Phonetic Accuracy on a Delayed Picture-Naming Task in Children with a Phonological Disorder

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Background and Objectives: The purposes of this experiment were: (a) to determine whether children with phonological disorder (PD) differ from children with typical language development (TD) in the time-course of lexical access and (b) to explore the factors associated with picture-naming accuracy by children with PD. ***Methods:*** Thirty-eight children consistingof 19 with PD and 19 with TD participated in this study. The children completed experimental tasks including a delayed naming task in which children were presented with pictures that they were instructed to name after a 0 ms, 500 ms, or 1,000 ms delay interval. Responses atthe 0 ms delay intervalwere presumed to reflect the combined influence of lexical access and post-access processes. Responses at the longer-delay intervals were presumed to primarily reflect post-access processes. ***Results:*** Children with PD produced a higher proportion of phonological errors at all three delay intervals. However, there was not a significant difference in the shorter delay intervals in children with PD. Based on the results of stepwise regression analyses, it was determined that the vocabulary size did not predict any additional variance in naming accuracy. Only the production accuracy of phonemes comprising the nonwords predicted error rates. ***Discussion & Conclusion:***The findings of this study suggest that children with PD have the same lexical access as children with TD. In other words, the group differences in error rates appeared to be entirely attributable to children's difficulty producing the phonemes in the pictures' names. The results discuss the potential underlying reasons for PD including weak phonological representations. (***Korean Journal of Communication Disorders*** 2012;17:187-200)

Key Words: phonological disorder, lexical access, picture naming, speech-production accuracy.

Ⅰ. Introduction

Children who produce speech-sound errors more than their age-matched typically developing peers in the absence of an obvious predisposing condition are said to have Phonological Disorder (PD). This diagnostic category is distinct from speech-production problems that occur secondary to known problems, such as hearing impairment, significant craniofacial anomaly, or neuromotor impairment. In a recent study, PD was estimated to occur in 3.8% of 5-year-old children, using a conservative criterion for its identification (Shriberg, Tomblin & McSweeny, 1999).

Much previous research on PD has examined children's error patterns, using carefully phonetically transcribed spontaneous and elicited productions. Researchers have interpreted these errors relative to a variety of linguistic theories, in an attempt to understand the possible linguistic basis of this impairment (Barlow & Gierut, 1999). In contrast, relatively less research has utilized on-line processing tasks to explore the nature of PD. Some of these studies have examined deficits in these children's ability to discriminate between a sound they produce in error and the correctly produced target (Ohde

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& Scharf, 1988; Rvachew & Jamieson, 1989). Others have investigated more general perceptual abilities, such as the identification of acoustically degraded words (Edwards, Fox & Rogers, 2002). Still other investigations have examined speech-motor control. Edwards (1992) and Towne (1994) found that children with PD have a reduced ability to produce speech in biomechanically restrained conditions relative to children with TD. Bradford and Dodd (1994) found that children with PD performed less accurately on a high level of fine-motor coordination, tracing, than children with TD. More recent studies have examined higher-level cognitive processing in children with PD. Both Couture & McCauley (2000), and Linassi, Keske-Soares & Mota (2005) found some evidence that children with PD have poorer working-memory abilities than children with TD. The findings of all of the studies in this paragraph suggest that PD may be associated with broader deficits in cognitive-linguistic processing and perceptual-motor ability. However, further research is needed to refine our understanding of the precise nature of these deficits.

The purpose of the current investigation is to examine whether children with PD differ from age-matched children with TD in one facet of cognitive-linguistic processing, lexical access. Contemporary theories of lexical representation posit two distinct representations for individual words, a conceptual/semantic representation, the *lemma*, and a word-form representation, the *lexeme*. Many contemporary theories of speech production posit that these representations are accessed, both in recognition and production, at different times. In models presented in Levelt (1989) and Levelt, Roelfs & Meyer (1999), lemma access in production is thought to precede lexeme access. The lemma access stage is typically called *lexical access*; the stage at which the lemma is associated with its lexeme is typically called *phonological encoding*. Evidence for the ordering of these stages can be seen by examining the time-course of semantic and phonological priming effects in experimental tasks, particularly those in which individuals name pictures while listening to spoken words presented prior to, concurrent with, or after the picture is presented (Schriefers, Meyer & Levelt, 1990). Spoken words that are semantically related to the picture's name inhibit production if they are presented prior to picture presentation, as measured by response times relative to a neutral baseline. In contrast, phonologically related spoken words facilitate production times; this effect is particularly strong when they are presented after the picture has been presented.

A reasonable starting hypothesis is that if children with PD differ from children with TD in either of lexical access or phonological encoding processes, it should be in phonological encoding, rather than in lexical access. The production problems of children with PD can occur in the presence of apparently intact morphosyntactic and semantic knowledge, as measured by age-appropriate performance on tests of receptive language. We might then predict that lexical access would be preserved in this population. In contrast, the less-accurate speech production of children with PD seems more likely to stem from, or at least co-occur with, deficits in phonological encoding.

This conjecture challenged by a number of recent studies has found a relationship between lexical access processes and variation in pronunciation. In ongoing speech production, adults may experience transient difficulties in lexical access, sometimes called tip-of-the-tongue states (Brown & McNeill, 1966). These are reflected in spoken language through disfluencies, such as repetitions, hesitations, pauses, and fillers like *um* and *uh*. As documented by Bell et al. (2003), Fox Tree & Clark (1997), Jurafsky, Bell & Girand (2002), and Shriberg (1995), these disfluencies are also associated with hyperarticulation. That is, hyperarticulation-a characteristic of an exaggerated form of speech production -is a reflex of transient lexical access failures. A related finding is reported in Munson (2007), who examined the acoustic characteristics of vowels from words read aloud by adults in two experimental conditions. In one condition, participants read words as soon as they saw them. In another condition, participants read words after a delay interval of 1,000 ms had been enforced. This interval presumably allowed

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written-word recognition and lexical access to take place. Munson found that words in the long-delay condition were hyperarticulated relative to those in the short-delay condition. These findings provide evidence that characteristics of articulation can be linked to processes related to lexical access. Given this association, it is plausible to posit that lexical access may be a locus of difficulty for children with PD.

Moreover, a growing literature (Edwards, Beckman & Munson, 2004; Pierrehumbert, 2003; Walley, Metsala & Garlock, 2003) suggests a closer link between vocabulary knowledge and phonological knowledge than has been suggested by classic modular theories of language. This can be seen in a number of methodologically diverse investigations. For example, children's learning of novel words is facilitated when these words contain sequences of sounds that are frequently attested in real words in the lexicon (Storkel, 2001). That is, children's ability to form lexical representations is related to their phonological knowledge. Edwards, Beckman & Munson (2004) found an interaction between diphone-probabililty effects on nonword repetition accuracy and measures of vocabulary size: children with higher scores on standardized vocabulary measures were better able to repeat nonword-embedded sequences of sounds occurring in few or no words than children with lower scores, even when chronological age was controlled statistically. This finding suggests that lexical development promotes development of autonomous phonemic representations of words, which would presumably support the repetition of sequences of sounds that don't occur in known lexical items. That conjecture is qualitatively similar to models presented in Walley (1993) and Walley et al. (2003) to explain associations between vocabulary development and other measures of word recognition and phonological knowledge. These and other findings have led some to posit that phonology and the lexicon are much more closely related than classic modular models of language would suggest (Beckman, Munson & Edwards, 2007; Pierrehumbert, 2003). They in turn have been grist for the development of models in which phonological knowledge is seen as generalizations over the phonological structure of known lexical items. In these models, knowledge of phonological structure is hypothesized to emerge as the lexicon grows and becomes elaborated (Beckman & Edwards, 2000; Storkel, 2002). The links between lexical and phonological knowledge in the works reviewed above motivates a systematic investigation of lexical access processes in children with PD.

At least two previous studies have examined lexical knowledge in children with PD. Munson, Edwards & Beckman (2005a) examined relationships between lexical and phonological knowledge in children with PD using the nonword repetition task of Edwards, Beckman & Munson (2004), described previously. Munson et al. found a similar-sized influence of phoneme-sequence frequency on nonword repetition in children with PD and children with TD, suggesting that PD is not the consequence of a reduced ability to make generalizations about phonological structure from known lexical items. Instead, Munson et al. found that a measure of speech perception best predicted speech-production accuracy in children with PD. Storkel (2004) compared the ability of children with PD to learn novel words to that of age-matched and vocabulary-matched peers. Children with PD showed particular difficulty in learning novel words that contained frequent sound sequences. This finding suggests that these children strive to maintain distinctiveness in their lexica, and that this drive counters the tendency seen in typically developing children to learn words containing frequent sound sequences more readily than ones containing infrequent sequences.

This investigation examined whether PD was associated with deficits in lexical access. Lexical access was examined using a *delayed naming* task. In this task, children viewed a picture, which they were instructed not to name until a response prompt has been presented. The interval between the presentation of the picture and the response prompt varied. The assumption underlying this method was that characteristics of responses in the immediate condition reflect the influence of both lexical access

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and post-access processes, while responses in the longer-delay conditions occur after lexical access has been completed. Consequently, they were thought to reflect the characteristics of post-access processes primarily, such as phonological encoding and motor execution. This task was a variant of the delayed reading task, designed by Balota & Chumbly (1985). Balota and Chumbly designed this paradigm to examine whether word-frequency effects on single-word reading latencies were due to the influence of frequency on lexical access, on the cognitive and motoric processes that occur after lexical access, or both. They showed that word-frequency effects in reading are due primarily to post-access processes. Lahey & Edwards (1996) used the delayed naming paradigm to examine whether the slower naming times of children with SLI compared to children with typical language development was due to lexical access, or to post-access processes. Children named seven pictures each at a variety of different delay intervals, ranging from 0 ms to 1200 ms. They found statistically equivalent group differences across different delay intervals, suggesting that group differences were attributable to post-access processes.

This study was one of the three studies (delayed naming, cross-modal picture-word interference, and long-term repetition priming) in which the nature of phonological knowledge deficits in children with PD was examined. The current investigation used the delayed naming paradigm to examine whether children with PD differ from children with TD. 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. If this conjecture is true, then we would expect the performance of children with PD to differ from children with TD more strongly in the condition that stresses lexical access processes, the immediate-response condition, than in the longer-delay conditions.

Ⅱ. Methods

1. Participants

Thirty-eight children (19 with PD, 19 with TD) participated in this study. All children were native English speakers. Children were participating in a larger study examining the nature of PD in children. Children with PD were recruited from public schools and private clinics in the Minneapolis/St. Paul, MN metropolitan area. All of these children had a prior diagnosis of PD made by a speech-language pathologist. Children with PD were within normal range on both receptive (The *Peabody Picture Vocabulary Test-Ⅲ*: PPVT-Ⅲ)(Dunn & Dunn, 1997) and expressive vocabulary (*Expressive Vocabulary Test*: EVT)(Williams, 1997). However, children with PD were significantly lower than normally developing children. Typically developing children were recruited from local day-care centers, and by word of mouth. No participant had a broader developmental delay, permanent hearing loss, craniofacial anomaly, or psychosocial impairment (e.g., autism), as gauged by parent report. None of the children with PD had any other diagnosed language impairment, nor were they receiving clinical services for any communication impairments other than their speech-production difficulties.

Children completed a series of standardized and nonstandardized assessments to measure their speech, language, hearing, and nonverbal IQ 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 GFTA-2 was scored two ways. First, it was scored using the conventional method, in which the accuracy of the production of selected sounds in words was tallied, and a percentile rank was determined based on the total number of errors. Second, each child's total percent phonemes correctly produced (PPC) was calculated, based on broad phonetic transcriptions of children's productions of entire words. These broad transcriptions were made by a trained phonetic transcriber, who was blind to children's group membership. Each child's

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score was rationalized arcsine transformed for statistical analyses, and are referred to henceforth as *GFTA-2 Total PPC*. The GFTA-2 Total PPC served two purposes. First, it was intended to be a finer-grained assessment of speech-production accuracy than is reflected by the GFTA-2 percentile rank, which takes into account only consonant-production accuracy for selected sounds. Second, it served as a more-appropriate measure for use in regression analyses to examine the association between speech-production accuracy and measures of lexical access. Given the inclusionary criteria for this study, the distribution of GFTA-2 percentile ranks was bimodal, and thus was not an appropriate variable for use in multiple regression. In contrast, the GFTA-2 Total PPC scores more closely approached a normal distribution, and were thus more suitable for use in regression.

The *Kahn-Lewis Phonological Analysis-2* (KLPA-2) (Kahn & Lewis, 2002) was also used to score the consistency of errors in children's productions. The (PPVT-Ⅲ)(Dunn & Dunn, 1997) and the (EVT) (Williams, 1997) measured children's receptive and expressive vocabulary, respectively. *The Kaufman Brief Intelligence Test* (KBIT, Kaufman & Kaufman, 1991) was used as a screening measure of non-verbal intelligence. Fourteen children in each group were old enough to complete this measure.

In addition to these standardized tests, all children completed three non-standard measures. The first was a speech discrimination task (Baylis, Munson & Moller, 2008), in which children identified minimal pairs of words. This task was administered to measure phonemic perception skills. Forty-one sets of minimal pairs of pictures were selected. Stimulus pictures were taken from the corpus described in Bates et al. (2004). These word pairs featured initial and final position phoneme contrasts, such as *boat-goat*, which differ in the place of articulation of the initial consonant, and *pan-man*, which differ in the voicing and nasality of the initial consonant. Stimuli were produced by an adult male and were recorded for audio presentation. Stimuli used in the task were determined to be 100% intelligible to a group of naïve adult listeners. The child was seated at a table as single auditory stimulus items were presented at 65dB HL using a Dell Latitude D600 laptop, E-Prime software, and two Audix speakers (Model PH5). As each auditory item was presented, a pair of black-and-white picture cards was shown to the child, who was asked to point to the correct response. Responses were scored as correct or incorrect. Overall percentage correct was calculated for each child, and was rationalized arcsine transformed for statistical analyses.

The second nonstandardized measure was a baseline test of nonlinguistic speed of processing. This task was administered in order to measure processing efficiency to nonlinguistic stimuli. This was an auditory-verbal response time task. During this task, children were instructed to say *yes* to a 100 ms, 1,000 Hz pure tone presented through headphones. Each child's average nonlinguistic response time in ms was calculated, excluding trials that occurred greater than 5 s after the tone, and ones that were greater than 2.5 standard deviations above the child's mean nonlinguistic RT, or less than 2.5 SD below it. This was intended to exclude response times that may have resulted from inattention or impulsivity.

Children participated in a diadochokinetic rate task to determine possible group differences in speech-motor control. Children repeated strings of the syllables [pʌ], [tʌ], [kʌ], and [pʌtʌkʌ] as fast as they could. Children's speech production rate in syllables per second was hand-measured from digitized waveforms for each of these sequences. These were averaged together for analysis. Children were also given a nonstandardized examination of oral-dental structures by a speech language pathologist from the Department of Otolaryngology, Head and Neck Surgery at University of Minnesota. There were no group differences in speech structures (e.g., in dental-occlusal structures).

All children completed pure-tone hearing screenings, in which they identified 0.5, 1, 2, and 4 kHz pure tones presented bilaterally. Sixteen children with TD and 17 children with PD passed the screening when the tones were presented at 20 dB HL; three children with TD and two children

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with PD detected the tones only when they were presented at 25 dB HL. The group difference in the intensity level needed to identify tones was not statistically significant, Tympanometry screenings were also administered. Two children with TD and five children with PD had abnormal tymponometry results, typically because of negative pressure peaks or atypically flat tympanograms. Again, the group difference in the rate of passing the tympanometric screening was not statistically significant. All of the tasks described in this section were completed prior to participating in the delayed naming experiment.

Group differences in other measures described in this section are presented in Table 1. As this table shows, the two groups of children differed significantly in GFTA-2 percentile rank and Total PPC, and KLPA-2 standard score, as expected. Qualitative inspection of the children's phonetic inventories showed that the children varied in the sounds and sound classes they produced in error, and in the error types that they made. Moreover, the groups differed in PPVT-Ⅲ standard score, and in EVT standard score. Group differences in the two vocabulary tests were also found in a previous study on PD (Munson, Edwards & Beckman, 2005a). However, note that no child had a score on either measure that was below 85 (i.e., lower than one standard deviation below the normative sample's mean score). This, along with the fact that no child with PD was receiving clinical services for language impairment, was sufficient to rule out the possibility that children with PD had a concomitant language impairment. The two groups did not differ in age, nonlinguistic IQ, DDK rate, or nonlinguistic response time. The two groups did not differ significantly in sex composition or discrimination accuracy at the $\alpha < 0.05$ level, but this asymmetry did approach statistical significance.

Table 1. Participant Characteristics

Measure	TD Mean (SD)	PD Mean (SD)	Group Difference
Age (months)	59.7 (15.9)	58.8 (15.9)	$t[36] < 1$, $p > 0.05$
Percentage Girls	63	37	$\chi^2[n = 38, df = 1] = 2.63$, $p < .05$
Nonlinguistic Response Time (ms)	501 (228)	524 (231)	$t[36] < 1$, $p > 0.05$
DDK Rate (syllables/sec)	95.6 (5.7)	92.2 (7.7)	$t[36] = 1.66$, $p < .05$[a]
DDK Rate (syllables/sec)	4.6 (0.6)	4.4 (0.9)	$t[36] < 1$, $p > .05$
GFTA-2 PPC[b]	94.1 (6.0)	71.6 (20.0)	$t[36] = 5.31$, $p < .001$[a]
GFTA-2 PR[c]	64.8 (16.3)	10.0 (6.6)	$t[36] = 13.58$, $p < .001$
KLPA-2 SS[d]	107.8 (5.2)	77.3 (17.1)	$t[36] = 7.43$, $p < .001$
PPVT-III SS[d]	117.2 (10.4)	107.5 (13.3)	$t[36] = 2.52$, $p < .05$
EVT SS[d]	119.5 (10.6)	110.6 (13.8)	$t[36] = 2.24$, $p < .05$
K-BIT SS[d]	110.2 (9.5)	106.0 (14.1)	$t[26] < 1$, $p > .05$

a) Difference test based on rationalized arcsine transformed values
b) Percent Phonemes Correctly Produced
c) Percentile Rank
d) Standard Score (M = 100, SD = 15)

2. Stimuli

Pictures used in the delayed naming task were 45 black and white line drawings taken from a public access corpus of pictures (Bates et al., 2004). Pictures were chosen because they had a high likelihood of being named uniformly, as determined by the performance of children in a normative study, and because they had relatively uniform visual complexity. The average rate at which the 50 children in the normative sample named the pictures similarly was 90% (SD = 11%). The pictures' names were all monosyllabic words of English. Lexical statistics were calculated for the stimuli, based on the procedures and values reported by Pisoni et al. (1985). The pictures' names had an average familiarity rating on a seven-point equal-interval scale of 6.97 (SD = 0.15), an average log frequency (in instances per million words in the Kucera and Francis [1967] corpus) of 3.78 (SD = 1.7), an average of 20.2 phonological neighbors (SD = 6.5, using the single-

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phoneme edit-distance measures presented in Pisoni et al. (1985), and an average log neighborhood frequency of 5.05 (SD = 1.2) which indicate that all of the words used were very familiar and easy.

A complete list of target words can be found in Table 2. Because words in the three lists were not phonemically equivalent, we conducted a series of analyses to determine whether children differed in their production of the sounds that the words in the three conditions contained. For this analysis, production accuracy was gauged by examining production on the GFTA-2 of the phonemes comprising the pictures' names. Two Kruskal-Willis test showed no effect of delay interval on production accuracy for children with TD or PD.

3. Procedure

The experimental items were preceded by two nonlinguistic response time tasks. The first of these was the "yes to tone" task, described earlier. In this task, children were instructed to say "yes" as soon as a 100 ms, 1000 Hz pure tone was played. Ten trials of this were administered. The inter-stimulus interval (ISI) between the trials varied, so that children could not anticipate the timing of the tone. The second task was intended as first step in training the children for the delayed naming task. In this task, children saw a black-and-white line drawing of a circle, centered on a 14" laptop monitor, framed by a red background. Children were positioned directly in front of the monitor, wearing headphones. They were instructed to say "yes" as soon as the background changed from red to green. Concurrent with this color change, a 100 ms, 1,000 Hz pure tone was played through the headphones. The ISI varied, so that children could not anticipate when the tone would be played.

The procedures for the delayed naming task were very similar. On each trial, a picture appeared framed by a red background. The background changed to green after a pre-specified delay interval, 0 ms (i.e., immediately), 500 ms, or 1,000 ms. Concurrent with the color change, a 100 ms, 1,000 Hz pure tone was played through headphones. Children were instructed to name the picture as fast as they could after the screen turned from red to green and they heard a tone. This change occurred 250ms after the red screen. The experiment was fully randomized, so that children could not anticipate an upcoming item's delay interval and develop response strategies. Children were given frequent encouragement, but were not provided with feedback on their accuracy. The delayed naming task was preceded by a practice block containing pictures not used in the experiment.

4. Analyses

Response Types

Each child's response was coded using as one of seven response categories, including six error types, and correct responses. Descriptions of the errors, and examples are listed in Table 3. These errors were intended to represent the different types of errors that have been reported in previous naming experiments (Lahey & Edwards, 1999), and which were observed by the examiners during this experiment. The proportion of each type of error was calculated separately at each delay interval. The second investigator re-coded two responses per child (4.6% of the total data set) to determine the reliability of assessing error type. 92% of errors were coded into identical categories. The majority of these differences were disagreements between whether an error was semantically related to the target, or phonologically and semantically unrelated to it. These categories were thus pooled for analyses.

Descriptive Statistics and Items Reduction

Accurate responses were defined relative to the presumed semantic target for the word. Hence, the categories *correct name-expected*, *correct name-unexpected*, and *phonological error* in Table 3 were all presumed to be correct responses. All other error types were combined as incorrect responses. Average accuracy scores were calculated separately for each word for children with TD and children with PD. In this analysis by items, children with TD and children with PD did not differ in the rate with which they named pictures accurately (z = -1.614,

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Table 2. Words Used in Delayed Naming Task. Words removed from the final analysis are underlined.

Delay Interval	Word list														
0ms	Bag	Ball	Bee	Bone	Cake	Cat	Comb	Dog	Fan	Hat	King	Moon	Pen	Pot	Tie
500ms	Bat	Boat	Book	Can	Coat	Cow	Egg	Fish	Foot	Key	Kite	Man	Mouse	Nut	Pig
1000ms	Bear	Bed	Boot	Cage	Cup	Deer	Eye	Goat	Hook	Neck	Nose	Pan	Pear	Pipe	Wing

p = 0.107, using a Wilcoxon signed ranks test); however, there was considerable variation across items in the percentage of subjects who named them correctly. Eight items had accuracy rates below 75%. This included one item each at the 0 ms and 500 ms delay intervals, and six items at the 1000 ms delay interval. These are underlined in Table 2. Multiple regression analyses were used to examine predictors of response accuracy for individual items. The dependent measure in this regression was the average responses accuracy, pooled across the 38 participants. The independent measures were the lexical variables described earlier. These were added to the regression in a stepwise fashion if they accounted for a significant proportion of variance in the dependent measure ($\alpha < 0.05$) beyond what was accounted for by the variable(s) entered in the previous step(s). Two variables predicted a significant proportion of variance in error rates. First, the uniformity with which children named words in the normative sample predicted 11.4% of the variance in errors. Items that were named more uniformly in the normative sample elicited less uniform responses in this sample. Moreover, phonological neighborhood density predicted 6.4% of the variance in responses. As in earlier studies (Vitevitch, 2002), children named pictures representing dense words more accurately than those representing sparse words. Based on these analyses, the eight highly inaccurately named pictures were eliminated from further analyses.

Ⅲ. Results

The first analysis examined the influence of delay interval and group on different types of errors. For this analysis, two types of correct responses (expected and unexpected) were pooled together. Moreover, false starts, which comprised very few of the responses, were pooled together with semantic and unrelated errors. The first set of analyses was a series of Mann-Whitney U tests, examining whether the groups differed in the proportion of the four response types (correct responses, no response, phonological error, and non-phonological error) at the three delay intervals. These data are shown graphically in Figures 1 and 2. When a conservative, Bonferroni-corrected α level of 0.0042 was used, three group differences were significant: phonological errors at the 0 ms delay interval (U = 90, z = -2.883, p = .004),

Table 3. Error types. Correct responses were indicated as Correct Name, Expected, Correct Name, Unexpected and Unexpected and Phonological Error. Incorrect responses were indicated as No response, Semantic Error, Unrelated Error, False start

Category	Description
No response	Child does not name the picture
Correct Name, Expected	Child names the picture using the expected word[a]
Correct Name, Unexpected	Child names the picture using a word that is unexpected but semantically appropriate
Phonological Error	Child names the picture correctly, but the name contains a phonological error
Semantic Error	Child produces a word that is incorrect, and is semantically related to the target word.
Unrelated Error	Child produces a word that is neither semantically nor phonologically related to the target word
False start	Child produces a hesitation, or revises a response

[a] Based on the most frequent response given by children in Bates et al. (2004).

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phonological errors at the 500 ms delay interval (*U* = 77.5, Wilcoxon, *z* = -3.486, *p* < .001), and no-responses at the 1,000 ms delay interval (*U* = 86, *z* = -2.974, *p* = .003). Two other error types achieved significance when the non-Bonferroni-corrected α level of 0.05 was applied. These were correct responses at the 1000 ms delay interval (*U* = 105.5, *z* = -2.215, *p* = .027) and phonological errors at the 1000 ms delay interval (*U* = 114.5, *z* = -2.060, *p* = .039). Children with PD produced a higher proportion of phonological errors at all three delay intervals, as well as a larger proportion of non-responses at the 1000 ms delay interval, than children with TD. Children with TD produced more correct responses than children with PD at the 1,000 ms delay interval.

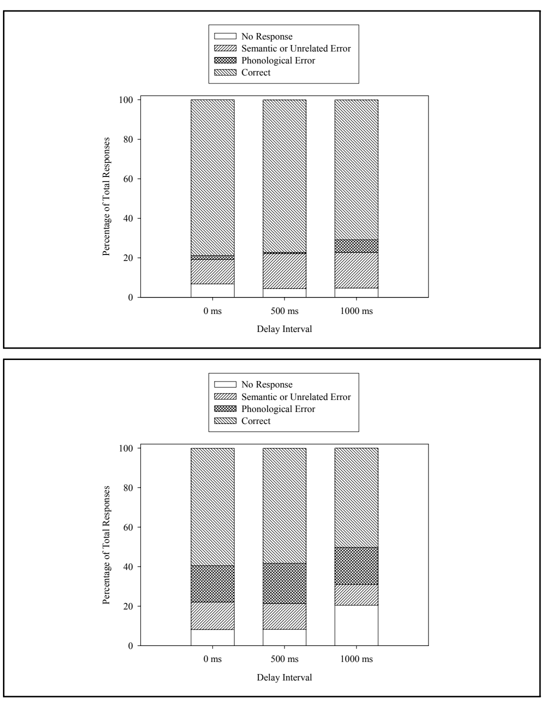

Figure 1. Proportion of error types for children with TD (top) and PD (bottom) at the 0 ms, 500 ms, and 1,000 ms delay intervals.

Recall that the two groups differed not only in speech-production accuracy, but also in estimates of vocabulary size, PPVT-Ⅲ and EVT scores. A second set of analyses examined whether variance in vocabulary- size measures predicted group differences in error rates beyond what was predicted by measures of speech-production accuracy. Partial correlations among measures of naming accuracy and selected standardized and nonstandardized measures are presented in Table 4. Included in this table are correlations between the error proportions and children's production accuracy on the GFTA-2 for the subset of sounds comprising the words in each of the delay intervals. Recall from Table 2 that these were not equivalent across the three delay intervals. By measuring this variable, we were able to assess whether errors (both phonological errors and other types of errors) were simply the consequence of children's difficulty producing these sounds.

Five hierarchical multiple regressions examined predictors of the five error types that were found to differ between groups. In these regressions, age was forced as the first variable. In the second block, production accuracy for the sounds comprising the words was entered. In the third block, the following variables were entered if they accounted for a significant proportion of variance in the dependent measure (α < 0.05) beyond that accounted for by the variable(s) entered in the previous step(s): EVT standard score, natural log-transformed EVT raw scores, PPVT-Ⅲ standard score, and log-transformed PPVT-Ⅲ raw score. In all of these regressions, production accuracy for the phonemes comprising the words predicted a significant proportion of variance in error proportions, beyond what was accounted for by age, as the correlations in Table 4 would suggest. However, in none of the regressions did measures of vocabulary size predict any additional variance in these proportions. This included the regressions examining rates of phonological errors, as well as correct. Despite the many significant correlations in Table 4, only production accuracy of phonemes comprising the nonwords predicted error rates. That is, the group differences in error rates appeared to be wholly attributable to children's difficulty producing the phonemes in the pictures' names.

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Table 4. Partial correlations between standardized and nonstandardized test scores and selected measures of naming accuracy, controlling for chronological age.

	1	2	3	4	5
Discrimination PC[a)]	−0.31	−0.30	−0.11	0.34*	−0.28
DDK Rate[b)]	−0.45*	−0.45*	−0.36(*)	0.52**	−0.02
Nonlinguistic RT[c)]	0.29	0.24	0.36(*)	−0.15	−0.33(*)
GFTA-2 PPC[d)]: Full set	−0.64**	−0.75**	−0.62**	0.75**	−0.18
GFTA-2 PPC[e)]: Subset	−0.75**	−0.86**	−0.67**	0.77**	−0.50**
GFTA-2 PR[e)]	−0.45*	−0.49*	−0.37(*)	0.55**	−0.47*
PPVT-III SS[f)]	−0.40*	−0.52**	−0.26	0.59**	−0.30
PPVT-III RS[g)]	−0.52**	−0.65**	−0.32(*)	0.65**	−0.29
EVT SS[f)]	−0.14	−0.34(*)	−0.15	0.53**	−0.30
EVT RS[g)]	−0.17	−0.36(*)	−0.15	0.53**	−0.09
K-BIT SS[f)]	−0.12	0.01	0.02	−0.01	

[1] Proportion of phonological errors, 0 ms delay interval,
[2] Propoportion of phonological errors, 500 ms delay interval,
[3] Proportion of phonological errors, 1,000 ms delay interval,
[4] Proportion of correct responses, 1000 ms delay interval,
[5] Proportion of no responses, 1000 ms delay interval,
[a)] percent correct, [b)] syllables per second, [c)] response time,
[d)] percent phonemes correctly produced, [e)] percentile rank,
[f)] standard scores, [g)] raw score, natural-log transformed
$^{**}p \leq 0.01$, $^{*}0.01 < p \leq 0.05$, $(^{*})\ 0.05 < p \leq 0.10$

Ⅳ. Discussion

This study examined whether children with phonological disorder (PD) have deficits in lexical access relative to their peers with typical phonological development (TD), by examining the accuracy with which pictures were named following different delay intervals. Overall, children with PD performed poorly than TD children on all three different delay intervals. Among the error types, phonological errors were significantly higher in children with PD in all three conditions. However, the magnitude of this effect was similar for both groups of children. Together, these findings provide no support for the hypothesis that children with PD differ from their peers in the speed of lexical access. Such a conclusion would only have been warranted if we had found disproportionately larger group differences in the 0 ms delay interval than in the longer-delay intervals. Additionally, our study examined the error rate as to define the underlying difference between groups. However, for the future study, not only offline results but also online results such as measuring response time for each interval as children respond might explain more about the reason behind this population.

Perhaps the most important finding in this investigation concerns the association between speech- production accuracy and performance on the delayed-naming task. Error rate were significantly correlated with many variables. However, regression analyses showed no significant relationship with naming accuracy when phoneme-production accuracy was controlled statistically. These results suggest that children with PD do not differ on the ability to access lexical items from typically developing children.

What, then, is the core processing deficit that underlies this disorder? As mentioned above, children with PD were approached from three dimensions; lexical access and post-lexical access, phonological encoding, and the ability to learn perceptual representations for novel words in the bigger study. A companion paper, Munson et al. (in preparation) examined phonological encoding during picture naming in a cohort of children with PD (comprising most of the same participants from this investigation) using a different experimental paradigm, cross-modal priming. In that paper, we found no evidence that children with PD have less-efficient phonological encoding processes than their peers with TD. Indeed, we found no association between measures of phonological encoding and measures of speech-production accuracy. However, the last companion paper which examined the ability to learn perceptual representations for novel words (Munson et al., 2011) found that children with PD have deficits in building perceptual representations for novel words in a long-term repetition priming paradigm. That is, the core processing deficit in the cohort of children with PD examined in this set of experiments appears to be perceptual. Thus, PD may arise from an inability to build robust perceptual representations for novel sounds. This, in turn, leads children to

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'default' to producing errors. The relationship between perceptual deficits and the precise types of errors remains to be elaborated. It is likely that these errors reflect a combination of articulatory ease, perceptual salience, and frequency in the ambient language. Moreover, though these experiments examined only perceptual abilities, it is possible that the perceptual problems relate not only to the auditory domain, but to tactile, kinesthetic, and somathetic feedback as well, and to children's learning of the mapping between articulatory events and their acoustic consequences. This argument is consistent with our earlier work on this topic using a different set of methods to assess different types of phonological knowledge (Beckman, Munson & Edwards, 2007; Munson, Edwards & Beckman, 2005b). Such a conjecture might also explain that association between speech-production accuracy and naming errors in the current paper, if we were to presume that naming errors are also the consequence, in part, of representational weaknesses.

Crucially, however, this program of research has found no evidence that PD is associated with deficits in on-line language formulation processes. In this way, then, PD stands apart from other speech and language deficits, such as word-finding deficits and developmental dysfluency. There is strong evidence that these disorders are associated with deficits in real-time formulation processes. These findings support the use of intervention regimens for PD that emphasize the development of perceptual abilities, and provide children with increased exposure to the sensory characteristics of sounds. We close by emphasizing, however, that children with PD may be heterogeneous with respect to underlying causes. Group studies like the one presented in this paper must be supplemented with rigorous individual case profiles to determine whether peripheral sensory deficits are indeed the sole cause of speech-sound disorders of an unknown origin.

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음운장애아동의 지연상황 이름대기 과제에 있어서 음운 정확도

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배경 및 목적: 음운장애 아동의 근본적인 특성을 어휘 접근과정에 초점을 맞추어 연구하였다. 본 연구는 지연상황 그림이름대기 과제를 사용하여 음운장애 아동의 어휘유출 능력을 정상아동과 비교하고, 이 과제에 있어서 이름대기의 정확도를 설명해주는 요소가 무엇인지 예측해 보았다. **방법:** 총 38명의 아동이 실험에 참가하였으며 (19 = 일반아동, 19 = 음운장애 아동), 실험과제는 지연상황 그림이름대기 과제로 아동이 그림을 보고 반응을 시작하는 속도를 0ms, 500ms. 1000ms로 지연하여 구성하였다. 반응지연속도가 0ms 인 상황은 어휘접근 단계와 어휘접근 단계-후 두 과정 모두를 포함하며, 지연시간이 500ms, 1000ms인 상황은 어휘접근 단계-후 과정을 주로 측정하는 것이다. 음운장애 아동의 어휘유출 능력을 정상아동과 비교한 후, 어휘력이 음운장애 아동의 어휘유출 과제의 수행력을 예측하는지 분석하였다. **결과:** 음운장애아동은 일반아동보다 모든 상황에서 유의미하게 높은 음운오류를 보였다. 그러나, 각각의 모든 상황에서 같은 비율의 차이를 보여 두 그룹간 단어유출 능력은 유사하다는 결과를 보였다. 회귀분석을 통한 결과 어휘력 (수용과 표현)은 지연이름대기 상황에서 음운장애 아동의 수행력을 예측해 주지 못하였다. 그러므로, 음운장애 아동의 오류율은 정확한 음운 산출 능력으로만 설명할 수 있었고, 이를 바탕으로, 두 그룹의 오류율 차이는 아동이 그림이름을 음운적으로 정확하게 산출하는 데 있어서 어려움의 차이로 설명되었다. **논의 및 결론:** 음운장애 아동은 어휘유출 능력에 있어서 정상아동과 차이가 없으며, 지연상황에서 그림이름대기 과제 수행 시 두 그룹의 오류율 차이는 음소산출에 어려움이 주 원인으로 밝혀졌다. 『**언어청각장애연구**』, 2012;17:177-200.

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