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Original Article

Stage-Specific Characteristics of Speech Processing in Children With Phonological Disorder and Typically Developing Children

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Purpose This study investigated stage-specific characteristics of speech processing in children with phonological disorders by comparing their performance on tasks representing the input, storage, and output stages of speech processing with that of children matched for chronological and language age.

Methods Thirty children, aged between 4 years and 0 months and 6 years and 11 months, participated in the study. They were divided into three groups: one with phonological disorders, one matched by chronological age, and one matched by language age. Speech processing was assessed through three tasks: a phonetic discrimination task (input stage), a phonological representation judgment task (storage stage), and a nonword repetition task (output stage). Group differences were analyzed using one-way and mixed-design analyses of variance, while the relationships among the tasks were examined using Pearson correlation analyses.

Results No significant differences were found between groups in phonetic discrimination performance, and there were no notable effects of task conditions. However, children with phonological disorder exhibited significantly lower performance on the phonological representation judgment task compared to chronological-age-matched peers, while their performance was comparable to that of language-age-matched children. In the nonword repetition task, the phonological disorder group performed significantly worse than both comparison groups, with performance declining for all groups as syllable length increased. Correlation analyses indicated a significant positive correlation between phonetic discrimination and phonological representation judgment, but only in the phonological disorder group. No significant correlations involving nonword repetition were found in any of the groups.

Conclusions The findings indicate that speech sound difficulties in children with phonological disorders are more closely linked to weaknesses in the storage and output stages of speech processing, rather than deficiencies in basic phonetic discrimination. These results emphasize the importance of using stage-specific assessment and intervention strategies that focus on phonological representation and the demands related to speech output.

Keywords Phonological disorder, Speech processing, Phonetic discrimination, Phonological representation, Nonword repetition

INTRODUCTION

In clinical settings, children who experience communication difficulties frequently present with inaccurate speech-sound production. A substantial proportion of children with inaccurate speech sound production have also been reported to exhibit delays in receptive and expressive language development [1,2]. These findings from previous studies suggest that the difficulties observed in children with articulation and phonological disorders are not confined to the accuracy of speech sound production but may be associated with broader problems related to language processing. Furthermore, these findings high-

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light the need to understand speech sound production errors at a more underlying level of processing [3].

From this perspective, a psycholinguistic approach seeks to explain speech-sound production errors in children with articulation and phonological disorders in terms of a series of speech-processing stages, including the perception of speech sounds, the storage of phonological information, and its subsequent connection to speech output [3]. That is, children with articulation and phonological disorders may exhibit vulnerabilities at a specific stage or across multiple stages of the speech processing system, including speech sound discrimination, the storage and access of phonological information, and the linkage of this information to speech output [4,5]. This speech processing model has been used as a framework for understanding speech sound errors not merely as output-level difficulties, but as reflecting different clinical profiles depending on vulnerabilities across specific stages of speech processing [6]. Empirical studies comparing speech processing in children with articulation and phonological disorders with that of typically developing children have reported no significant group differences on speech-sound discrimination tasks. In contrast, children with articulation and phonological disorders showed significantly lower performance in phonological representation judgment and nonword repetition tasks. In addition, a positive correlation was observed between speech sound discrimination and phonological representation judgment. In contrast, nonword repetition was not significantly correlated with the other tasks, suggesting that vulnerabilities may lie not at the input level of speech processing but rather at the stages of storing and outputting phonological information [7].

Meanwhile, children with articulation and phonological disorders are classified as having articulation disorder, phonological delay, or phonological disorder based on the characteristics of error patterns observed in speech production [8]. Among these subtypes, phonological disorder is characterized by the co-occurrence of developmental and nondevelopmental error patterns. In particular, nondevelopmental error patterns are atypical and not observed in typical developmental trajectories, and therefore cannot be readily explained by articulatory immaturity or developmental delay alone. Such errors have been reported to be associated with vulnerabilities in phonological knowledge, including abstract representations of the phonological system and the application of phonological rules [9,10].

These differences in error patterns across subtypes may be related to differences in processing demands required throughout the speech production process. In particular, tasks that need access to phonological representations or the maintenance and manipulation of phonological information for subsequent production may yield differential performance across subtypes. In this context, the nonword repetition task has been proposed as a measure that reflects not only the accuracy of speech sound production but also the processing demands involved in storing, maintaining, and linking phonological information to speech output [3,11].

Taken together, previous studies suggest that children with articulation and phonological disorders should not be regarded as a homogeneous group characterized by a single speech-sound deficit, but rather as a heterogeneous population exhibiting different patterns of vulnerability across error types and stages of speech processing [3,8]. In particular, children with phonological disorders may experience relatively greater processing demands in storing and maintaining speech sound information and linking it to speech output. This perspective highlights the need to interpret speech sound errors not merely as surface-level production difficulties, but in relation to vulnerable stages within the speech processing system [12].

However, previous studies have primarily focused either on comparing children with articulation and phonological disorders as a single group with typically developing children or on examining specific components of

speech sound performance. Consequently, relatively few studies have directly compared stage-specific performance characteristics of speech processing between children with phonological disorders—who show pronounced vulnerabilities in phonological processing—and typically developing children. In addition, there is a lack of research distinguishing whether the reduced performance observed in children with phonological disorders reflects a simple delay in language development or indicates qualitative vulnerabilities in the speech processing system that persist even after controlling for language developmental level.

Accordingly, the present study aimed to compare stage-specific performance characteristics of speech processing by administering phonetic discrimination, phonological representation judgment, and nonword repetition tasks to three groups of children: children with phonological disorder, chronological-age-matched children, and language-age-matched children. Furthermore, this study sought to examine more precisely whether the performance characteristics observed in children with phonological disorder reflect differences beyond language developmental level, indicating qualitative vulnerabilities associated with specific stages of the speech processing system.

METHODS

Participants

This study included 30 children aged between 4 years and 0 months and 6years and 11 months. All children were reported by their parents or teachers to have no sensory, neurological, physical, or cognitive impairments, and no structural abnormalities of the speech mechanism.

The children were assessed using the Receptive and Expressive Vocabulary Test (REVT) and the Urimal Test of Articulation and Phonology-2 (U-TAP2). They were classified into a phonological disorder group, a language-age-matched group, and a chronological-age-matched group based on the assessment results [13,14].

The phonological disorder group consisted of children who showed articulation abilities below -1.5SD on the U-TAP2 and exhibited both developmental and non-developmental error patterns. The comparison groups included children who scored -1.5SD or above on the U-TAP2, and -1SD or above on receptive vocabulary measures of the REVT. The language-age-matched group comprised children whose receptive vocabulary levels were comparable to those of the phonological disorder group. In contrast, the chronological-age-matched group consisted of children matched in chronological age with the phonological disorder group.

As a result of group classification, no statistically significant difference was found in receptive vocabulary between the phonological disorder group and the language-age-matched group ($p > .05$), whereas a significant difference was observed in chronological age ($p < .05$). Similarly, no statistically significant difference in chronological age was found between the phonological disorder group and the chronological-age-matched group ($p > .05$); however, a significant difference was observed in receptive vocabulary between these groups ($p < .05$).

Table 1. Group differences in Chronological Age, Receptive Vocabulary, and Percentage of Consonants Correct

Group	Chronological Age (months)	Receptive Vocabulary Age (months)	Percentage of Consonants Correct (%)
PD (N = 10)	62.70 (6.91)	44.20 (16.02)	64.46 (15.76)
LA (N = 10)	56.20 (4.13)	51.50 (11.25)	98.33 (2.55)
CA (N = 10)	62.90 (5.60)	73.80 (8.86)	98.33 (2.15)
F	6.321**	15.435***	44.197***

*$p < .05$, **$p < .01$, ***$p < .001$.

Percentage of consonants correct (PCC) differed significantly among the three groups ($p < .001$), with the phonological disorder group showing substantially lower performance than the other two groups. The statistical characteristics of the participants are presented in Table 1.

Research tasks

The speech processing tasks were organized into three stages—input, storage, and output—following the speech processing model [3]. The functions for each stage were modified and refined to align with the objectives of the present study, drawing on previous research [7,15]. The phonetic discrimination task was used to assess the input stage of speech processing, the phonological representation judgment task to assess phonological information storage, and the nonword repetition task to evaluate speech output and speech programming processes [3,7].

The phonetic discrimination task was designed to assess the ability to distinguish a target speech sound from other sounds based on their acoustic properties. Children with articulation and phonological disorders may show relatively intact performance in general speech-sound discrimination; however, they may experience difficulties discriminating speech sounds they produce inaccurately [16,17]. Accordingly, the target stimuli consisted of meaningful words and nonwords forming minimal pairs in which only one phonological feature-place of articulation, manner of articulation, or phonation type-was manipulated. Five word pairs were presented for each condition. For example, the target word /pɑdʑi/ was paired with the minimal contrast /pɑdi/, differing only in manner of articulation. The stimuli were presented in mixed formats, including target-contrast (/pɑdʑi-pɑdi/), contrast-target (/pɑdi-pɑdʑi/), target-target (/pɑdʑi-pɑdʑi/), and contrast-contrast (/pɑdi-pɑdi/) pairs, comprising both correct and incorrect response trials. This design minimized response strategies based on repetition or presentation order and enabled the assessment of children's ability to discriminate acoustic differences among individual speech sounds [16].

The phonological representation judgment task was designed to assess access to and accuracy of stored phonological representations while minimizing speech production demands, allowing children's phonological representation abilities to be examined at a receptive level [18-20]. The task consisted of eight trisyllabic words paired with minimal contrast stimuli in which either a consonant or a vowel was manipulated. For each item, a picture stimulus was presented simultaneously with an auditory stimulus word, and the child was asked to judge whether the picture and the presented stimulus word matched [21,22]. To maximize phonological similarity between target and contrast stimuli, the auditory stimuli were constructed by altering only one phonological feature, either place of articulation or manner of articulation. For example, consonant manipulation stimuli included /piɦɑŋgi/ → /tiɦɑŋgi/ and /tɕɑdoŋtɕʰɑ/ → /tɑdoŋtɕʰɑ/, which differed minimally from the target words in a single phonological feature [22].

The nonword repetition task was designed to minimize the influence of semantic information stored in phonological representations and to assess speech programming ability more sensitively. Accordingly, the task consisted of nonwords with low wordlikeness and included only early-acquired consonants, taking into account the typical consonant acquisition levels of children aged 4-6 years [23,24]. The task comprised nonwords of three, four, and five syllables. It was structured such that increases in syllable length progressively increased the demands on phonological information maintenance and speech programming during speech production. For example, as syllable length increased (e.g., /tuniɬ̟ɯ/, /gudɛk̟odʑɯ/, /kɯkʰʌnidu k̟o/), children were required to maintain phonological information for longer durations and produce it sequentially, allowing differences in speech production processing capacity to be more sensitively reflected.

Research procedure

In the present study, all speech processing tasks were developed as digital stimuli using recordings produced by a female adult speaker in her 30s who spoke standard Korean. All tasks were administered in a quiet, separate room, with the examiner and the child seated face-to-face in a one-to-one setting. Before each task, practice items were provided to ensure that the child fully understood the task requirements before proceeding to the test items.

The tasks were administered in an order that reflected the sequential characteristics of the speech processing framework, beginning with the phonetic discrimination task, followed by the phonological representation judgment task, and the nonword repetition task. Stimuli were presented in a randomized order to minimize the formation of specific response patterns or strategies. If a child did not clearly perceive a stimulus, requested a repetition, or showed a temporary lapse in attention during task administration, the same stimulus was presented once more.

The phonetic discrimination task consisted of 40 stimulus pairs. Each correct response was scored 1 point, and each incorrect response 0 points, yielding a maximum total score of 40. The phonological representation judgment task consisted of 24 items, each scored 1 point for a correct response and 0 points for an incorrect response. The nonword repetition task comprised 15 items, and responses were analyzed at the syllable level, with 1 point assigned for correct production and 0 points for incorrect production. To enhance the accuracy of response analysis in the nonword repetition task, all productions were audio-recorded and subsequently transcribed at the syllable level for analysis.

Data processing and analysis

In this study, the groups (phonological disorder group, chronological-age-matched group, and language-age-matched group) were set as the independent variables, and performance scores on the phonetic discrimination, phonological representation judgment, and nonword repetition tasks were set as the dependent variables. All statistical analyses were conducted using SPSS Statistics version 31.0.

Before performing the statistical analyses, Levene's test was conducted to assess the assumption of homogeneity of variances across groups for each dependent variable. To investigate differences in performance on the speech processing task among the three groups, one-way analysis of variance (ANOVA) was conducted. When a significant main effect was found, Bonferroni post hoc tests were performed to identify group differences.

To examine within-group performance differences according to task conditions and interaction effects between group and task condition, a mixed-design ANOVA was conducted. In addition, Pearson correlation analyses were performed to examine relationships among performances on the speech processing tasks. The level of statistical significance was set at $p < .05$.

RESULTS

Phonetic discrimination

To examine differences in phonetic discrimination performance among the phonological disorder group, the language-age-matched group, and the chronological-age-matched group, a one-way ANOVA was conducted. The results, presented in Table 2, revealed no statistically significant differences among the three groups ($p > .05$).

Table 2. Results of the Phonetic Discrimination Task Between Groups

	N	mean (SD)	*F*	*p*
PD (N = 10)	10	29.30(6.91)		
LA (N = 10)	10	30.20(5.53)	3.342	.051
CA (N = 10)	10	34.70(3.02)		

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

To examine performance differences according to task conditions, a mixed-design ANOVA was conducted. The analysis revealed no significant main effects of group or condition ($p > .05$), and no significant interaction effect between group and condition ($p > .05$).

Accordingly, phonetic discrimination performance was comparable across the phonological disorder group, the language-age-matched group, and the chronological-age-matched group. Detailed results are presented in Tables 3 and 4.

Phonological representation judgment

To examine differences in phonological representation judgment performance among the phonological disorder group, the language-age-matched group, and the chronological-age-matched group, a one-way ANOVA was conducted, and the results are presented in Table 5. The analysis revealed a statistically significant difference in phonological representation judgment performance among the three groups ($p < .01$).

Post hoc analyses were performed to examine the pattern of group differences further. The phonological disorder group showed significantly lower performance than the chronological-age-matched group ($p < .01$). In contrast, no significant difference was found between the phonological disorder group and the language-age-matched group ($p > .05$). Additionally, the language-age-matched group and the chronological-age-matched group did not differ significantly in performance ($p > .05$).

Nonword repetition

To examine differences in nonword repetition performance among the phonological disorder group, the language-age-matched group, and the chronological-age-matched group, a one-way ANOVA was conducted, and the results are presented in Table 6.

The analysis revealed a statistically significant difference in nonword repetition performance among the three groups ($p < .001$). Post hoc analyses indicated that the phonological disorder group performed significantly worse than both the language-age-matched and chronological-age-matched groups ($p < .001$). In contrast, no significant difference was observed between the language-age-matched and chronological-age-matched groups ($p > .05$).

To examine performance differences according to task conditions, a mixed-design ANOVA was conducted. The results showed significant main effects of group and task condition ($p < .001$). In contrast, the interaction effect between group and task condition was not statistically

Table 3. Phonetic Discrimination Performance Between Groups by Task Condition

	N	meaningful words mean (SD)	nonwords mean (SD)
PD (N = 10)	10	14.20(3.29)	15.10(4.60)
LA (N = 10)	10	15.40(3.40)	14.80(2.93)
CA (N = 10)	10	17.50(3.03)	17.20(2.53)

Table 4. Repeated-Measures ANOVA Results for the Phonetic Discrimination Task

	df	F	p	ηp^2
Group	2, 27	2.704	.085	.167
Task Condition	1, 27	.000	1.000	.000
Group × Task Condition	2, 27	.717	.498	.050

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 5. Results of the Phonological Representation Judgment Task Between Groups

	N	mean (SD)	F	p
PD (N = 10)	10	16.50(3.50)		
LA (N = 10)	10	18.20(3.80)	6.179	.006**
CA (N = 10)	10	21.40(1.84)		

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 6. Results of the Nonword Repetition Task between Groups

	N	mean (SD)	F	p
PD (N = 10)	10	26.00(10.09)		
LA (N = 10)	10	47.80(8.65)	21.828	< .001***
CA (N = 10)	10	48.00(6.57)		

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

significant ($p > .05$). Post hoc analyses further revealed that the phonological disorder group demonstrated significantly lower performance than both comparison groups across conditions ($p < .001$), with no significant difference between the language-age-matched group and the chronological-age-matched group ($p > .05$). In addition, performance significantly decreased across all groups as syllable length increased ($p < .001$). Detailed results are presented in Tables 7 and 8.

Correlation

To examine the relationships among performance on the phonetic discrimination, phonological representation judgment, and nonword repetition tasks, Pearson correlation analyses were conducted, and the results are presented in Table 9.

The results indicated that a significant positive correlation was observed between phonetic discrimination and phonological representation judgment in the phonological disorder group ($p < .01$). In contrast, no statistically significant correlations between these tasks were found in the language-age-matched or chronological-age-matched groups ($p > .05$).

In addition, no significant correlations were observed between phonetic discrimination and nonword repetition, or between phonological representation judgment and nonword repetition, in any of the three groups ($p > .05$).

Table 7. Nonword Repetition Performance between Groups by Task Condition (%)

	N	three-syllable	four-syllable	five-syllable
PD (N = 10)	10	56.00(23.13)	47.00(25.07)	42.40(21.43)
LA (N = 10)	10	84.66(16.64)	83.00(18.88)	74.00(14.99)
CA (N = 10)	10	85.33(13.62)	78.50(9.44)	76.40(13.78)

Table 8. Repeated-Measures ANOVA Results for the Nonword Repetition Task

	df	*F*	*P*	ηp^2
Group	2, 27	12.894	< .001***	.489
Task Condition	2, 54	9.406	< .001***	.258
Group × Task Condition	4, 54	0.545	.703	.039

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 9. Results of Correlation Analysis Among Speech Processing Tasks

	PD × PRJ	PD × NWR	PRJ × NWR
PD (N = 10)	.778**	-.016	-.132
LA (N = 10)	.077	-.015	.567
CA (N = 10)	.364	.571	.580

PD = phonetic discrimination, PRJ = phonological representation judgment, NWR = nonword repetition.
*$p < .05$, **$p < .01$, ***$p < .001$.

DISCUSSION AND CONCLUSION

This study compared stage-specific performance characteristics of speech processing across the input, storage, and output stages by administering phonetic discrimination, phonological representation judgment, and nonword repetition tasks to children with phonological disorder, chronological-age-matched children, and language-age-matched children.

First, with respect to the input stage, no significant differences were found among the three groups in phonetic discrimination performance, and no significant effects of task condition were observed. These findings suggest that, under the task conditions employed in the present study, basic phonetic discrimination ability in children with phonological disorder may be relatively preserved, which is consistent with previous studies [7,17,25,26]. In contrast, some studies on speech perception have reported poorer performance in children with articulation and phonological disorders compared to typically developing children [27,28]. However, these studies differed from the present study in that they employed speech identification tasks that required explicit identification of specific phonemes or assessed speech perception under increased processing demands, such as background noise or reduced stimulus clarity. Such methodological differ-

ences may have contributed to the discrepant findings. Taken together, the present results indicate that basic phonetic discrimination ability, corresponding to the input stage of speech processing, is likely to be generally preserved in children with phonological disorder, and that phonetic discrimination performance may vary with the level of processing demand imposed by the task.

Second, with respect to the storage stage, children with phonological disorder showed significantly lower performance on the phonological representation judgment task compared to the chronological-age-matched group. In contrast, their performance was comparable to that of the language-age-matched group. These findings suggest that phonological representation ability in children with phonological disorder may be more closely associated with language developmental level than with chronological age, and are consistent with previous studies reporting that the refinement of phonological representations is more strongly related to language development than to age-related maturation [21,29].

Notably, although children with phonological disorder and language-age-matched children demonstrated comparable performance on the phonological representation judgment task, it would not be easy to assume that the underlying processing characteristics of the two groups are equivalent. Children with phonological disorder exhibit speech production characteristics, including atypical error patterns, in addition to reduced language ability. Atypical error patterns have been described as reflecting nondevelopmental characteristics that cannot be explained simply as an extension of delayed language development, but rather as being associated with atypical organization of the phonological system or nonstandard application of phonological rules [9,10]. From this perspective, although children with phonological disorder may show surface-level performance comparable to that of language-age-matched children, their phonological representations may not be sufficiently robust, and the efficiency with which stored phonological information is accessed and utilized may be relatively constrained [20,30,31].

Third, with respect to the output stage assessed via the nonword repetition task, children with phonological disorder demonstrated significantly lower performance than both the language-age-matched and chronological-age-matched groups. In addition, all three groups showed a pattern of decreasing performance as syllable length increased. Previous studies that classified children with articulation and phonological disorders by components of speech processing ability reported that children with vulnerabilities in phonological working memory or phonological representation processing exhibit abysmal performance on nonword repetition tasks. These findings suggest that nonword repetition performance reflects not merely speech production accuracy, but the overall processing demands associated with speech processing abilities that contribute to output performance [3,11,23,24]. Furthermore, the observed decline in performance with increasing syllable length can be interpreted as reflecting the characteristics of the nonword repetition task, in which demands on phonological working memory and speech-output processing progressively increase with syllable length [23,24,32]. In contrast, the language-age-matched group and the chronological-age-matched group showed comparable performance on the nonword repetition task. This may be explained by the fact that the task stimuli consisted of early-acquired phonemes, and, given the mean age of the language-age-matched group, both comparison groups were able to meet the introductory speech-output demands of the task. Taken together, the difficulties observed in nonword repetition among children with phonological disorder cannot be sufficiently explained by language ability alone. Instead, these findings are more plausibly interpreted as reflecting qualitative vulnerabilities at the output stage of speech processing, particularly in the temporary maintenance, sequencing, and transformation of phonological information into speech output, as well as increased processing de-

mands associated with this stage.

Fourth, correlation analyses across stages of speech processing revealed a significant positive correlation between phonetic discrimination at the input stage and phonological representation judgment at the storage stage only in the phonological disorder group. In contrast, no significant correlations between processing stages were observed in either the chronological-age-matched group or the language-age-matched group. These findings suggest that the stages of speech processing do not necessarily operate uniformly across all children; instead, the relationships among stages may vary depending on individual speech processing characteristics and the stability of the processing system [3].

Notably, the significant correlation between phonetic discrimination and phonological representation judgment in the phonological disorder group suggests that the input and storage stages of speech processing may be more closely coupled in this group [3]. That is, when the efficiency of processing between speech input and phonological representation storage is not sufficiently established, performance in phonetic discrimination may exert a more direct influence on phonological representation judgment, resulting in parallel variation across the two stages.

In contrast, the absence of significant correlations between phonetic discrimination and phonological representation judgment in the chronological-age-matched and language-age-matched groups suggests that, in these groups, the input and storage stages may function as relatively stable and independent processing components. In other words, once phonetic discrimination and phonological representation abilities have reached a certain level of developmental stability, performance at one stage may not be directly reflected in performance at another stage.

Meanwhile, no significant correlations were observed between either phonetic discrimination or phonological representation judgment and nonword repetition, which represents the output stage, in any of the groups. This finding suggests that performance at the output stage may involve additional processing demands that are relatively independent of the input and storage stages. That speech processing does not continuously operate as a strictly sequential input-storage-output pathway [3,12,31].

The findings of the present study are meaningful in that they highlight the need to interpret speech sound errors in children with phonological disorder not merely as surface-level output deficits, but as reflecting processing demands and vulnerabilities, particularly at the storage and output stages of speech processing. Specifically, while phonetic discrimination performance was relatively well preserved, consistent performance deficits were observed in phonological representation judgment and nonword repetition tasks. This pattern suggests that the difficulties experienced by children with phonological disorder may be more closely related to the processes involved in the storage and maintenance of phonological information and its linkage to speech output, rather than to deficits at the input stage. These findings underscore the importance of moving beyond evaluations that focus solely on surface-level articulatory accuracy and adopting a comprehensive assessment approach that considers stage-specific performance characteristics across the speech processing system. Furthermore, the results suggest that intervention planning for children with phonological disorder may benefit from strategies that emphasize strengthening phonological representations and reducing processing demands at the output stage of speech production.

Despite these contributions, the present study has several limitations that should be acknowledged. First, the relatively small sample size in each group warrants caution when generalizing the findings, particularly regarding correlations among speech processing stages. The absence of significant correlations in some groups may reflect true independence between processing stages; however, it may also be attributable to limited statistical pow-

er resulting from the small sample size. Second, because the present study relied on behavioral performance measures to assess speech processing tasks, it is inherently limited in its ability to explain the underlying mechanisms across processing stages in greater depth. Behavioral indices alone may not fully capture the complexity of the cognitive and neural processes involved in speech processing. Finally, the present study focused primarily on children with phonological disorder. Future research would benefit from a more fine-grained classification of articulation and phonological disorder subtypes to examine heterogeneity in speech processing mechanisms across subgroups more precisely.

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