Clinical Forum

Assessment of Phonological Representations in Children With Speech Impairment

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To become an effective reader, children must learn to decode unfamiliar printed words (Adams, 1990). This process involves translating a written or orthographic representation of a word into the corresponding phonological representation of the word. Early spelling development is also facilitated by understanding the association between a word's orthographic and phonological representation (Treiman, Sotak, & Bowman, 2001). Children with speech impairment[1] typically struggle with this translation process. They demonstrate poor performance on tasks that require phonetic reading or spelling ability such as nonword reading and spelling tasks (Carroll & Snowling, 2004; Larivee & Catts, 1999). Researchers have hypothesized that poorly specified phonological representations of words stored in memory underlie the difficulty that some children experience in using phonological information when reading and spelling (Carroll & Snowling, 2004; Elbro, 1996; Elbro, Borstrøm, & Petersen, 1998). Such a hypothesis, however, has rarely been tested with children with speech impairment in relation to how poorly specified phonological representations may restrict these children's phonological awareness and subsequent reading and spelling development. In particular, better understanding of the importance of phonological representations to literacy development is needed for preschool children with moderate and severe

[1]The term speech impairment will be used throughout this article to refer to children who have phonologically based speech errors in the absence of any other significant physical, sensory, or cognitive impairment.

ABSTRACT: **Purpose:** This study explored the use of assessment tasks to examine underlying phonological representations in preschool children with speech impairment. The study also investigated the association between performance on phonological representation tasks and phonological awareness development.
Method: The performance of 9 children (aged 3;09 [years;months] to 5;03) with moderate or severe speech impairment and 17 children of the same age with typical speech development was investigated on a range of novel receptive-based assessment tasks designed to tap underlying phonological representations.
Results: Preschool children with speech impairment experienced more difficulty judging correct and incorrect speech productions of familiar multisyllable words and showed inferior performance in the ability to learn nonwords as compared to children without speech impairment. Performance on these tasks was moderately correlated with phonological awareness ability.
Clinical Implications: Factors such as the precision and accessibility of underlying phonological representations of spoken words may contribute to problems in phonological awareness and subsequent reading development for young children with speech impairment. Receptive-based assessments that examine underlying phonological representations provide clinically relevant information for children with speech impairment.

KEY WORDS: phonological representation, speech impairment, phonological awareness, preschool children

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speech impairment. This group of children is at risk for long-term difficulties in effectively using phonological information when reading and spelling even when their speech error patterns have resolved (Nathan, Stackhouse, Goulandris & Snowling, 2004).

Testing of a phonological representation hypothesis requires the establishment of reliable assessment measures that can provide clinically useful information for working with children with unintelligible speech. Development of appropriate assessments tasks may help ensure that interventions to improve speech intelligibility for preschool children also develop more fully specified underlying phonological representations of spoken words—a potentially important factor in phonological awareness, reading, and spelling development. This study begins to address this need. Novel receptive and production-based assessment tasks are trialled to determine the characteristics of underlying phonological representations in 4- and 5-year-old children with moderate or severe speech impairment. Task performance for these children is compared to that of their peers without speech impairment, and the association between measures of phonological representations and phonological awareness ability is examined.

WHAT IS A PHONOLOGICAL REPRESENTATION?

The term phonological representation is widely used to describe the storage of phonological information about words in long-term memory. Although the concept of phonological representations is relatively abstract, they are considered to be the repository for speech sound information that forms the basis of spoken words. Phonological representations are either holistic (i.e., words are the smallest unit and can only be produced or considered as single units) or segmental (i.e., words consist of subunits that can be consciously manipulated). Segmental phonological representations enable speakers to process phonological information at a syllable, onset-rime, or phoneme level and evolve during the first few years of a child's speech and language development (Fowler, 1991). The "segmentation" (Fowler, 1991) and "lexical restructuring" (Metsala & Walley, 1998) hypotheses suggested that infants' words are initially stored as whole units, then as memory storage requirements increase for vocabulary growth, words are gradually segmented into smaller units. As lexical items become stored in a more segmented manner, children's ability to perform phonological awareness tasks develops. For example, to be able to identify the first phoneme in a word, a common phonological awareness task for young children—access to a phonological representation that is segmental in nature—is necessary. Fowler proposed that this segmentation process takes place over a period of time from 1 to 8 years of age. This hypothesis is supported by research that has shown that as children's vocabularies increase, so does their ability to perform phoneme awareness tasks (Metsala, 1999).

WHAT IS THE ASSOCIATION BETWEEN PHONOLOGICAL REPRESENTATIONS AND READING DEVELOPMENT?

Research has begun to elucidate the associations between a child's underlying phonological representations of words and the development of speaking and reading skills. Snowling, van Wagtendonk, and Stafford (1988) found that children with dyslexia performed as well as typically developing readers in selecting pictures based on verbally presented object names, but performed poorly when they were required to articulate the name of pictures. The researchers interpreted this reduced naming performance as being indicative of potential weaknesses in the storage and accessibility of phonological representations. Carroll and Snowling (2004) reached a similar conclusion when they found the same pattern of deficits in phonological processing and prereading skills in 4- to 6-year-old children with speech impairment and children who had no speech impairment but who were considered at risk for dyslexia based on having a parent or sibling with dyslexia. Both of these groups performed poorly compared to a control group on a range of phonological awareness, word recognition, and phonological processing tasks. The phonological processing tasks examined children's ability to learn new words, detect mispronounced words, repeat nonwords, and produce speech sounds. The researchers suggested that a common underlying deficit in phonological representations may have accounted for the similar performance of the groups (Carroll & Snowling, 2004).

The 17 children with speech impairment who participated in Carroll and Snowling's (2004) study were described as having significantly delayed speech by referring speech therapists. However, wide variation in their severity of speech impairment was evident. For example, 4 of the children scored between 80% and 96% of consonants correct (PCC) and therefore presented with mild or resolved speech error patterns at the time of assessment. Further detail regarding how children with unintelligible speech perform on tasks designed to tap underlying phonological representations is necessary as these are the children that typically receive intervention services within a limited resource-funding model.

Elbro (1996) proposed that children have difficulty pronouncing words and consciously reflecting on words with less "distinct" or poor quality phonological representations. "Distinctness" refers to the degrees of difference or separateness of a word's phonological representation from similar words and the amount of phonological information that is stored with the word. A word with many phonological features that can be used to differentiate it from other words in the child's lexicon is considered more distinct than words with many similar phonological features. For example, a word such as *voice* is likely to be more distinct from its lexical neighbors than *light* because light has a greater number of words with the same rime pattern (e.g., fight, bite, kite, sight, might, night, right, tight). Elbro also proposed that words can be represented at different levels of distinction. A word such as *February,* for example, could be represented as [februeri] or [febri]. Elbro suggested that children with a less distinct phonological representation of a word have greater difficulty performing tasks that require an ability to think about or manipulate the word's segmental components. Findings from Elbro et al. (1998) support this hypothesis. Two groups of Danish children were compared on language, cognitive, phonological awareness, and phonological representation tasks. The groups consisted of 49 children who were considered at risk of developing a reading disorder (due to a genetic disposition for dyslexia) and 42 children with typical development. Children were first assessed at age 6 years (1 year before formal reading instruction begins in Denmark) and again 2 years later. Poor performance on tasks designed to examine the "distinctness" of phonological representations at 6 years predicted poor performance on phonological awareness tasks at 8 years of age (Elbro et al., 1998). This study included the use of a novel task that involved training children to teach a handheld puppet to pronounce names of pictures correctly. In an attempt to obtain the most distinct pronunciation of words, children were told that the puppet had both a speech and a hearing impairment. Nine multisyllable Danish nouns were selected as stimulus items. The researchers also developed an in-depth analysis of the children's most accurate productions. Analyses included the following:

- Accuracy—A percentage score was calculated for the number of words a child produced correctly. Judgment of correct word production was based on acceptable Danish pronunciations.
- Control score—This measure was based on the number of words a child produced that reflected the words' written form.
- Distinctness—A percentage score was obtained by analyzing expected and produced vowel productions for omissions or reductions (e.g., a full vowel being reduced to a schwa). A distinctness score of 100% would require a child to produce each vowel in its most distinct form. A score of 0% would be obtained if a child omitted or reduced all reducible vowels (Elbro et al., 1998).

Children's distinctness scores and performance on letter naming and phoneme identification tasks at age 6 were predictive of reading ability at age 8. This study demonstrated the use of naming tasks to examine underlying phonological representations. However, poor performance on these tasks may also be attributed to problems with the components of the motor speech system and thus restrict their clinical usefulness for children with unintelligible speech. Exploring other assessment methods for children with severe speech impairment is therefore necessary.

The role played by phonological representations during speech and literacy development can also be considered within a psycholinguistic speech-processing model that was developed by Stackhouse and Wells (1997). Stackhouse and Wells proposed that a phonological representation "is the basis for spontaneous written or spoken production" (p. 15). A well-developed phonological representation may contain auditory (e.g., speech sound) and visual (e.g., lip movement) information about a word that enables it to be perceived and then differentiated from other words. On hearing a word, the auditory and visual information perceived is matched with the information contained in the phonological representation, which then enables access to the word's semantic representation. Both the phonological and semantic representation components link to a motor program component that contains instructions on how to articulate a word. This model highlights the need for well-defined phonological representations that contain the appropriate level and clarity of speech sound information to enable children to say or spell the word. Children who do not have access to correct or precise phonological representations of words are likely to experience problems developing speech and literacy skills (Stackhouse & Wells, 1997).

The speech-processing model developed by Stackhouse and Wells (1997) provides a framework to consider what specific skills are examined by various speech production and receptive-based assessment tasks when attempting to examine underlying phonological representations. The speech-processing model suggests that for many words, children may have prestored motor programs that do not require access to phonological representations in order to speak the word. Production tasks such as a confrontational picture naming task require a child to access a semantic representation that then provides access to the word's motor program, bypassing the need to access the word's phonological representation. In contrast, tasks that only require a yes or no response to indicate perception of mispronounced words are more likely to reflect information on underlying phonological representations. It is important to consider the different components of speech processing when examining assessment tasks that are used to create hypotheses about the nature of phonological representations.

HOW HAVE PHONOLOGICAL REPRESENTATIONS PREVIOUSLY BEEN ASSESSED?

Production Tasks

In addition to the naming task (Elbro et al., 1998) described above, researchers have employed a range of tasks requiring speech production to draw inferences on underlying phonological representations in children with reading disorders and children with specific language impairments. The use of these tasks with children who may have speech impairment requires careful controlling for speech production problems. These tasks include naming tasks, the gating paradigm, and nonword repetition.

Naming tasks. Children with reading problems demonstrate weakness in naming pictures, numerical digits, and shapes (Elbro, 1996; Snowling et al., 1988; Swan & Goswami, 1997b). Naming tasks are presented in several formats. Showing a series of pictures and asking subjects to name the objects shown is known as *confrontation naming* (Snowling, van Wagtendonk, & Stafford, 1988). *Picture naming* assumes that accurate speech sound information must be obtained from well-specified phonological representations (Swan & Goswami, 1997b). Variants of naming tasks include requiring a child to name a series of pictures as quickly as possible (Katz, 1986) or identifying an object from its verbal description (Snowling et al., 1988).

The gating paradigm. Developed by Grosjean (1980), the gating paradigm has been employed by researchers investigating spoken word and phonemic perception skills in children with language, phonological, and reading disorders (Metsala, 1997; Walley, Michela, & Wood, 1995; Wesseling & Reitsma, 2001). Gating paradigm tasks require participants to identify single words from increasingly longer segments of acoustic signal. The term “gate” refers to the point at which the acoustic signal is cut off during presentation. For example, Metsala initially presented the first 100 ms of single-syllable words and then increased the length of the signal by 50 ms on subsequent gates. Participants were instructed that they would hear the beginning of a word and then they would gradually hear increasing amounts of the word. After each presentation, participants were asked to identify the target word. Performance on gating tasks by younger children (6–7 years) in Metsala’s study predicted their level of reading ability. In contrast to Metsala’s clear findings of an association between performance on a gating task and reading skills, Wesseling and Reitsma obtained less conclusive results. These researchers employed a gating paradigm in two studies investigating the development of reading skills and the quality of phonological representations in typically developing Dutch children. Ninety-one children aged 5 to 6 years participated in these 2-year longitudinal studies. Inconsistent results from the gating tasks were reported, and the researchers concluded that it may not be a suitable measure of the “quality” of phonological representations.

Consideration of the gating paradigm task requirements within a model of speech processing (Dodd & McCormack, 1995; Stackhouse & Wells, 1997) highlights components of speech processing that could result in poor task performance. Although the correct identification and production of a gated word before the delivery of all acoustic information will test aspects of underlying phonological representations, task performance may be influenced by (a) weaknesses in auditory detection and perception, (b) the need to search underlying phonological representations for matching words, and (c) problems with components of the motor speech system.

Nonword repetition. Performance on nonword repetition tasks has been used to provide support for efficient or impaired lexical systems and poor phonological representations (Edwards & Lahey, 1996; Fowler, 1991; Larivee & Catts, 1999). Nonword repetition tasks investigate children’s phonological and lexical skills without the confounding influence of word familiarity (Snowling, 1981). Fowler argued that poor nonword processing indicates a weakness in integrating phonological stimulus into a cognitive form that is readily accessible for production purposes. This weakness may result in unstable representations developing for real words and so lead to difficulty preparing articulatory codes for production (Swan & Goswami, 1997b). Conversely, Metsala (1999) reported that nonword repetition skill is a function of vocabulary size, encompassing the number of words known, familiarity of words, and similar sound characteristics between words.

The use of nonword repetition tasks using multisyllable stimuli has also been proposed as a measure of the quality of phonological representations. Larivee and Catts (1999) compared children with and without speech impairment on phonological awareness, speech production, and language tasks. Initial measurements were taken at the end of kindergarten, and reading ability was measured 1 year later. Children with more severe speech disorders (as measured by PCC, based on multisyllable real and nonword production tasks) and coexisting phonological awareness weakness (as measured by syllable segmentation, initial phoneme identity, phoneme blending, and phoneme isolation) were likely to have poor reading ability. The authors concluded that deficits in phonological awareness and expressive phonology are linked to differences in children’s underlying phonological representations.

Production tasks, however, restrict the ability to identify children with speech difficulties who may have well-developed underlying phonological representations. Although it is accepted that many children with significant speech impairment struggle with literacy development, some of these children perform at age-appropriate levels in reading and spelling (Nathan et al., 2004). This creates the need to examine receptive-based phonological representation tasks that eliminate the influence of speech output difficulties on task performance.

Receptive-based Tasks

Although a number of earlier studies of children with speech impairment or who are at risk of language or reading disorders have not attempted to specifically address phonological representations, they have employed tasks that provide insight into phonological representations such as receptive judgements of speech stimuli. Bird and Bishop (1992) reported that 5- and 6-year-old children with speech impairment performed poorly compared to age-matched controls on speech discrimination tasks requiring judgment of mispronounced real and nonwords as well as initial phoneme identification and matching. The researchers concluded that the poor performance on these tasks was due to children with speech impairment not being able to analyze segmental aspects of words. Edwards and Lahey (1996) investigated children with specific language impairment (SLI), children with speech impairment, and a control group on a timed task that required children to identify sound sequences that represented real words. The researchers reported that the children with SLI were slower at identifying correct sound sequences than were the children with and without speech impairment. These studies did not discuss the potential involvement of phonological representations in children’s task performance.

More recent studies have begun to address the need to explore phonological representations in children with speech impairment and have used receptive-based tasks to counter the speech production difficulties of this population (Carroll & Snowling, 2004; Rvachew, Ohberg, Grawburg, &

Heyding, 2003). These tasks have involved children listening to auditory stimuli and then making a behavioral response (e.g., pointing to a picture) based on their perception of the stimuli. Rvachew et al. (2003) assessed phonemic perception in 13 children with speech impairment using a task developed on Speech Assessment and Interactive Learning System (SAILS) software (Avaaz Innovations, 1997). The 70 task items were productions of four single-syllable words (i.e., lake, cat, rat, and Sue) spoken by a range of adults and children. Each word was spoken either correctly or with a misarticulated initial phoneme (e.g., lake said as wake). Children were trained to point to either a picture of the target word to indicate a correct production or a large cross to indicate an incorrect production. Children with speech impairment performed poorly compared to matched controls on this task. The researchers attributed this reduced performance to poor quality underlying phonological representations of the target words. This finding provides further evidence for the important role of phonological representations in the development of speaking and literacy skills. The current study expands this research by examining additional aspects of underlying phonological representations such as representation of vowel sounds within multisyllable words, the creation of new phonological representations, and the use of a wider range of stimulus items that address differing phonetic features.

This study investigated the following research questions:

- To what extent do receptive-based tasks designed to measure phonological representations differentiate children with speech impairment from children with typical speech development?
- Does children's performance on phonological representation tasks correlate with their performance on measures of phonological awareness?

Our hypotheses for these research questions were:

- The use of novel receptive-based tasks designed to investigate children's phonological representations will enable the differentiation of children with speech impairment from children without speech impairment.
- Children's performance on receptive-based phonological representation tasks will correlate with their performance on early phonological awareness assessment tasks.

METHOD

Participants

Children with speech impairment were referred to the study by local kindergarten and preschool teachers and by speech-language pathologists. These agents were asked to refer any child aged between 4 and 5 years who spoke New Zealand English as their first language and whose speech was very difficult to understand. On referral, each child's speech was assessed using the procedures described below. Children in the control group were recruited by random selection from local kindergarten and preschool attendance lists. The study's inclusion criteria required that each child with and without speech impairment (a) had no history of sensory, neurological, physical, or intellectual impairment; (b) demonstrated receptive vocabulary knowledge within the normal range (i.e., a standard score between 85–115) or no higher than 1.5 *SD* above the mean as evidenced by the Peabody Picture Vocabulary Test—Third Edition (PPVT–III; Dunn & Dunn, 1997); (c) performed within or above the normal range on the receptive language subtests of the Clinical Evaluation of Language Fundamentals—Preschool (CELF–P; Wiig, Secord, & Semel, 1992) (i.e., a standard score of 85 or higher); and (d) responded to pure-tone thresholds and provided tympanograms within normal limits using pure-tone audiometric testing and tympanometry.

Nine children (1 girl and 8 boys) from the 10 children with severe speech impairment referred to the study and 17 children (7 girls and 10 boys) from the randomly selected 20 children with typically developing speech skills met the inclusion criteria. These children attended kindergartens from suburban middle or upper socioeconomic status areas and were monolingual speakers of standard New Zealand English. No statistically significant differences at $p < 0.05$ were observed between groups on the inclusion criteria of age or PPVT–III and CELF–P receptive language subtest standard scores. A summary of group characteristics is provided in Table 1.

Procedures

Each participant was presented with assessments to examine his or her speech production, phonological representations, and phonological awareness. The first author assessed the children individually in a sound-controlled university clinic facility. Each assessment session was video- and audio-taped for reliability and scoring purposes. The assessments are detailed below.

Speech assessment. The Goldman-Fristoe Test of Articulation (GFTA; Goldman & Fristoe, 1986) and the 25 words from the Phonological Variability Test (Dodd, 1995, p. 270) were used as measures of speech production. Children were trained on the test items on the Phonological Variability Test before testing. If children were unable to spontaneously name target pictures during testing, delayed modelling techniques were used to stimulate responses. All responses were transcribed using a broad phonetic transcription and were analyzed using the Computerized Profiling (CP; Long, 2002) software. Total PCC (Shriberg & Kwiatkowski, 1982) and PCC for the late eight developing phonemes were computed (Shriberg, Austin, Lewis, & McSweeny, 1997). The children with speech impairment (SI group) produced significantly lower PCC scores than the children with typical speech development (TS group) ($p < 0.001$), as shown in Table 1. Appendix A provides a description of the phonological error patterns that were produced by children in the SI group.

The verification of children's speech transcription involved transcribing a child's speech online using broad

Table 1. Characteristics of the children with speech impairment (SI group) and the children with typical speech development (TS group).

	SI group		*TS group*				
	M	SD	M	SD	P *value*	*Cohen's* d	*Effect size* r
Age (months)	53.33	6.50	55.88	2.39	0.1566	0.5207	0.2520
PPVT–III	107.78	10.89	107.41	5.75	0.9099	0.0425	0.0212
PCC, Total	38.89	12.00	90.94***	7.68	<0.0010	5.1666	0.9326
PCC, Late 8	18.67	14.96	84.82***	10.06	<0.0001	5.1892	0.9331
Linguistic Concepts[a]	12.67	2.18	12.76	1.92	0.9144	0.0438	0.0219
Basic Concepts[a]	12.11	2.09	11.88	1.65	0.7604	0.1222	0.0610
Sentence Structure[a]	12.44	3.09	11.18	2.40	0.2601	0.4554	0.2220

Note. PPVT–III = Peabody Picture Vocabulary Test—III (Dunn & Dunn 1997); PCC, Total = total percentage of consonants correct; PCC, Late 8 = percentage of consonants correct for the late 8 developing phonemes.

[a]These are receptive language subtests from the Clinical Evaluations of Language Fundamentals—Preschool (Wiig, Secord, & Semel, 1992); standard scores are reported.

***Statistically significant group difference at $p < 0.001$.

transcription techniques and recording productions using a digital tape recorder (Sony Digital Audio Tape-corder TCD-D8). Recordings were then reviewed by the first author together with an independent examiner who was experienced in phonetic transcription of disordered speech. Productions by all children in the SI group and 4 children in the TS group were reviewed. Disagreements were resolved by the two examiners repeatedly listening to the production and discussing interpretations until 100% agreement of the transcribed utterance was reached.

Phonological representation tasks

Receptive-based tasks. Three receptive-based tasks were developed to investigate participants' underlying phonological representations. Each task was developed using Microsoft PowerPoint slide presentation software with a combination of picture and sound stimuli. The slides were presented on a notebook computer (Model Acer TravelMate320 with a Celeron CPU 2.0 GHz processor and 256 MB of RAM) using Powerpoint. All speech stimuli were produced by a male native New Zealand English speaker. All stimuli were digitized at 22 kHz using a commercially available speech analysis system (Kay CSL-4300B). All stimuli were edited using PRAAT software (Boersma & Weenink, 2004) to eliminate redundant acoustic signals before and after the target stimuli. Each edited stimulus was then stored as a .wav file on the notebook computer's hard disk drive. Stimuli used on the gating task described below were obtained by using PRAAT software to segment the appropriate acoustic signal from the target word.

Experimental tasks were first piloted with 3 children (aged 4;8 [years;months] to 4;11) with typical development to ensure that task requirements were within the capability of young children and that picture stimuli used were appropriate for this age group. The tasks were also presented to 5 adults to ensure that speech stimuli were perceived as either a correct or an incorrect production of target words. Tasks were modified to accommodate feedback from child and adult trials. This involved discarding several word productions that adults could not agree on the correctness of the production.

Before the presentation of each experimental task, the participants in the study were asked to name all stimuli pictures used in the tasks. If a child was unable to name a picture, prompts were provided to help the child produce the target word. If the child was still unable to name the target picture, he or she was provided with a model and asked to repeat the picture name.

Phonological representation accuracy judgment task (PR judgment). To extend previous research, a receptive-based assessment tool that examines children's underlying phonological representations based on Elbro et al.'s (1998) production task was developed. Elbro et al. recorded the accuracy of vowel productions in multisyllable words to gauge the distinctness of phonological representation. Vowels contain significant acoustic information, therefore enabling more distinct phonological representation. Thus, the stimuli in the receptive-based task developed for this study included multisyllable words that had alterations made to vowel sounds.

This task consisted of 40 slides that each contained one picture of an object (e.g., watermelon, caterpillar, helicopter), a "happy" face, and a large black cross. Filler slides containing a large "00000" were placed between each stimulus slide to cue the participant for a new task item. Children used stereo headphones (Sony MDR-V300) connected to the computer with the volume set at a comfortable listening level. Children were instructed that they would see single pictures of the target word and hear a prerecorded production of the target word. The children were asked to decide if the spoken word was a "good" or "not a good" way of saying the target word. Corrective feedback was provided on the first 10 items. Children were then presented with 30 test items (a word list and specific instructions provided are included in Appendix B) and asked to point to either the happy face or the black cross to indicate their judgment decision. Each item was either a good representation of the target (nine items) or had one of the following alterations made:

- All vowel sounds were changed (one item). For example, “motorbike” was produced as “mertieboke” (/mɜtibouk/).
- A vowel in a stressed syllable was changed (seven items). For example, “dinosaur” was produced as “dunasaur” (/dʌnəsɔ/).
- A vowel in an unstressed syllable was changed (six items). For example, “caterpillar” was produced as “catupillar” (/kætupɪla/).
- A vowel was deleted from an unstressed syllable (seven items). For example, “kangaroo” was produced as ‘kangroo’ (/kæŋru/).

Nonword learning task. To examine children’s ability to create new phonological representations and then immediately reflect on the representation during a receptive-based judgment task, a nonword learning task using Powerpoint slides with abstract colored objects was developed. These picture slides also contained prerecorded production of the object’s “nonword” name or a short phrase containing the name of the object. Each object was shown on six different “training” slides together with the name of the object or a phrase containing the target name (e.g., “this is a blaig”; “the girl is jumping over the blaig”; “big blaig”). After the training slides, children were told that they would see the object again and hear a prerecorded production of the target word. The judgment task required children to point to either a green tick or a red cross after deciding if the spoken word was a good or not good way of saying the target word. Corrective feedback was given during a training task that involved presentation of six training slides and then a set of four judgments concerning the trained word. Children were presented with 20 test items (see Appendix C) that consisted of a set of four productions for five different nonwords. Each item was either a good representation of the target or had one of the following alterations made:

- One vowel sound was changed. For example, “melached” (/mælətʃed/) was produced as “meloched” (/mæloutʃed/.
- One consonant sound was changed. For example, “cherfote” (/tʃɜfout/) was produced as “cherfoge” (/tʃɜfoug/).

Receptive gating task. Previous studies have presented gating paradigm tasks requiring spoken word productions. This is the first attempt to develop a receptive-based task based on the gating paradigm for children with speech impairment. The task was developed by providing three pictures (one target and two distracter items) on each Powerpoint slide together with auditory presentation of the gated stimulus. Nine prerecorded target words were segmented into gated stimuli. A list of target words is included in Appendix D. Three different lengths of acoustic stimuli for each target word were saved. The shortest stimuli for each word included the initial phoneme and a small segment of the first vowel. Subsequent stimuli lengths were the initial length plus 50 ms and plus 100 ms. Each recording started 10 ms before the onset of the word. For example, “cup” had three recorded stimuli at lengths of 150 ms, 200 ms, and 250 ms. The target word “shark” had stimuli lengths of 240 ms, 290 ms, and 340 ms. Because of the variety of initial consonant sounds, the length of each stimulus varied. Participants were instructed that they would hear the beginning of a word and were required to point to the target picture.

Test item and scoring reliability. All data obtained from the presentation of the three receptive-based phonological representation tasks were analyzed to examine the reliability of test items used. A classical item analysis of correct and incorrect responses on each task was undertaken. Internal consistency reliability for the PR judgment task yielded a coefficient alpha of 0.835, which met the most stringent measure of internal consistency (i.e., $\alpha = 0.8$; Nunnally, 1978). The receptive gating task also showed high internal consistency ($\alpha = 0.7$). The nonword learning task, however, showed less favorable internal consistency ($\alpha = 0.46$). Item analysis indicated that three items from one set of stimuli showed poor reliability. Most participants found these items difficult and scored incorrect responses. These items were therefore removed from the data set. The revised data showed more acceptable levels of reliability ($\alpha = 0$ .601) and were therefore used for statistical analyses.

An independent examiner reviewed videotapes of 4 participants (2 randomly selected children from the SI group and 2 children from the TS group) performing the PR judgment, nonword learning, and receptive gating tasks. The independent examiner was asked to judge whether a child responded correctly or incorrectly to each item presented based on a prepared score sheet for each task. The examiner’s records were then compared with the participants’ original score sheets. No differences were observed between the independent examiner’s scores and original scores, providing an interrater reliability score of 100% for each task.

Production tasks

Real and nonword repetition tasks. To contrast the receptive-based assessments tasks, two repetition tasks were used to provide information on children’s phonological processing of multisyllable real and nonwords. Each child was provided with a model of 10 multisyllable real words and 10 multisyllable nonwords for repetition. The stimulus words and instructions provided for each child are included in Appendix E. Both sets of stimuli were developed to ensure that a wide range of speech sounds was covered within each set. A total PCC and late 8 PCC scores were obtained for each set of nonwords. The recording, transcription, and verification procedures used for the speech assessment tasks were repeated for this task.

Phonological awareness. The Preschool and Primary Inventory of Phonological Awareness (PIPA; Dodd, Crosbie, McIntosh, Teitzel, & Ozanne, 2000) was administered to measure the following phonological awareness skills: syllable segmentation, rhyme awareness, alliteration awareness, phoneme isolation, and phoneme segmentation. The Letter Knowledge subtest of the PIPA was also administered. The examiner carefully followed the administration and scoring procedures outlined in the test manual. The technical information reported in the test manual indicates that the PIPA has strong psychometric properties (see pp. 21–26 for details). The internal consistency of subtests is strong, with reliability coefficient alpha scores above an acceptable level of 0.7 (Dodd et al., 2000).

RESULTS

Phonological Representation Tasks

The data were analyzed to compare the performance of the two groups on the phonological representation tasks. Multivariate analysis of variance (MANOVA; Wilks's lambda) indicated a significant group difference, $F(5, 20) = 34.59$, $p < 0.001$. Inspection of univariate tests indicated a significant difference for the PR judgement task, $F(1, 24) = 6.17$, $p < .05$; nonword learning task, $F(1, 24) = 5.29$, $p < .05$; real word repetition, $F(1, 24) = 152.47$, $p < .0001$; and nonword repetition, $F(1, 24) = 103.21$, $p < .0001$. There was no statistically significant group difference for the receptive gating task, $F(1, 24) = 0.65$, $p = 0.427$. Descriptive and effect size data are shown in Table 2. Cohen's *d* effect size estimates were considered large for the PR judgement task ($d = 0.9583$) and the nonword learning task ($d = 1.2584$). A small effect size ($d = 0.3201$) was calculated for the receptive gating task. These findings indicate that the receptive-based tasks may be more appropriate measures than production tasks to examine phonological representations. The very large effect size estimates of the real word ($d = 4.8304$) and nonword ($d = 4.0046$) repetition tasks suggest that these tasks may overestimate phonological representation deficits due to the need for speech output on these tasks.

Correlation Analyses

A correlation analysis (Pearson correlation matrix) was undertaken to examine associations between the phonological representation experimental tasks and phonological awareness ability as well as other measures of speech and language that were assessed. The combined raw score from the phonological awareness subtests of the PIPA was used to gain an overall measure of phonological awareness development. The PIPA Letter Knowledge subtest was isolated as a separate task for the correlation analysis. Group comparison on PIPA subtests is shown in Table 3. Raw scores from the phonological representation tasks were converted into percentage correct scores for analysis purposes. Results revealed that two of the receptive-based phonological representation tasks, PR judgment and nonword learning, were moderately correlated with phonological awareness ability ($r = 0.47$ and $r = 0.55$, respectively). Performance on these two tasks was also moderately correlated with speech production, receptive vocabulary, and letter knowledge measures, as shown in Table 4. However, performance on the third receptive-based task (receptive gating) showed little association with other

Table 2. Group performance on phonological representation tasks.

Task	*SI group*	*TS group*	p *value*	*Cohen's* d	*Effect size* r
PR judgment ($N = 30$ test items)					
M	18.00	23.24	0.0202*	0.9583	0.4321
SD	6.42	4.31			
Range	10–27	12–29			
Nonword learning ($N = 20$ test items)					
M	12.33	15.24	0.0034**	1.2584	0.5325
SD	2.69	1.86			
Range	8–18	12–19			
Receptive gating ($N = 27$ test items)					
M	19.67	20.88	0.4290	0.3201	0.1580
SD	4.15	3.37			
Range	13–25	16–27			
Real word repetition (PCC)					
M	38.67	88.41	<0.0001	4.8304	0.9239
SD	11.73	8.63			
Range	19–56	69–100			
Nonword repetition (PCC)					
M	37.56	84.06	<0.0001	4.0046	0.8946
SD	13.01	10.02			
Range	20–58	58–97			

*Statistically significant group difference at $p < 0.05$; **Statistically significant group difference at $p < 0.01$.

Table 3. Mean group scores on the Preschool and Primary Inventory of Phonological Awareness (Dodd et al., 2000) subtests.

	SI group	*TS group*	p *value*	*Cohen's* d	*Effect size* r
Rhyme					
M	3.67	4.82	0.3414	0.4034	0.1977
SD	2.78	2.92			
Alliteration					
M	3.67	3.88	0.8525	0.0714	0.0357
SD	3.54	2.18			
Syllable					
M	5.00	5.24	0.8769	0.0617	0.0309
SD	4.36	3.35			
Isolation					
M	3.22	4.06	0.6388	0.1936	0.0964
SD	4.49	4.18			
Segmentation					
M	0.33	1.82*	0.0200*	1.1019	0.4826
SD	1.00	1.63			
Letter Knowledge					
M	5.33	5.18	0.9611	0.0191	0.0096
SD	9.07	6.39			

Note. With the exception of letter sound knowledge, which had 32 items, each subtest had 12 items; mean raw scores are reported.

*Statistically significant group difference at $p < 0.05$.

measures employed. The two production tasks (real and nonword repetition) were highly correlated with the speech production measure (as expected) but showed little association with performance on phonological awareness, receptive vocabulary, or letter knowledge, as indicated in Table 4. Consistently, the speech production measure showed little association ($r = 0.23$) with phonological awareness performance.

From a clinical perspective, the association observed between the children's performances on some of the phonological representation tasks and phonological awareness ability was supported through qualitative inspection of results from the phonological awareness subtests that were administered. Qualitative analysis of individual children's performance compared to the normative data provided with the test indicated that the majority of children with speech impairment (6 of the 9 children) could be considered at risk. They performed 1 *SD* or more below the mean standard score expected for their age level on at least two of the phonological awareness subtests. In contrast, the performance of only 3 of the 17 children without speech impairment was identified as being of concern.

DISCUSSION

This study examined the performance of preschool children with moderate or severe speech impairment on experimental tasks designed to tap underlying phonological representations and phonological awareness. The first hypothesis stated that the use of novel receptive-based tasks would differentiate between children with speech impairment and children with typical speech development. This hypothesis was supported by the results of two of the three receptive-based experimental tasks. Children with speech

Table 4. Pearson's *r* values for correlations between phonological representation, phonological awareness (PA), and speech tasks.

	Receptive gating	*PR judgment*	*Nonword learning*	*Real word repetition (PCC)*	*Nonword repetition (PCC)*	*Combined PA score*	*Letter Knowledge*	*Speech*
Receptive vocabulary	0.25	0.52	0.55	0.16	0.20	0.47	0.54	0.32
Speech	0.01	0.57	0.57	0.97	0.94	0.23	0.10	–
Letter Knowledge	0.31	0.58	0.43	0.12	0.14	0.89	–	–
Combined PA score	0.27	0.47	0.55	0.26	0.25	–	–	–
Nonword repetition (PCC)	0.18	0.59	0.49	0.93	–	–	–	–
Real word repetition (PCC)	0.11	0.55	0.60	–	–	–	–	–
Nonword learning	0.20	0.67	–	–	–	–	–	–
PR judgment	0.30	–	–	–	–	–	–	–

impairment performed significantly below children without speech impairment on the PR judgment and nonword learning tasks. These experimental tasks eliminated the use of children's motor speech system, which previous investigations into phonological representations have engaged (Larivee & Catts, 1999; Swan & Goswami, 1997a). The PR judgment task required children to judge the correctness of the production of words based on a comparison with their own internal phonological representation of the target word. To perform well on this task, the children needed to perceive the spoken word and access an accurate underlying phonological representation of the target word. As a group, children with speech impairment were more likely to make incorrect judgments of the accuracy of spoken words as compared to children with typical speech development.

The nonword learning task required children to quickly develop a phonological representation for a new word (nonword) based on six training slides with visual and auditory stimuli. Children were then required to reflect on their newly acquired phonological representation to make judgments on the accuracy of spoken productions of the target word. Again, children with speech impairment had more difficulty making judgments on the correctness of target words as compared to children with typical speech development. These findings support previous studies that have reported that children's speech impairment may be partly attributable to poor quality underlying phonological representations (Larivee & Catts, 1999; Rvachew et al., 2003; Swan & Goswami, 1997a). The results also suggest that children with speech impairment are more likely to have difficulties forming new phonological representations and then consciously reflecting on these representations as compared to children without speech impairment.

The findings indicated that the PR judgment and nonword learning tasks presented were appropriate assessment tasks for this population. The tasks differentiated children with and without speech impairment and were positively associated with development in other areas known to influence literacy development (e.g., vocabulary and letter knowledge). The results support previous studies that have reported the use of receptive-based judgment tasks to infer characteristics of underlying phonological representations (Carroll & Snowling, 2004; Nittrouer, 1996; Rvachew et al., 2003). Although both the PR judgment and nonword learning tasks provided significant performance differences between groups, further fine-tuning of stimulus items using information on known areas of weakness in children's developing phonological system, such as unstressed vowels and fricative consonants, will help create greater task sensitivity. Delineating the accessibility and preciseness of underlying phonological representations will continue to challenge future research. This study did not specifically examine the accessibility of underlying representations. Timing children's responses on task items in future studies may provide valuable information on access to phonological representations. This will require some ingenuity to control for the natural variability in the pace of young children's task performance.

The receptive gating task that was presented to children did not produce any significant group differences. The small effect size (d = 0.3201) for this task indicates that as presented, the receptive-based gating task was not sensitive to phonological representation deficits. This task was based on a reported gating paradigm task that required children to say the target word as opposed to the current study's requirement of selecting the target from a choice of three items. The response criteria and stimuli used in this study may have contributed to the insignificant findings. Children were provided with a visual representation of the correct response together with two distracter items, thus reducing the need to perform a wider search and comparison of underlying phonological representations. A previous study that reported a correlation between reading development and performance on a gating paradigm task involved the careful selection of *high* and *low* use words from *sparse* and *dense* lexical neighborhoods (Metsala, 1997). Further revision of the current receptive-based version of this task to accommodate words from sparse and dense lexical neighborhoods may result in observable differences between groups. However, the current finding is consistent with an earlier report that the gating paradigm task may not be an appropriate measure of phonological representations (Wesseling & Reitsma, 2001).

The second hypothesis examined the correlation between children's performance on receptive-based phonological representation tasks and performance on early phonological awareness assessment tasks. Participants' performance on phonological awareness measures provided moderate correlations with performance on the PR judgment and nonword learning tasks. These results provide some support for earlier studies that proposed the importance of children's underlying phonological representations to the development of phonological awareness and early reading abilities (Carroll & Snowling, 2004; Catts, 1986; Elbro et al., 1998; Nathan et al., 2004). The study also identified stronger correlations between performance on phonological awareness tasks and the PR judgment task and nonword learning tasks than between the measures of speech production and phonological awareness tasks. This finding suggests that the development of effective phonological awareness and subsequent reading skills relies more on an ability to form precise and detailed underlying phonological representations than on the accurate production of spoken words. This is consistent with previous findings of similar profiles of phonological awareness weakness in children with speech impairment and children who are at risk for reading disorder but have no obvious speech impairment (Carroll & Snowling, 2004). Children who do not have access to precise phonological representations will struggle to consciously consider and manipulate a word's segmental components, as required during phonological awareness tasks (Elbro, 1996). This difficulty is also likely to influence early decoding of printed words with children having difficulty accessing or retrieving information from underlying phonological representations.

This study found a moderate correlation between receptive vocabulary and performance on the PR judgment (r = .52) and nonword learning (r = .55) tasks. This finding provides partial support for a relationship between vocabulary acquisition and development of well-specified phonological representations as proposed by the "lexical restructuring" (Metsala & Walley, 1998) and "segmentation" (Fowler, 1991) hypotheses. No correlation was observed between word (non and real) repetition tasks and receptive vocabulary skills. This does not support Metsala's (1999) report of nonword repetition skill as a function of vocabulary size. However, the speech impairments of children in this study confound the use of real word and nonword repetition tasks. Although performances on nonword repetition tasks may provide valuable information about a child's phonological perception and production, it has also been argued that these tasks are better described as a test of short-term phonological memory (Gathercole, 1995; Gathercole & Baddeley, 1997). Poor nonword repetition could be caused by reduced perception, errors in encoding phonological information, storage difficulties, and retrieval and motor planning impairments (Edwards & Lahey, 1996; Elbro, 1996). Another possibility is that nonword repetition tasks may bypass the need to create an underlying phonological representation when considered within Dodd and McCormack's (1995) speech processing model. The model specifies that speech may be produced by moving a phonological plan directly from the perceptual analysis system to the motor speech system without a need to involve higher level phonological representations.

The findings from this study suggest that PR judgment and nonword learning tasks are useful tasks in providing information on children's underlying phonological representations. Additional perception and production areas to investigate the nature of phonological representations include short phrases and connected speech for comparison with single-word productions. However, the central location of phonological representations in the speech process and their abstract nature will continue to provide challenges for attempts to isolate and clearly describe the development and storage of, and access to, phonological representations. Results from assessments designed to measure phonological representations may contribute to the explanation as to why some children fail to make appropriate progress in their phonological awareness and written language development.

CLINICAL IMPLICATIONS

The clinical implications from this study include a need to assess underlying phonological representations of children with speech impairment. In addition to speech production problems, children with speech impairment may have impairments in the storage and retrieval of phonological representations. Clinicians, therefore, should consider the use of receptive-based tasks that provide information on the quality of children's phonological representations. If phonological representations are found to be inaccurate or difficult to access, remediation techniques must consider how to enhance this area. Although no research to date has specifically investigated the influence of various interventions on the development of children's underlying phonological representations, research has shown that the integration of phoneme awareness and letter knowledge activities with speech intelligibility work assist the development of phoneme awareness, speech production, and early reading skills (Gillon, 2000). Future research may confirm that the inclusion of these activities into intervention may in fact aid the development of more precise and accessible phonological representations.

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APPENDIX A. PERCENT OF USAGE OF SPEECH ERROR PATTERNS PRODUCED BY CHILDREN IN THE PHONOLOGICAL IMPAIRMENT GROUP

	Child's identification number								
Phonological error pattern	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Velar fronting	42	44	38	47	80	89	37	–	–
Early stopping	28	–	20	24	33	58	–	–	–
Final consonant deletion	–	86	–	76	–	–	–	–	21
Cluster reduction	23	75	79	47	63	71	66	78	77
Liquid simplification	–	–	60	21	71	80	77	75	56
Palatal fronting	60	–	60	–	60	20	60	60	20
Later stopping	23	–	–	–	36	69		–	–
Fricative simplification	57	33	71	29	50	–	88	63	29
Deletions	–	34		20	–	–	–	–	–
Substitutions (%)	90	47	93	62	90	96	92	96	87
Omissions (%)	10	53	7	38	10	4	8	4	13

Note. For example, on 42% of opportunities to produce velar sounds [k] and [g], Child 1 displayed a velar fronting error pattern by producing a [t] or [d]. Also, on 28% of opportunities to produce fricative sounds [f], [s] and [ʃ], Child 1 displayed an early stopping error pattern by producing [p], [b], [t], or [d]. Phonological processes produced on 20% or more of opportunities to demonstrate process are included. Deletion error patterns have been combined into a composite figure. Names of phonological error patterns are as specified in the Computerized Profiling (CP) software (Long, 2002). All errors have been classified as either substitutions or omissions in order to calculate substitution or omission percentages.

APPENDIX B. PHONOLOGICAL REPRESENTATION ACCURACY JUDGMENT TASK WORD LIST

Instructions given to children: "You will hear me say 'this is a telephone.' I want you to listen to how I say telephone. If I say it a good way, point to the happy face. If I say it not a good way, point to the cross."

Word gloss	*Pronunciation*	*Type of change*
Telephone	/tæləfoun/	typical
Dinosaur	/dainəsɔ/	typical
Motorbike	/mɜtaibouk/	change each vowel
Hippopotamus	/hɪpɒtəmɪs/	delete unstressed syllable
Caterpillar	/kætəpɪlə/	typical
Elephant	/ælfɪnt/	delete unstressed vowel
Kangaroo	/kæŋgəru/	typical
Helicopter	/hælaikɒptə/	change unstressed vowel
Telephone	/tælfoun/	delete unstressed vowel
Butterfly	/bʌtəflai/	typical
Caterpillar	/kautəpɪlə/	change stressed vowel
Motorbike	/meatəbaik/	change stressed vowel
Helicopter	/hælikɒptə/	typical
Dinosaur	/dainsɔ/	delete unstressed vowel
Caterpillar	/kætupɪlə/	change unstressed vowel
Elephant	/æləfɪnt/	typical
Kangaroo	/kæŋgauru/	change unstressed vowel
Butterfly	/bɒtəflai/	change stressed vowel
Elephant	/æloufɪnt/	change unstressed vowel
Motorbike	/moutibaik/	change unstressed vowel
Telephone	/touləfoun/	change stressed vowel
Kangaroo	/kæŋru/	delete unstressed syllable
Hippopotamus	/hɪpəpɒtəmɪs/	typical
Dinosaur	/dʌnəsɔ/	change stressed vowel
Hippopotamus	/hɪpɒtəmɪs/	delete unstressed vowel
Caterpillar	/kætpɪlə/	delete unstressed vowel
Butterfly	/bʌtuflai/	change unstressed vowel
Motorbike	/moutəbaik/	typical
Elephant	/ɜləfɪnt/	change stressed vowel
Motorbike	/moutbaik/	delete unstressed vowel

APPENDIX C. NONWORD LEARNING WORD LIST

Instructions given to children: "We are going to learn some new words. First you will see pictures of the word and hear me say the name of the word. After you have learned about the word, you will see and hear the word again. This time, you will need to show me if the word is said the right way or a wrong way. If it is right, point to the green tick. If it is wrong, point to the red cross."

Transcription of nonword	*Transcription of each task item*
1. /blaig/ (training item)	/blaig/, /flaig/, /blaig/, /blæg/
2. /gwɔimz/	/gwɔimz/, /gwɔmz/, /gwʌmz/, /gwɔimz/
3. /mælətʃed/	/mælətʃep/, /mæləʃed/, /mælətʃed/, /mæloutʃed/
4. /krepdislʌv/	/krepdislʌv/, /krepdislʌv/, /krɒpdislʌv/, /kredislʌv/
5. /tʃɜfout/	/tʃifout/, /tʃɜfout/, /tʃɜfʊt/, /tʃɜfoug/
6. /kʊstɒn/	/kʊstɒn/, /kʊstbip/, /kʊstɒn/, /kʊftɒn/

APPENDIX D. RECEPTIVE GATING TASK WORD LIST

Instructions given to children: "You will hear me say the very first part of a word. I want you to point to the picture for the word you think I am trying to say."

Word list	*Length of stimulus (ms)*
Book*	200
Bed*	200
sheep*	250
cup	150
fish	290
light	260
shark	240
spoon	400
dog	130
cheese	200
clock	170
map	210
fish	340
light	310
shark	290
clock	220
cup	200
dog	180
cheese	250
map	260
spoon	450
cup	250
map	310
spoon	500
light	410
shark	340
fish	440
clock	320
dog	230
cheese	300

*Training item

APPENDIX E. REAL AND NONWORD REPETITION TASK WORD LIST

Instructions given to children: "I am going to say some words. I want you to say the words back to me. The first 10 words are words you will have heard before. The next group of words are made-up words that you will not have heard before."

Real Words

gymnasium	helicopter	ambulance	volcano
stopwatch	asteroid	frozen	hospital
Australia	kindergarten		

Nonwords

Gloss	*Phonetic transcription*
Steyboose	/steibus/
Flowdarshay	/floudaʃei/
Kazartog	/kəzatɒg/
Munobleem	/mʌnoublim/
Snaipouseedy	/snaipousidi/
Nookloudayshot	/nʊkloudeiʃɒt/
Chickoufer	/tʃɪkoufɜ/
Rangafayjop	/ræŋgəfeidʒɒp/
Wigenzord	/wɪgɪnzɔd/
Yomwadgi	/jɒmwadʒi/