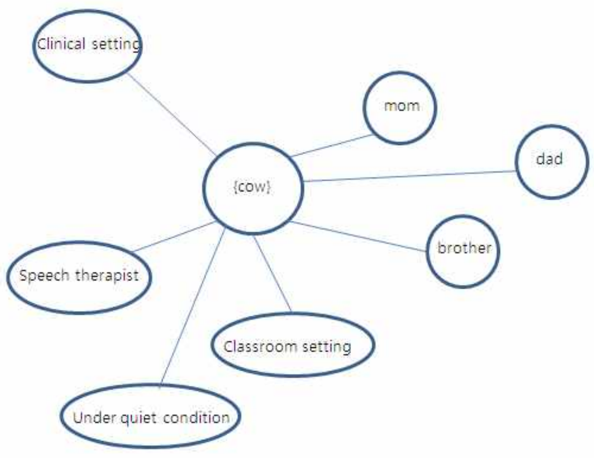
〈검색어〉 음운장애아동, 원어민의 말/비원어민의 말 처리과정

Ⅰ. INTRODUCTION

Recent literatures on speech processing no longer emphasize superficial aspects of speech sounds but rather focus on underlying mechanisms involved in the perception, production, and representation (Munson et al., 2006). The main topic of these previous research is on how speech processing performance changes under various contexts and what factors may influence these performance results. For example, when individuals are familiar with a particular speaker or voice, then they will be able to identify words more easily (Nygaard & Pisoni, 1998). It has been also found that children and adults were better at word identification when the stimuli were presented by a single speaker as opposed to multiple speakers (Ryalls & Pisoni, 1997). Additionally, numerous studies of children have shown that younger children perform more poorly than older children and adults on perception tasks when the signal is distorted or degraded in some way (Fallon et al., 2002; Munson, 2001; Nittrouer, 1992; Ryalls & Pisoni, 1997; Walley, 1988). Lastly, it was found that previous linguistic experience influences speech and nonspeech sound processing (Bent et al., 2006). From these studies, three important conclusions are raised. First, when speech sounds are variable children have more difficulty processing those speech. Second, age is an important factor when processing speech that is variable. Thus when cognitive load, given by complexity (assuming that variable speech is more complex), is higher younger children suffer than older children. Third, speech processing can be influenced by previous linguistic experience. In this study, we will investigate all of these factors, age, linguistic, and speech variability, when children process speech.

One of the hallmark of speech variabilities from the talker is accent variation which highlights of its importance these days due to a wide range of social, political and economic reasons. Many conversations across the globe today are between interlocutors who do not share a "mother tongue." Speech learning involves a process of tuning to the sound structure of the particular language(s). Thus, a child acquiring their language must learn their accent which matches his or her environment and, on the other hand, develop the ability to process other accent systems to which he or she is likely to be exposed. This includes speech learning which is spoken by different native language backgrounds with non-optimally aligned speech perception and production systems. Thus, in this study, speech variable is defined by accented speech spoken by a non-native speaker.

When children learn a sound of /k/ in a word "cow" they build the representation of a sound /k/ through many different contexts (e.g., clinical setting, classroom setting, and etc) and under various talkers (mom, dad, and etc). A simple diagram can be illustrated as in Figure I.1 This is why variability is important because stable and strong phonological representations are built through practicing each sound within many different exemplars in diverse conditions.



<Figure I.1> Diagram of how the representation of the speech sound /k/ in a word /cow/ builds on with diverse settings.

Thus, if a child does not have a robust phonological representation of speech sounds of their own as found in the study by Munson et al. (2010), he/she might have difficulties processing speech sounds when it is slightly different from their norm speech sounds. This might be the case for children with Phonological Disorders (PD). In this study (Munson et al., 2010), the delayed naming paradigm was used to examine whether children with PD differ from children without PD Specifically children were tested on whether they have slower speed of lexical access than age-matched children without PD. This hypothesis presumes that the habitual speech-sound errors of children with PD might be the by-product of an inefficient process of searching the mental lexicon due to unstable representation of sounds. The results showed that children with PD were slower on naming tasks compared to children without PD. They concluded that slow Response Time (RT) in children with PD should be taken into account when analyzing their performance.

It has been suggested that the reason why children with PD have difficulties with speech errors are not due to poor lexical access or due to poor phonological encoding but due to poor ability to build a robust perceptual representation of novel sounds (Munson et al., 2010). In other words, children with PD who have difficulties building a robust phonological representation of sounds may have not fully learned the process of tuning to the sound structure of speech sounds. As a result, children with PD may have difficulties processing accented speech that is characterized by variable speech. This may be the reason why children with PD have difficult time generalizing the sounds that they have mastered during the therapy sessions across conversational talkers and across settings. Thus, this study will explore how both children with and without PD process non-native speech over native speech.

Recent research (Nathan et al., 1998; Nathan & Wells, 2001) found the evidence that accent variation interferes the access to lexical representation and also children with PD have difficulty processing accented speech. Thus, Nathan & Wells (2001) highlighted the importance of examining the processing of accent-related variability in children with speech difficulties. However, these previous studies (Nathan et al., 1998; Nathan & Wells, 2001) had their limitations because the task was at a single word level and also accent was derived from the speech spoken by a person who shares their native language. In this study, we investigated how children with PD process accented speech at a sentence level spoken by a nonnative speaker (who does not share the native language). Additionally, this study explored how other factors such as age, speech and language skills measured by standardized tests influence performance in processing non-native speech. For methodological issue, it has been found that children with PD are slower on speech and/or language tasks such as picture naming tasks (Munson et al., 2010). Thus, it is critical to closely examine both quantitative and qualitative data. Current study used both accuracy (quantitative) and RT (qualitative) to investigate children's accented speech processing more in depth.

The research questions that we ask in this project are:

1. How do native English speaker children with PD process accented speech vs. non-accented speech compared to children without PD?

2. Which variables among age, speech and language skills, best predict non-native speech processing?

For the first research question, it is hypothesized that due to their unstable phonological representation of the sounds, children with PD will have more difficulties in processing speech that are accented compared to non-accented speech than children without PD. For the second research question, it is hypothesized that speech processing ability will be significantly influenced by age, speech and language skills.

Ⅱ. METHOD

1. Participants

Fifty five children whose first language was English and do not speak any other languages at home participated in this study. All participants passed hearing screening (pure tones presented at 25 dB at 1, 2, and 4 KHz bilaterally) and showed a normal nonverbal intelligence test score on the Leiter International Performance Scale-Revised (Roid & Miller, 2002). No participant had a broader developmental delay, permanent hearing loss, craniofacial anomaly, or psychosocial impairment (e.g., autism), as gauged by a parental report. Thirty-five typical children had no history of speech and/or language difficulties (mean age=6;9, SD=1.8) and none of twenty children with PD (mean age=6;3, SD=1.7) have had diagnosed with language impairment, nor have they received clinical services for any communication impairments other than their speech-production difficulties based on parental questionnaire.

Children completed a series of standardized assessments to measure their speech and language skills. The Sounds-in-Words subtest of the Goldman-Fristoe Test of Articulation-2 (GFTA-2, Goldman & Fristoe, 2000) was used to measure speech-production accuracy. The Peabody Picture Vocabulary Test-IV (PPVT-IV, Dunn & Dunn, 2007) and the Expressive Vocabulary Test (EVT, Williams, 1997) were used to measure children's receptive and expressive vocabulary, respectively. Both groups performed within normal range on receptive and expressive language skills. However, children with PD performed significantly poorly than typical children on EVT (children without PD mean=116, SD=13.5, children with PD mean= 105, SD=16.2) and on GFTA (children without PD mean=104, SD=12.9, children with PD mean=94, SD=15.1). See Table II.1 for more information on characteristics of both groups; age, nonverbal IQ, speech and language scores.

<Table II.1> Mean and SD (in parenthesis) on speech, language and nonverbal IQ scores for both groups

	Speech, Language and Nonverbal IQ Scores			
	PPVT	EVT	GFTA	LEITER
CA	115 (16)	116 (13)	104 (12)	108 (16)
PD	109 (11)	105 (16)	96 (14)	116 (19)

Note. PPVT-IV; Peabody Picture Vocabulary Test-IV (Dunn & Dunn, 2007); EVT; Expressive Vocabulary Test (Williams, 1997), GFTA; GFTA-2 (Goldman & Fristoe, 2000), LEITER; Leiter International Performance Scale-Revised (Roid & Miller, 2002).

2. Stimuli

A total of 60 sentences were directly used from the study of Fallon et al. (2002). These sentences were chosen because they were successfully tested by typical children who were aged from 5-9 years old. For the non-accented speech, a native English speaker recorded the sentence. For the accented speech, all sentences were initially recorded by five Mandarin speakers. Then 10 English native speakers listened to these five speaker's sentences and rated on a five-point scale whether they sounded very native like, native like, somewhere in the middle, non-native like and very non-native like. Then the average of the scores across 10 subjects ratings were obtained. We eliminated the two which were native like, and two which were non-native like which interferes the understanding of the sentence. Finally, we selected the middle one which was intelligible and also accented. The example for the sentence was "Mom talked about the belt." Four visual images including the target image and three designated foils were presented on the computer screen. Children had to select the picture that was correspondent to the target word which was at the final position in the sentence.

The recordings were excised and normalized in volume to 70 dB using the free speech software Praat. Images were cropped to remove blank space. The experiment program automatically re-sized them to occupy equal screen space during display. Each image occupied approximately 3cm x 3cm of space on the display.

3. Procedure

Children performed a picture identification task, in which they were shown with pictures and heard the sentence whose final word (the target) matched one of the pictures. Children first saw four pictures in a horizontal row, with the numbers 1-4 printed below the pictures, with 1 corresponding to the leftmost image and 4 corresponding to the rightmost image. They were allowed to look at the pictures as long as they wanted ("Let me know when you are ready, then I will press this button so that you can hear the sentence."). Once children were ready to listen to the sentence, the auditory stimulus was played over the headphones. The child pressed the number on the response box that corresponded to the image named by the final word in the auditory stimulus as fast as they could and as accurate as they could. There were three practice items before participants move on to real test items. After the child presses a button, they might hear, "I don't like to drive a car when I can ride a <u>BUS</u>." During or after the stimulus presentation, the child pressed the number corresponding to the target picture.

The experiment was administered by the E-Prime experiment software (Psychological Software Tools, 2000) in which auditory stimuli were presented over headphones (Sennheiser, HD228). The display screen size was 30 cm x 20 cm (Samsung SyncMaster 2243BWX Computer).

At the end of each session, children were tested on target words as an off line task, to confirm their knowledge of all target words. All children were asked to point to the picture (word identification task) and they all performed 100% accuracy on every single target word.

All children listened to non-accented speech and accented speech with several offline tasks performed in between. Half of the children listened to non-accented speech first and half of the children listened to accented speech first. Based on one way ANOVA analysis, there was no difference between those two performance. See Table II.2 which lead us to combine the data to further analyze.

<Table II.2> Mean and SD (in parenthesis) for each condition by order

Group factor	Source	SS	*df*	MS	F	*p*
CA accented first	between	32.3	1	32.3	.09	.76
	within	11899	33	360.6		
	sum	11932	34			
CA native first	between	3.47	1	3.4	.02	.88
	within	5427	33	164.4		
	sum	5430	34			
PD accented first	between	5.5	1	5.5	.01	.91
	within	8252	18	458.4		
	sum	8258	19			
PD native first	between	48.0	1	48.0	.16	.68
	within	5115	18	284.2		
	sum	5163	19			

Note. One way ANOVA was run to find out whether the order of the task condition influenced the performance. Both groups showed no order preference.

4. Analysis

Mean accuracy and RT measures were obtained for each child in both conditions, with all children completing the tasks successfully. For the RT measures, only accurate responses were included. Outliers, defined as ±2 SD from the mean task RT for an individual child, were excluded. This resulted in eliminating about 3.5% of the data from subsequent analysis in each task. 2×2 ANOVA with speech accentedness (native speech vs. non-native speech) as within variable and group (children with PD and without PD hereafter CA which stands for Chronologically Age matched group) as between variable was used to examine the group difference by condition. A separate correlation and regression analysis were used to find the most influential variable on non-native speech processing performance.

III. RESULTS

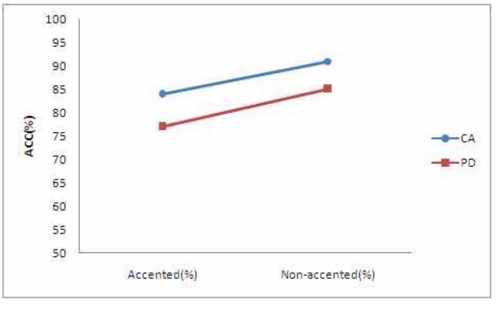
The mean accuracy and RT in each condition for both groups are shown in Table III.1. Accuracy and RT results are reported separately. There was no main effect of group, and interaction for accuracy data as shown in Table III.1. However, there was a condition effect; percent accuracy on non-native speech processing was statistically significantly harder than non-accented speech ($F(1,53) = 33.1$, $p<.001$).

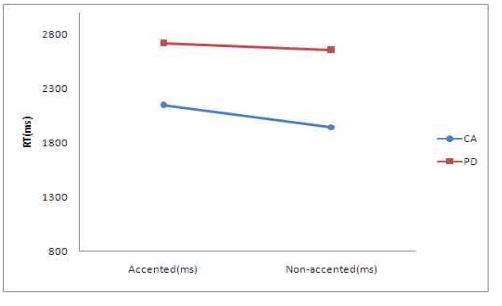
<Table III.1> Mean and SD (in parenthesis) for both groups on accented and non-accented speech conditions

	Accuracy (%)		RT (ms)	
	Accented	Non-accented	Accented	Non-accented
CA	84 (18)	91 (12)	2148 (1150)	1948 (1097)
PD	77 (20)	85 (16)	2718 (1261)	2655 (1249)

Figure III.1 illustrate how children with PD and CA children performed on accented speech and non-accented speech. Overall, CA children outperformed children with PD on both conditions which failed to reach a conventional level of statistical significance.

As shown in Figure III.1, RT was statistically significantly slower on accented speech than non-accented speech ($F(1, 53)=39.8$, $p<.001$), and there was a significant interaction effect ($F(1, 53)=10.7$, $p<.01$). The main effect of group between CA and PD approached, but did not reach, statistical significance ($p=.057$).





<Figure III.1> Graphs on accuracy and RT for both groups in each condition

Table III.2 shows the correlation results among age, PPVT, EVT, GFTA scores and dependent measures (both accuracy and RT on accented and non-accented speech). As expected, age was highly correlated with overall speech processing ability whether they were accented or not and whether they were measured quantitatively or qualitatively. Thus, when age was partialled out other language scores were not correlated with the speech processing ability. However, accuracy and RT were negatively correlated even after controlling for age.

〈Table III.2〉 Correlations among variables in CA and PD children

	Age	PPVT	EVT	GFTA	ACC (accented/non)	RT (accented/non)
Age	__	.035	-408**	-432**	.735**/.691**	-740**/-728**
PPVT		__	.489**	.085	.133/.150	-.156/-.099
EVT			__	.416	-.343*/-.317*	.223/.231
GFTA				__	-.375**/-.291*	.313*/.315*
ACC accented					__ /.909**	-.815**/-.810**
ACC non accented					__	-.773**/-.771**
RT accented						__ /.991**
RT non accented						__
Partial correlations, controlling for age						
PPVT	__	__	.552**	.111	.158/.174	-.193/-.108
EVT			__	.292	-.069/-.053	-.128/-.106
GFTA				__	-.093/.011	-.010/.000
ACC accented					__ /.817**	-.595**/-.591**
ACC non accented					__	-.538**/-.540**
RT accented						__ /.981**
RT non accented						__

Note. PPVT = Peabody Picture Vocabulary Test; EVT = Expressive Vocabulary Test; GFTA = Goldman Fristoe Articulation Test; ACC (accented) = Percent accuracy on accented (non-native) speech processing; ACC (non-accented) = Percent accuracy on non-accented (native) speech processing; RT (accented) = Response Time on accented (non-native) speech processing; RT (non-accented) = Response Time on non-accented (native) speech processing.

*p<.05, **p<.01

Lastly, multiple stepwise regression was run in order to examine how much of the variance in accuracy of accented speech was explained by other variables. Age, PPVT, EVT, GFTA, accuracy for non-accented, RT for both accented and non-accented were entered as dependent variables to predict the performance of accuracy for accented speech. The results showed that it was accuracy on non-accented ($F(1, 54)=250.7$, $p<.001$ $R^2=.826$) and RT for accented speech sentence ($F(2, 54)=156.2$, $p<.001$, $R^2=.857$) that best predicted the performance of accented speech.

IV. CONCLUSION AND DISCUSSION

This study investigated how children with PD process accented speech spoken by a non-native speaker over non-accented speech. Performance was compared to typically developing children without PD. Both accuracy and RT results showed that when sentences are accented, the performance suffered compared to native sentences for both groups. These findings are in line with previous studies in which speech variability makes it harder to process (Nygaard & Pisoni, 1998; Ryalls & Pisoni, 1997). Quantitative data, represented by accuracy, did not show any group difference by condition. However, with more qualitative data measured by RT, it was found that typical children were able to take advantage of non-accented speech. They were much more faster on speech spoken by a native speaker. In other words, children with PD were slow on both conditions and they could not process faster even when the sentence was spoken by a native speaker. Munson et al., (2010) reported the overall slowness in children with PD on naming tasks. Results from our study also suggest the slowness of processing in children with PD which may be due to their unstable representation of speech sounds. This may be the reason why children with PD are inefficient in accessing and/or retrieving of a target sound.

Results from this study also found that age is an important factor when processing speech whether it is accented or not which was also found from previous studies (Fallon et al., 2002; Munson, 2001; Nittrouer, 1992; Ryalls & Pisoni, 1997; Walley, 1988). Along with age, Bent et al. (2006) suggested that previous linguistic experience is another variable that needs to be taken into account when processing speech. In our study, speech and language skills were measured by standardized tests and the results showed that when age was covaried out, linguistic experience no longer predicted the speech processing performance. These findings again emphasized that age is a strong factor that influence speech processing ability. However, for future study, it maybe interesting to investigate whether phonological processing abilities such as phonological awareness and/or other factors such as semantic contexts in sentence predict accented speech processing ability. Lastly, it may be worth pursuing the basic underlying mechanism for speech processing abilities for future study.

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Abstract

Non-native Speech Processing by Children with Phonological Disorders

Dong Sun Yim*(Dept. of Communication Disorders, EWHA Womans University)

This study examined how children with and without Phonological Disorders (PD) process accented speech spoken by a non-native speaker. Two research questions were asked in this project. The first was to compare how children with and without PD perform on accented speech over non-accented speech. The second was to investigate which variables (age, speech, and language skills) correlate and best predict the performance of non-native speech processing. Children were aged from 3 to 8 years old and were native English speakers. Twenty children with PD and 35 children without PD participated. The task was to identify the final words of sentences on each condition. Both quantitative (accuracy) and qualitative (RT) methods were used to collect the data. Overall, both groups performed similarly on both conditions; speech spoken by a non-native speaker which was accented was harder than the non-accented speech. Additionally, there was group by condition interaction effect in which typical children were faster on non-accented speech. Correlation analysis showed that age was highly correlated with speech processing performance whether it was accented or not. Additionally, it was the accuracy of non-accented speech, and RT of accented speech that best predicted the performance for non-native speech processing performance. These results indicated that sound representation in children with PD are less stable than typically-developing children.

Keywords : Non-native/accented speech processing, children phonological disorders

* 임동선(제1저자, 교신저자) : 이화여자대학교 언어병리학과 전임강사(sunyim@ewha.ac.kr)

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