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Tutorial

# Assessing Phonological Processing in Children With Speech Sound Disorders

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ABSTRACT

**Purpose:** Phonological processing skills, or using phoneme knowledge to process language, in preschool- and kindergarten-age children are an important indicator of children's future reading abilities. However, assessing phonological processing skills can be difficult in children with speech sound disorders because scoring often requires that children produce speech sound accurately. This tutorial presents assessment tasks that are appropriate for children with speech sound disorders to better identify children with phonological processing difficulties.
**Conclusions:** The following phonological processing assessment tasks are recommended for children with speech sound disorders: receptive tasks for phonological awareness, the Syllable Repetition Task for phonological memory, and limited letter choices for rapid automatized naming in phonological retrieval tasks. These tasks can be modified for multilingual children. Appropriate assessment of phonological processing skills will help speech-language pathologists in differential diagnosis of children with true phonological processing difficulties and children whose speech sound errors may mask phonological processing abilities. Assessment of phonological processing skills is particularly important for children with speech sound disorders, whose speech errors may be evidence of phonological processing difficulties.

Children with speech sound disorders (SSD) have difficulty acquiring the speech sounds of their language compared to their peers. Speech acquisition is a complex process, involving speech perception, storage and retrieval of phonological information, motor planning, motor execution, and monitoring (Stackhouse & Wells, 1997). Because speech errors may involve difficulties at multiple levels of speech processing, children with SSD are a heterogenous group, presenting with different speech profiles. This tutorial focuses on identifying children whose speech profile includes difficulties at the level of phonological processing.

## Phonological Processing Skills

*Phonological processing skills* are the ability to use knowledge of phonemes to process spoken and written language (Wagner & Torgesen, 1987). There are three general domains of phonological processing skills. The first skill is *phonological awareness*, the ability to identify and manipulate sounds in spoken words. The area of phonological awareness that is most closely related to reading skill is *phonemic awareness*, which refers specifically to a child's knowledge of *single* sounds within words. The second phonological processing skill is *phonological memory*, or the ability to store and retrieve new sequences of sounds. The third phonological processing skill is *phonological retrieval,* or the ability to recode written symbols to phonemes (Wagner & Torgesen, 1987).

Phonological processing skills differ from phonological processes. *Phonological processes* (also known as *phonological patterns*) refer to patterns of speech errors described in relationship to the features of the target sounds. In this tutorial, these speech errors will be referred to as *phonological patterns* for clarity. Examples of phonological patterns include fronting of velars, final consonant deletion, and stopping of fricatives. Table 1 presents a non-exhaustive list highlighting the differences in how these terms are used.

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**Table 1.** Phonological processing versus phonological processes/patterns.

| Phonological processing | | Phonological processes/patterns | |
|---|---|---|---|
| Phonological awareness | | Fronting of velars | /kip/ > [tip] |
| Blending | Put together the sounds /m, i, t/ (meet) | Stopping of fricatives/affricates | /si/ > [ti] |
| Segmenting | What sounds are in the word *meet*? | Gliding of liquids | /blu/ > [bwu] |
| Elision | Say *meet* without saying /m/ (eat) | Prevocalic voicing | /ti/ > [di] |
| Identifying | What is the first sound in *meet*? | Deaffrication | /tʃik/ > [ʃik] |
| Rhyming | Which word rhymes with *meet*? | Cluster reduction | /blu/ > [bu] |
| Phonological memory | | Weak syllable deletion | /bəlun/ > [lun] |
| Nonword repetition | Say /tævɑtʃinɑɪɡ/ | Final consonant deletion | /lif/ > [li] |
| Phonological retrieval | | Assimilation | /jɛlo/ > [lɛlo] |
| Rapid automatized naming | Say the letter names quickly and accurately: B R T O A X | Final consonant devoicing | /pɪɡ/ > [pɪk] |

Phonological processing skills in preliterate children support the development of later reading abilities (Catts et al., 2005; Hogan et al., 2005). Directly assessing phonological processing skills will help speech-language pathologists (SLPs) identify children who are at risk of later reading difficulties. Early identification of phonological processing difficulties is important because there is a cumulative benefit of early decoding knowledge (i.e., sounding out words; Gillon et al., 2019). Early intervention in this area leads to continued growth in decoding ability as the child learns to read (Gillon et al., 2019).

## Phonological Processing Skills in Children With SSD

There are multiple subtypes of SSD, with different hypothesized causes of speech errors. Shriberg et al. (2010) propose that SSD subtypes include (a) genetic speech delay, (b) speech delay associated with otitis media, (c) speech delay associated with psychosocial involvement, (d) speech distortion errors affecting sibilants such as /s/ and /z/, (e) speech distortion errors affecting /ɹ/, (f) apraxia of speech, (g) dysarthria, and (h) other motor speech disorders. Dodd et al. (2005) propose five subtypes of SSD: (a) articulation disorder, (b) delayed phonological acquisition, (c) consistent deviant phonological disorder, (d) inconsistent deviant phonological disorder, and (e) other. Across subtype classification systems, there is some agreement about three major areas of difficulty: (a) patterns of speech errors reflecting a presumed phonological, cognitive-linguistic etiology; (b) speech errors affecting single sounds reflecting a presumed perceptual-articulatory deficit; and (c) speech disorders arising from some degree of motor speech difficulties.

Many children with SSD present with phonological processing difficulties, regardless of whether the speech errors are associated with cognitive–linguistic, perceptual-articulatory, or motor speech difficulties. Children with phonological speech errors have difficulty with phonological awareness (Rvachew, 2007) and phonological memory (Roepke et al., 2020). Children with atypical speech errors, such as omitting initial consonants or gliding fricatives, obtained lower scores than children with typical speech errors, such as omitting final consonants and gliding liquids, on measures of both phonological awareness (J. Preston & Edwards, 2010; Roepke et al., 2020) and phonological retrieval (Ha & Pi, 2022). Adolescents with single-sound errors on /ɹ/ obtained lower scores than children with typical speech development on measures of phonological awareness and phonological memory (J. Preston & Edwards, 2007). Children with childhood apraxia of speech often present with phonological awareness difficulties and benefit from phonological awareness intervention (McNeill et al., 2009; Moriarty & Gillon, 2006; Murray et al., 2014).

The aim of this tutorial is to outline recommended approaches for assessing phonological processing skills in children with SSD. Many phonological processing assessment tasks rely on spoken responses, and single-sound substitutions or omissions may affect scoring of these responses. Therefore, not all phonological processing tasks are appropriate for children with SSD. For example, phonological memory tasks are often scored as percentage consonants correct, and phonological awareness tasks may include questions requiring children to produce a specific sound in a word. On such tasks, even if the child's ability to *process* phonological information is within the expected range, the child's speech *production* errors might impact scoring. However, since children with SSD are at increased risk of reading difficulties because of phonological processing difficulties, accurate assessment of these skills is essential.

This tutorial is divided into five sections, with the first three sections each reviewing a different area of phonological processing skills: (a) phonological awareness, (b) phonological memory, and (c) phonological retrieval.

These sections focus on assessment considerations for children with SSD whose speech patterns may impact performance on verbal assessments, reviewing the nature of the difficulty, suggestions for how to assess each area, how to interpret assessment results, and how to use the results to make intervention decisions. The fourth section provides recommendations for assessing phonological processing skills in multilingual children. Finally, the fifth section is a case study of the assessment process for a child with SSD and phonological processing difficulties.

## Phonological Awareness

### *The Nature of Phonological Awareness Difficulties*

Phonological awareness is the ability to identify and manipulate the individual sounds or syllables in spoken words. In preliterate children, phonological awareness is related to later reading success (Hogan et al., 2005). Phonological awareness can be tested at many different levels: the syllable, onset–rime, or the phoneme. Onset and rime are elements of the syllable; the onset includes any consonants before the vowel, and the rime includes the vowel (nucleus) and any syllable-final consonants (coda). In the word *flips*, *fl* is the onset, *ips* is the rime, and *ps* is the coda. Phonological awareness tasks often include blending sounds or syllables together, eliding or omitting sounds or syllables, segmenting sounds or syllables, rhyming, identifying initial or final sounds of a word, and identifying words that begin or end with the same sound. Importantly, phoneme awareness, measured using tasks such as phoneme identification and deletion, is more closely related to later reading success than are syllable-level or rhyming tasks (Mann & Foy, 2003).

Phonological awareness is related to the quality of children's phonological representations (Sutherland & Gillon, 2007). Many children with SSD have poor phonological awareness (Roepke & Brosseau-Lapré, 2023), suggesting that the quality of their phonological representations is related to their speech production errors (Brosseau-Lapré & Roepke, 2019). Children with poor phonological awareness skills may benefit from targeted intervention during speech-language therapy to remediate the underlying phonological representation difficulties (Brosseau-Lapré & Roepke, 2022). Phonological awareness abilities and speech sound production accuracy are both salient predictors of future reading ability in children with SSD (Tambyraja et al., 2020, 2023). In fact, the risk of reading difficulties in children with SSD is entirely mediated by phoneme awareness difficulties (Burgoyne et al., 2019). Thus, when working with children with SSD, a complete phonological assessment, including both phonological processing skills and speech sound production, is essential for planning individualized intervention (Stackhouse & Wells, 1997; Tambyraja et al., 2023).

### *Assessing Phonological Awareness in Children With SSD*

Many common phonological awareness tests are not designed for assessing children with speech production errors. In tasks that require a spoken response, it can be unclear whether the child's response reflects a surface-level speech error, where the child is aware of the correct sound but is unable to produce it, or an inaccurate phonological representation. Table 2 lists some common phonological awareness assessment tasks and examples of scoring difficulty for children with SSD. For example, if an examiner asked a child with word-final cluster reduction to name a word that rhymes with *jump* (/dʒʌmp/), and the child produced [dʌm], the examiner would not know whether the child intended to produce the word *dumb* or *dump*. The clinician administering the assessment would need to follow up to determine whether this child's answer reflected poor rhyme awareness or consonant cluster reduction. Overall, scoring and interpreting a phonological awareness assessment requires the examiner to determine whether speech sound production or phonological processing accounts for specific incorrect responses.

One approach to assessing phonological awareness in children with SSD is to select words containing only sounds and sound structures that the child can produce correctly. For example, if a child fronts velars, then the clinician would avoid words like *cat* (/kæt/) and instead use words like *fish* (/fɪʃ/) to assess a child's phonological awareness. A drawback to this approach is that it

**Table 2.** Phonological awareness tasks and scoring difficulties.

| Phonological awareness skill | Example test item | Target production | Child speech error | Child production |
|---|---|---|---|---|
| Blending | Put together these sounds: /h/, /aɪ/, /k/ | /haɪk/ | Final consonant deletion | /haɪ/ (hike) |
| Rhyming | What word rhymes with *list*? | *mist* /mɪst/ | Consonant cluster reduction | /mɪs/ |
| First sound identification | What is the first sound in *sheep*? | /ʃ/ | Palatal fronting | /s/ |
| Elision | Say *toothbrush* without saying *tooth*. | /bɹʌʃ/ | Consonant cluster reduction and palatal fronting | /bʌs/ |

provides limited insight into the child's underlying knowledge of the phonological forms they cannot produce. For example, if a child reduces consonant clusters in speech, assessing their awareness of phonemes in a cluster can clarify whether the speech errors arise from incomplete awareness of the clusters in words. For this reason, including test items containing the child's specific speech production errors within assessments of the child's phonological representations is preferred, as these targets may provide insight into the relationship between the child's speech errors and phonological processing skills.

A second approach to assessing phonological awareness is to use receptive phonological awareness tasks that do not require a spoken response. Instead of asking, "What sound does *cat* start with?", when the child cannot produce velar sounds correctly, the clinician could ask, "Do *cat* and *tie* start with the same sound?" or "Point to the picture of all the words that start with the sound /k/." Using receptive assessment tasks circumvents the need to decide whether an incorrect response is due to speech errors or phonological awareness difficulties. By using receptive assessments, clinicians can assess the accuracy of a child's phonological representations separately from speech sound production abilities, thus providing insight into the nature of the child's SSD.

## Assessment Resources

There are a growing number of receptive phonological awareness skill measures that are appropriate for children with SSD. Many of these measures have been used in research with this population. Some of these assessment tools are listed below.

1. Rapid Online Assessment of Reading (ROAR, n.d.; Gijbels et al., 2023). This assessment is administered online and is free to use. The phonological awareness test includes five measures: first sound matching, last sound matching, rhyming, blending, and deletion. The ROAR also includes online tests for single-word recognition, sentence reading efficiency, and receptive vocabulary.

2. Access to Literacy Assessment System (ATLAS-PA, n.d.). This assessment is administered online, and it is currently free to use. The phonological awareness subtest examines rhyming, blending, and segmenting. An alphabet knowledge subtest is also available, testing letter name knowledge and letter sound knowledge.

3. Bird et al. (1995) created a criterion-referenced receptive phonological awareness measure for children with SSD. The measure is available in the Appendix in the study of Bird et al. (1995). Text for the test items is available in the appendix of the article. Measures include rime matching, onset matching, and onset segmentation and matching. To use this measure, clinicians would need to prepare images to correspond with the text in the appendix.

4. J. Preston and Edwards (2010) also developed criterion-referenced phonological awareness testing measures for preschool-age children with SSD, which are available as PowerPoint files from the researcher's website (J. L. Preston, n.d.). These measures include blending, onset matching, onset segmentation and matching, and rhyme matching.

5. Silent Deletion of Phonemes (Claessen et al., 2010). On this task, children are shown an image (e.g., *pie*) and asked to think of the word but not to say it aloud. Then they are shown four images and asked to point to the image of the first word but with part of the word deleted (e.g., delete the first sound, *pie* ➔ *eye*). The Silent Deletion of Phonemes task was related to children's reading performance. Clinicians can reproduce this task using Appendix A in the article of Claessen et al. (2010).

6. Phonological awareness probes. Gillon (2005) developed phonological awareness assessment tools for preschool-age children with SSD. These materials are available at the researcher's website (Gillon, n.d.-b). Skills assessed include rhyme detection (identifying the odd one out) and phoneme matching (identifying words that begin with the same sound). Child-friendly images accompany each phonological awareness assessment task. The same website hosts a second assessment probe for 5- to 7-year-old children, used in the work of Gillon et al. (2007); this probe includes phoneme isolation at the beginning and end of words, phoneme blending, phoneme deletion, and phoneme segmentation.

7. Dynamic assessment. Nonverbal dynamic assessment of phonological awareness is related to word-level reading in children with SSD (S. L. Gillam & Ford, 2012). Clinicians can reproduce the task using Appendix A in the study of S. L. Gillam et al. (2011).

8. Comprehensive Test of Phonological Processing–Second Edition (CTOPP-2; Wagner et al., 2013). The sound-matching Phonological Awareness subtest on the CTOPP-2 uses receptive responses. This subtest requires children to point to an image that starts with the same sound as another word.

## Interpreting Assessment Results

To interpret phonological awareness performance, clinicians should first identify whether there are data for expected performance on the assessment and whether the child being assessed matches the standardization sample on relevant factors. Clinicians should consider the dialect spoken by the sample (e.g., standardization samples including only mainstream American English [MAE] speakers are not appropriate for speakers of other English dialects); whether the children in the sample were monolingual or multilingual; whether the children in the sample had a speech and/or language disorder; and age, geographical location, and socioeconomic status (McCauley & Swisher, 1984). If these factors differ between the children in the sample and the child the clinician is testing, then the "expected range" of performance is not valid for the child in question. A monolingual 4-year-old MAE speaker from Indiana from a high socioeconomic background is expected to perform differently on speech and language tests than a trilingual 3-year-old Australian English speaker from a low socioeconomic background. Comparing the trilingual child's performance to the performance of monolingual children with vastly different speech and language experiences is like comparing apples to oranges: It does not provide clinically useful data about the trilingual child's relative performance. Therefore, clinicians should be cautious about comparing a child's performance to sample performance on tests, particularly when the child being assessed does not match the sample or when there are insufficient data reported on the sample to determine if it is an appropriate test.

For standardized tests such as the CTOPP-2, clinicians can consult the manual. For assessments used only in research contexts such as the J. Preston and Edwards (2010) probes, clinicians can consult the relevant articles listed with the measures in the list above, as the researchers may have identified expected performance at different ages. If these data are not available, then the clinician may consult Schuele and Boudreau (2008) for general information on the sequence of phonological awareness development. In addition, there are child-related factors and task-level factors that may affect performance on phonological awareness tasks.

## Child Factors and Phonological Awareness

Child factors that may influence phonological awareness performance include age, letter knowledge, vocabulary size, and speech perception. In terms of age, older children generally have more advanced phonological awareness abilities than younger children (Lonigan et al., 2009). This development of phonological awareness affects which tasks a child can be expected to complete successfully, as children are aware of larger units such as syllables and rimes before they are aware of smaller units such as single sounds (Carroll et al., 2003).

A second child factor is letter knowledge. The development of some phoneme awareness skills is closely related to knowledge of at least a few letters (Carroll, 2004). In preschoolers, early letter name knowledge is associated with growth in phonological awareness; at the same time, early phonological awareness is associated with growth in letter name knowledge (Lerner & Lonigan, 2016). There is a complex relationship between letter knowledge, phoneme awareness, and reading development; however, in general, phonological awareness combined with letter knowledge is a necessary foundation for reading in English (Schuele & Boudreau, 2008). For a child to transfer phonological awareness knowledge to reading, that child needs to understand that letters represent sounds (Schuele & Boudreau, 2008). Because both phonological awareness and letter knowledge are important for reading, clinicians should consider probing letter knowledge when assessing phoneme awareness in children at risk for reading difficulties.

A third child factor, vocabulary size, is reliably related to phonological awareness in preschool-age children (Brosseau-Lapré & Roepke, 2019; Metsala, 1999; Roepke & Brosseau-Lapré, 2023; Rvachew & Grawburg, 2006). The relationship between vocabulary and phonological awareness is hypothesized to derive from the structure of children's phonological representations. As children have to store new words in their memory, these representations have to become increasingly specific to differentiate similar words, such as *go–dough–toe* (lexical restructuring hypothesis; Walley et al., 2003). Therefore, testing vocabulary together with phonological awareness is recommended, as comparing the two measures may help clinicians identify possible causes of poor phonological awareness. In addition, if a child's phonological awareness is low despite a large vocabulary size, then clinicians should consider integrated phonological awareness intervention (Gillon, 2000).

Finally, speech perception is related to phonological awareness in young children (Carroll et al., 2003; Foy & Mann, 2001; Rvachew & Grawburg, 2006). In children with SSD, speech perception difficulties can manifest as difficulties discriminating two sounds that children collapse in speech production (Roepke & Brosseau-Lapré, 2019). Thus, speech perception difficulties may affect performance on some phonological awareness items. For example, if a child with SSD has difficulties discriminating /s ~ ʃ/, then that speech perception difficulty might affect the child's performance on specific phonological awareness test items such as, *Do "save" and "shower" start with the same sound?* For this reason, it is recommended that clinicians conduct a full assessment of a child's phonological profile, including speech production, speech perception, receptive vocabulary, and phonological processing skills.

## Task Factors and Phonological Awareness

At the task level, task difficulty and neighborhood density should be considered when interpreting performance.

Task difficulty relates to the developmental sequence of phonological awareness. Assessment should include awareness of both larger units and smaller units, rather than assessing only smaller units. For example, the Silent Deletion of Phonemes task (Claessen et al., 2010) requires the advanced skill *phoneme elision*, which is a later-developing skill (Schuele & Boudreau, 2008). Children who struggle to complete this task may nevertheless have strengths in earlier-acquired phonological awareness skills, which will not be identified if the only phoneme elision is assessed. Therefore, an assessment should include multiple types of phonological awareness tasks to identify both strengths and needs in this area.

A second task-level consideration is phonological neighborhood density of the test items. Phonological neighborhood density is measured as the number of words that are one phoneme different from the target word (Vitevitch & Luce, 2016). Neighbors are formed by substituting, adding, or omitting a single sound. For example, some of the phonological neighbors for the word *cat* include *at*, *hat*, *rat*, *mat*, *sat*, *fat*, *pat*, *bat*, *gnat*, *chat*, *that*, *can*, *cap*, *catch*, *catty*, *cats*, *scat*, and *cattle*. Children often have better awareness of the phonological structure of words with high neighborhood density than those with low neighborhood density (Farquharson et al., 2014; Metsala, 1999), though this relationship depends on a child's vocabulary size (De Cara & Goswami, 2003). If children perform poorly on a task with a target word from a low-density neighborhood, clinicians may probe performance on the same task using a word from a high-density neighborhood. The results from such a probe may help in identifying whether a child cannot complete the phonological awareness task at all or whether poor performance is word specific.

## Making Intervention Decisions

If a child with SSD has phonological awareness difficulties, clinicians should directly address phonological awareness in intervention. It is well established that direct phonological awareness intervention facilitates the development of phonological awareness and reading skills, including in children with speech and language disorders (Gillon, 2000, 2002, 2005; Gillon et al., 2019; Moriarty & Gillon, 2006). Group phonological awareness intervention is generally effective (van Kleeck et al., 1998). However, not all children respond equally to phonological awareness instruction (Al Otaiba et al., 2009), so performance should be monitored, as individualized intervention may be required for some children.

One method of monitoring growth is to track data on a list of probe words that are not used within intervention. The clinician can create a list of 30–50 probe words and use 10 randomly selected words each session for progress monitoring. The clinician can use these words to measure the extent to which a child can apply phonological awareness skills to untrained words. These same words can be used as children progress through different phonological awareness skills, such as blending, segmenting, and eliding, from syllables to single sounds. Progress monitoring should be specific to these different skills. In other words, progress should be measured on blending syllables over time, not on blending syllables one week and eliding phonemes the next week, as these phonological awareness skills have different levels of difficulty. Probes should be administered without feedback or scaffolding so that the child's performance is not based on the amount of support but instead is representative of what the child is able to do independently as a result of applying skills learned during intervention.

Although some children may generalize phonological awareness skills quickly to a variety of word types, other children may need to master phonological awareness skills within certain word contexts before applying those skills to other word contexts. In other words, some children may need to master combining syllables in words with spondaic meter (strong–strong stress pattern, such as *ice cream* or *hot dog*) before moving to trochees (strong–weak stress pattern, such as *butter* or *pirate*) and then iambs (weak–strong stress pattern, such as *balloon* or *police*). For these children, probe words should match the targeted structure in therapy. Clinicians could have separate probe word lists for different stress patterns, which are used during therapy to assess whether the child has learned to combine syllables in these different prosodic contexts. Other phonological considerations may include number of syllables, syllable shape (CV [C = consonant, V = vowel], CVC, CCVC, etc.), and neighborhood density. Another consideration is whether the child knows the word already and is analyzing their underlying representation of the target word (such as *cat*) or whether they are encountering a word for the first time and therefore attempting to identify the sounds in a word that they are simultaneously trying to remember (such as *cumbersome*).

There are online resources for developing probe word lists with specific phonological, orthographic, and familiarity features. These resources were originally developed for researchers conducting psychology experiments, but they can be used within the therapy setting. Three online resources include the Medical Research Council Psycholinguistic Database (Fearnley, 1997), the South Carolina Psycholinguistic Metabase (Gao et al., 2023), and the Paivio et al. (1968) Word List Generator (Friendly & Dubins, 2019).

While addressing phonological awareness skills directly is recommended, clinicians may also consider incorporating related skills. Vocabulary size is closely related to both phonological awareness and phonological memory in young children (Metsala, 1999; Walley et al., 2003). Therefore, incorporating a vocabulary component into intervention, focusing on the sounds in words, may facilitate growth in phonological awareness. Vocabulary can be targeted through a dialogic reading home program. For example, Rvachew and Brosseau-Lapré (2015) found that a caregiver-implemented dialogic reading program supported phonological awareness and articulation accuracy among children with SSD. Finally, clinicians may consider incorporating musical activities into phonological awareness intervention, as musical training has been found to facilitate phonological awareness and reading skills in children (Flaugnacco et al., 2015). Musical activities might include beating a drum with each syllable of a multisyllabic word, singing songs that emphasize rhymes, or singing songs that explicitly manipulate sounds in a word, such as *I like to eat, eat, eat apples and bananas* or *Willaby wallaby woo.*

Several resources are available for SLPs looking for information on phonological awareness intervention. Clinicians may find the extensive review in the work of Schuele and Boudreau (2008) and the tutorial on phonological awareness intervention in the work of Brosseau-Lapré and Roepke (2022) helpful. In addition, a program for implementing the evidence-based integrated phonological awareness intervention specifically designed for children with SSD is available from Gillon (n.d.-a, n.d.-b). Integrated phonological awareness intervention has repeated research evidence demonstrating its effectiveness in improving speech production, spelling, and emergent reading in young children with SSD (Gillon, 2005; Moriarty & Gillon, 2006; McNeill et al., 2009). The integrated phonological awareness intervention materials are available on the researcher's website.

## Phonological Memory

### *The Nature of Phonological Memory Difficulties*

Phonological memory is the ability to hold phonological information in short-term memory. Phonological memory is typically measured using Nonword Repetition Tasks (NRTs), during which a child listens to a pseudoword and attempts to repeat the word back after hearing it only once. Skills required for successful nonword repetition include speech perception, phonological encoding, phonological assembly, and articulation (Coady & Evans, 2008). Many of these skills are challenges for children with SSD. Unsurprisingly, then, children with SSD have poorer phonological memory than children with typical speech development (Farquharson et al., 2018, 2021; Roepke et al., 2020; Vuolo & Goffman, 2020).

Nonword repetition may be helpful in clinical decision making for determining which children would benefit from intervention for speech sounds. Young children with strong nonword repetition skills and SSD are likely to remediate their speech sound errors, while children with poorer nonword repetition performance are more likely to have persistent SSD (Wren et al., 2016). In older children with persistent SSD, however, nonword repetition skill is mediated by nonverbal intelligence (Farquharson et al., 2018).

Although nonword repetition difficulties have been repeatedly linked to language impairment in children (see Graf Estes et al., 2007, for a meta-analysis), Catts et al. (2005) found that phonological processing measures, including nonword repetition, were more closely related to dyslexia than to language impairment. While nonword repetition is related to children's reading abilities (Melby-Lervåg et al., 2012), nonword repetition is a weaker predictor of reading than phonological awareness (Melby-Lervåg et al., 2012). Overall, nonword repetition as a measure of phonological memory can contribute to clinical decision making, as part of a battery of assessments, to identify children at risk of long-term, sound-based difficulties such as persistent SSD and dyslexia. The following sections provide guidelines for assessing and addressing phonological memory in children with SSD.

### *Assessing Phonological Memory in Children With SSD*

The phonological properties of nonwords on phonological memory tasks affect performance, especially among children with SSD. Performance is often measured as percentage of phonemes correct, while the nonwords contain sounds and structures that children with SSD cannot produce correctly even in isolation. If difficult sounds are included in nonword targets, then children with SSD could present with low nonword repetition scores despite strong phonological memory skills. For example, the NRT (Dollaghan & Campbell, 1998) is a frequently used measure. A child with multiple phonological patterns may produce the NRT target /tævatʃinaɪg/ as [dæbadinaɪ]. This child would receive credit for only one of the five target consonant sounds. Clinicians will need to analyze responses carefully to determine whether the child's primary area of difficulty is phonological memory or speech sound production accuracy.

One possible approach to address this scoring difficulty is to exclude target sounds that children produce incorrectly in words while calculating the score (Deevy et al., 2010). However, depending on the number of speech errors that a child with SSD produces, this approach could exclude most target sounds and make interpretation difficult. A child might have phonological memory difficulties that are not identified because the target items contain many difficult sounds.

Another approach to measuring nonword repetition in children with SSD is to include only sounds that the child can produce correctly. One NRT was designed specifically for children with SSD, the syllable repetition task (SRT; Shriberg et al., 2009). The SRT contains only the syllables /ba/, /da/, /ma/, and /na/, combined to create two-, three-, and four-syllable targets. The target consonants /b, d, m, n/ and the target syllable structure (CV) were chosen because most children with SSD can produce these sounds correctly (Shriberg et al., 2009).

Clinicians can access and administer the SRT using a computer or tablet. The SRT is currently available online at no cost (Shriberg, n.d.). Clinicians can download a PowerPoint file that includes audio with the target nonwords, as well as a scoring sheet. The scoring sheet can be accessed on page 19 of Shriberg and Lohmeier's (2008) work. To administer the SRT, clinicians turn the computer screen away from the child and present the PowerPoint file one slide at a time, pausing to allow the child to repeat the target word.

## *Interpreting Assessment Results*

There are no normative data for the SRT. However, performance from a large sample of children with diverse speech and language profiles is reported in Table 6 of Shriberg et al.'s (2012) work. The profiles included are (a) typical speech and language, (b) SSD and typical language, (c) SSD and language disorder, and (d) childhood apraxia of speech and language disorder. Additionally, Roepke et al. (2020) report performance from a small sample of preschool-age children with the following profiles: (a) typical speech and language, (b) SSD and typical language, and (c) SSD and language disorder. These resources may help clinicians determine expected performance on this task for children within a certain age range.

If nonword repetition is a difficult task for a child, then the first step in interpreting the results is to analyze the errors to identify possible underlying difficulties. Although nonword repetition is ostensibly a memory task, successful performance requires related speech processing skills (Coady & Evans, 2008). Shriberg et al. (2012) offer guidance for analyzing SRT responses to obtain a competence, memory, encoding, and transcoding score. Shriberg et al. (2012) and Roepke et al. (2020) both report performance on all the measures listed below.

### Calculating the Competence Score

The competence score represents an overall score on the SRT, calculated similarly to percentage consonants correct across all syllable lengths. To obtain the competence score for the SRT, divide the number of consonants correct (defined as having the same manner and place as the target consonant) by the total number of consonant targets, ignoring distortions and voicing errors (p/b, t/d). Omissions are scored as *incorrect*. Additions should be noted for later calculations, but they are not included in the competency score.

Vowels are not included in the scoring of the SRT. However, clinicians may still choose to transcribe vowels, as vowel errors on this task may be associated with possible language disorder (Roepke et al., 2020; see also Vuolo & Goffman, 2020) or childhood apraxia of speech (Shriberg et al., 2012). Full scoring guidelines are available from Shriberg and Lohmeier (2008).

The competence score is a general measure. If a child obtains a low competence score, then the clinician should conduct further analysis of the errors. Since nonword repetition depends on multiple speech skills (Coady & Evans, 2008), poor overall performance could reflect memory, encoding, or transcoding difficulties or low attention and interest in the task.

### Calculating the Memory Score

One possible cause for poor performance is phonological memory difficulties. Phonological memory is more taxed at four syllables than at two syllables, so phonological memory difficulties may be revealed when comparing performance on longer and shorter sequences of sounds. Shriberg et al. (2012) found that the ratio of percentage consonants correct between three and two syllables was a sensitive measure for phonological memory using the SRT. This ratio is calculated by dividing the percent of correct consonants at three syllables by the percent of correct consonants at two syllables. For example, if a child produced 14/16 consonants correct at two syllables (14/16 = .875) and 9/18 consonants correct at three syllables (9/18 = .50), then the memory ratio would be .50/.875 = .57.

Higher numbers on this measure (closer to 1) indicate better phonological memory, while lower numbers (closer to 0) indicate difficulty with phonological memory. If children obtain high values on this measure, then phonological memory may be a relative strength. However, in some cases, a child may obtain a high memory score because of poor performance on the two-syllable items. If this is the case, clinicians may consider probing the child's performance on one-syllable items (*ba*, *da*, *ma*, *na*). Performance on one-syllable items may help the clinician select follow-up tests to determine whether the underlying difficulty is consistent with memory or another difficulty, such as hearing, speech perception, or motor speech abilities.

To compare the memory measure to the data reported in the work of Shriberg et al. (2012), clinicians can consult Shriberg et al. (2012) for detailed instructions. Briefly, the ratio should be transformed using the following formula, truncating values below 0 or above 100 (Shriberg et al., 2012, p. 458):

$$100 \times (1 + 1\mathrm{n}[3 : 2\,\mathrm{ratio}]). \tag{1}$$

For the example child above with the memory ratio of .57, the transformed value would be 44. Using this final number allows clinicians to compare the child's performance to the data reported by Shriberg et al. (2012). While this data set is not normative, it may nevertheless be helpful to clinicians as a guide for the expected range of phonological memory scores in this population.

### Calculating the Encoding Score

Phonological encoding is the ability to translate the acoustic speech signal to an accurate representation of the salient features each segmented phoneme to be stored in short-term memory (Coady & Evans, 2008; Shriberg et al., 2012). In Shriberg et al. (2012), children with CAS obtained lower scores on encoding than children with other subtypes of SSD but similar scores to children with SSD and developmental language disorder (DLD).

The phonological encoding score on the SRT is the percentage of within-class manner substitutions (Shriberg et al., 2012). Within-class manner substitutions include a nasal substituted for another nasal (e.g., /m/ substituted for /n/) or a stop substituted for another stop (e.g., /d/ substituted for /b/). The encoding score is calculated as the "number of consonant substitutions with the same manner class as the target phoneme" divided by the total number of substitution errors (Shriberg et al., 2012, p. 457).

While performance on this measure may provide some valuable information, to date, there has not been research explicitly examining to what extent this score measures encoding. Therefore, directly examining children's speech perception skills may provide more easily interpretable information for clinical assessment purposes. Most of the research on the speech perception skills of children with SSD has found that, if a child does have speech perception difficulties, they match the children's speech production errors (Hearnshaw et al., 2018; Roepke & Brosseau-Lapré, 2019; Rvachew & Jamieson, 1989). A review of speech perception tasks that can be modified for the child's specific speech errors can be found in the work of Hearnshaw et al. (2018).

### Calculating the Transcoding Score

Another possible source of difficulty on an NRT is motor planning and programming, referred to here as *transcoding*. Because childhood apraxia of speech is a disorder of motor planning and programming, difficulties with transcoding are more likely to be observed in childhood apraxia of speech than in other subtypes of SSD (Shriberg et al., 2012). Specifically, a transcoding score below 80% is 8.3 times more likely to be associated with childhood apraxia of speech than with speech delay (Shriberg et al., 2012).

Children with transcoding difficulties frequently add homorganic nasals before stops on the SRT items. For example, the target /bada/ might be produced as /banda/, or /naba/ might be produced as /namba/. Guidelines for calculating the transcoding score can be found in Shriberg et al. (2012, p. 458–459). These guidelines are summarized below.

1. Count the number of target nonwords that contain additional sounds.
2. Calculate the percentage of nonwords with additional sounds.
3. Subtract the result from Step 2 from 100 to obtain the transcoding score.

Although the SRT is not a standalone diagnostic test on its own for childhood apraxia of speech, it may nevertheless provide support for the diagnosis when used with other assessments. Rvachew and Matthews (2017) provide a detailed tutorial on using the SRT to identify underlying processing skills in childhood apraxia of speech.

## *Making Intervention Decisions*

Analyzing a child's performance on the SRT is important because assessments guide intervention approaches. If a child's difficulties are motor based, then intervention should match the deficit and target motor skills rather than memory skills. If a child's difficulties are memory related, then intervention should target phonological processing, not motor movements.

Although nonword repetition training in a research setting has improved reading outcomes (Maridaki-Kassotaki, 2002), there are some limitations that clinicians should consider before targeting nonword repetition in therapy. First, repeating nonwords is not a functional intervention task that will increase communication abilities. Second, clinicians working with children with SSD would need to decide whether to target speech sound production accuracy on these multisyllabic words, or whether to target phonological memory separately from speech sound accuracy. Third, there is limited evidence in favor of nonword repetition as a goal, but there is ample evidence in favor of working on phonological awareness or direct reading instruction. Working on nonword repetition is likely not the most efficient intervention approach for this phonological processing skill.

Instead, clinicians should consider providing phonological awareness intervention for children with phonological memory limitations. There is an established relationship between phonological awareness and phonological memory (Bowey, 2001; Hansen & Bowey, 1994), which can be leveraged in intervention by targeting phonological awareness skills. Phonological awareness is an evidence-based intervention supporting children's phonological memory (van Kleeck et al., 2006; see also R. B. Gillam & van Kleeck, 1996; Hariri et al., 2019). In addition, phonological awareness is more closely related to reading ability than phonological memory is (Hansen & Bowey, 1994). Thus, phonological awareness intervention is recommended for children with poor phonological memory to target both phonological processing skills and reading.

## Phonological Retrieval

### *The Nature of Phonological Retrieval Difficulties*

Phonological retrieval is the ability to recode written symbols to phonemes (Wagner & Torgesen, 1987), though there is some debate whether this is a phonological skill or another type of skill (see Norton & Wolf, 2012). Specifically, phonological retrieval is not related to phonological awareness, but it is closely related to naming speed for nonphonological items such as colors or objects, leading researchers to question the phonological nature of this skill. Phonological retrieval is related to reading ability (Araújo et al., 2015; Catts, 1991). However, while phonological awareness is associated with decoding abilities, phonological retrieval appears to be more closely related to reading fluency (Pennington et al., 2001).

There is some evidence that children with SSD have phonological retrieval difficulties. For example, phonological retrieval of *numbers* is lower in children with SSD than children with typical speech (Ha & Pi, 2022). However, there has been limited research on the relationship between phonological retrieval and reading specifically in children with SSD, and the research that has been done suggests that phonological retrieval is not a robust predictor of reading skills in this population. For example, Catts (1993) found that phonological retrieval and phonological awareness are both related to written word recognition in children with speech and language impairments. Tambyraja et al. (2020) did not identify phonological retrieval of objects as a salient predictor of reading risk among children with SSD as a *group*, but many individual children in the work of Tambyraja et al. (2023) who were poor readers experienced phonological processing difficulties across multiple domains, often including phonological retrieval. Therefore, phonological retrieval difficulties in isolation are likely not cause for significant literacy concerns in a child with SSD, but the presence of phonological retrieval difficulties together with other phonological processing or language impairments does likely indicate an increased risk of reading difficulties.

An important consideration when making clinical decisions is the child's full profile. If a child's only phonological processing difficulty is phonological retrieval, and the child has typical language development, then the child's risk of reading difficulties is low (see Tambyraja et al., 2023). However, if a child presents with phonological retrieval difficulties in addition to phonological awareness difficulties and/or language impairment, then the child's risk of reading difficulties is higher. The child's full language profile is relevant in clinical decision making, as there are multiple risk and protective factors in reading acquisition that should be considered (McGrath et al., 2020).

### *Assessing Phonological Retrieval in Children With SSD*

Phonological retrieval is assessed using rapid automatized naming (RAN). To complete an RAN assessment, children look at a series of letters, objects, colors, and/or shapes, and the children name the items left to right as quickly and as accurately as possible. RAN stimuli are often present in an array, with 10 symbols on five rows, for a total of 50 symbols. A total of five different symbols are used in a single test, with each occurring twice on a row. Symbols are spaced out across the rows, and the assessor measures the time taken to complete the task and the number of correctly and incorrectly labeled symbols. However, an alternative approach that appears more closely related to word recognition skills was examined by Compton et al. (2002). This alternative approach uses six symbols presented once each in five rows. In this approach, children name as many items as possible within 15 s.

While rapid naming has been assessed using letters, colors, and objects (Wagner et al., 2013), this tutorial focuses on the impact of SSD on the naming of *letter*s, as naming letters is more closely related to reading than naming colors or objects (Araújo et al., 2015). However, for children who do not yet know letter names, clinicians can instead use colors or objects, keeping in mind the child's speech sound production abilities and limitations when selecting stimuli.

SLPs can create their own RAN stimuli to use in assessment. Considerations for creating stimuli include the familiarity of the items, the child's speech errors, and the child's awareness of their speech errors. First, RAN tasks should include items that are familiar to the child. Before beginning any RAN assessment, the clinician should first test the child's knowledge of the items in the series in an untimed task. If the child is not able to name certain items correctly in an untimed task, then those items should be excluded from the timed assessment.

Second, clinicians should consider the child's awareness of their speech errors before including specific letters. RAN is a timed task, and articulation time can increase the time to complete the task (Neuhaus et al., 2001). Children who have participated in speech-language therapy may be aware of their speech difficulties and take additional time to produce the sounds in certain letters correctly if these sounds have been explicitly targeted in therapy. For example, a child who has previously received therapy for /s/ might produce words with /s/ slowly, even if they produce it correctly, as a learned carefulness in articulation. If sounds that children produce carefully (e.g., the rhotic in the letter *R*) are included in the RAN task, performance might reflect careful articulation rather than difficulty retrieving the letter name.

Third, speech errors by children with SSD may impact letter naming during an RAN assessment. For example, if the child produces stops for fricative targets, the letter *C* /si/ (produced as [ti]) could be confused with *T* /ti/ due to the speech error. This speech production error might not reflect a child's letter knowledge, but rather the limitations of the child's speech accuracy. Scoring RAN tasks when the children's speech errors cause two letter names to be pronounced identically presents similar difficulties to scoring phonological awareness or phonological memory tasks: It is unclear whether errors reflect phonological processing or speech production difficulties. In the absence of clear clinical guidelines, clinicians are encouraged to select stimuli according to the child's speech production abilities.

Clinicians can individualize RAN assessments based on a child's speech production abilities by selecting stimulus items from the set of letters that the child articulates correctly. Table 3 lists some letters to include on RAN tasks based on common speech production error patterns. By selecting letters that the child can produce correctly, scoring and interpretation of the RAN task are likely to reflect the child's phonological retrieval skills rather than speech production limitations.

**Table 3.** Recommended rapid automatized naming letter targets by speech sound error pattern.

| Phonological pattern | Letter targets |
|---|---|
| Final consonant deletion | Exclude: F, H, L, M, N, S, X |
| | Include: A, B, C, D, E, G, I, J, K, O, P, Q, T, U, V, W, Y, Z |
| Stopping | Exclude: C, F, G, H, J, S, V, X, Z |
| | Include: A, B, D, E, I, K, L, M, N, O, P, Q, R, T, U, W, Y |
| Prevocalic voicing | Exclude: C, K, P, Q, T |
| | Include: A, B, D, E, F, G, H, I, J, L, M, N, O, R, S, U, V, W, X, Y, Z |
| Cluster reduction | Exclude: Q, X |
| | Include: A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, R, S, T, U, V, W, Y, Z |
| Vowelization, gliding | Exclude: L, R |
| | Include: A, B, C, D, E, F, G, H, I, J, K, M, N, O, P, Q, S, T, U, V, W, X, Y, Z |

## *Interpreting Assessment Results*

There is no single cutoff score for RAN tasks that reliably predicts reading fluency difficulties. Instead, clinicians can use the results to identify the child's profile of strengths and needs on this task. If the child's RAN accuracy level is low, then errors should be analyzed to identify whether specific letter names are causing the low accuracy or whether performance reflects a difficulty of letter naming in general. In addition, some naming errors are expected in young elementary-age children, such as confusing the lowercase letters *b* and *d* (Denckla & Rudel, 1974). Error types can be analyzed for typical and atypical confusions. If letter name knowledge is an area of need, then that is an appropriate area for intervention, possibly in collaboration with a reading specialist. Letter name knowledge is strongly related to reading ability in addition to phonological retrieval (Pennington & Lefly, 2001). Therefore, letter knowledge may be an appropriate area to target in children who are at risk for reading difficulties and present with low letter name knowledge on a phonological retrieval assessment.

Naming speed can also impact performance. There are some data on naming speed that clinicians can use to determine whether a child's naming speed is lower than expected. Denckla and Rudel (1974) provided some early data on naming speed in typically developing English-speaking children. These children named 50 items on an RAN task: Using capital high-frequency letters, 5-year-old children completed the task in an average of 90.8 s ($SD$ = 38.9); 6-year-old children, in an average of 56.1 s ($SD$ = 21.9); 7-year-old children, in an average of 34.4 s ($SD$ = 7.9), and 8-year-old children, in an average of 30.3 s ($SD$ = 5.3). The same task using low-frequency capital letters required about 1.25 times the amount of time to complete. Another source of reference information for general expectations by age on an RAN task is the CTOPP-2 (Wagner et al., 2013). However, in interpreting performance, clinicians should keep in mind that speed varies with letter familiarity and should examine their own stimuli to determine whether the letters included are very familiar or less familiar to the children.

If the child's naming *speed* is lower than expected, then clinicians may be able to analyze the child's performance to identify the underlying cause of low naming speed. Overall speed of completing the task might be negatively affected by attention difficulties if the child did not fully attend to the task for its entire duration; attention difficulties should not be considered a phonological processing difficulty. However, pause time between letter names does appear to be related to reading fluency (see Siddaiah & Padakannaya, 2015). Clinicians should provide appropriate interventions for children with significant pause time on this task, particularly if the children have concomitant difficulties in other areas of phonological processing skills (Tambyraja et al., 2023).

### *Making Intervention Decisions*

Poor performance on RAN tasks could indicate a number of difficulties, including incomplete letter name knowledge, attention difficulties, or phonological retrieval difficulties. For children whose performance is consistent with incomplete letter name knowledge, targeted intervention in letter name knowledge should be conducted to address this foundational reading skill.

When children present with low naming speed on this task, a multiple-component reading intervention is appropriate. There is limited research suggesting that practicing rapid naming improves reading speed (Vander Stappen & Van Reybroeck, 2018). However, there are many more studies arguing that intervention for rapid naming is not an effective approach to improve reading (see Kirby et al., 2010, for a review). Therefore, targeting naming in isolation is not currently recommended.

Importantly, children with reading difficulties do not present with RAN deficits in isolation; reading difficulties are multifactorial and frequently occur in children with deficits across a range of skills (Tambyraja et al., 2023). Therefore, instead of targeting naming speed in isolation, clinicians should consider partnering with reading interventionists to address multiple components of literacy instruction. Importantly, children with low naming speed appear to be less responsive to reading treatment than children with greater naming speed (Al Otaiba & Fuchs, 2002; Nelson et al., 2003) and therefore may require a more intensive reading intervention than children with age-appropriate naming speeds. Few studies have remediated reading fluency in children, but Morris et al. (2012) report a treatment–control study that did so. This study compared gains in reading measures, including fluency, when children received multiple-component intervention compared to phonological-only intervention. The most effective intervention in this study was the Retrieval, Automaticity, Vocabulary, Engagement with Language, and Orthography intervention (Wolf et al., 2009) combined with a phonology program. This intervention led to measurable gains in reading fluency. To translate these findings to clinical practice when working with children with limited phonological retrieval abilities, SLPs may consider partnering with reading specialists for evidence-based reading intervention. In this partnership, the clinicians can support foundational skills such as phonology, vocabulary, and language that support reading.

## Multilingual and Multidialectal Children With SSD

Phonological processing skills can also help identify multilingual children at risk for dyslexia (Taha et al., 2022). Phonological processing assessment tasks can match the sounds a child can produce, as reviewed above. This approach may be particularly helpful in the case of a multilingual child with SSD, as different languages may have phonemes that are not present in both languages spoken by the child. Choosing activities and stimuli that align with the phonemes present in a multilingual child's primary language might allow for an accurate assessment of their skills. Phonological processing skills are an early indicator of later reading ability in many different languages, even in languages like Chinese that use a logographic orthography (see Anthony et al., 2006, for Spanish; Hu & Catts, 1998, for Chinese). Therefore, phonological processing skills may be appropriate assessment tools to identify multilingual children who would benefit from reading intervention. Such intervention could include pre-reading instruction to build foundational literacy skills and prepare children for reading success.

It is important to note when working with multilingual children that many standardized assessments include a standardization sample of only, or primarily, monolingual children. In cases where the child being assessed differs from the standardization sample on factors such as the number of languages spoken, it is not appropriate to calculate standard scores. Some assessments may allow for dialect-specific scoring if the child speaks a minoritized dialect; clinicians should consult the manual to determine whether to use this scoring approach. Tests can be administered in order to develop a profile of the child's strengths and weaknesses in a specific area. Criterion-referenced tests or probes may be more appropriate profiling strengths and needs than standardized tests. Dynamic assessments are also appropriate for children who do not match the characteristics of the standardization sample.

Performance on phonological processing tasks is affected by the phonological characteristics of a speaker's language or dialect (Ortiz, 2021). Spanish–English bilingual children are more accurate on an NRT based on Spanish phonology than on one based on English phonology (Windsor et al., 2010). Test bias can impact performance. Children who speak African American English (AAE) frequently obtain lower scores than children who speak MAE on tests of phonological awareness, likely due to dialectal differences in the phonological realization of English words (Mitri & Terry, 2014; Shollenbarger et al., 2017; Terry et al., 2010; Terry & Scarborough, 2011). For example, Shollenbarger et al. (2017) examined rhyme and segmentation of words containing word-final consonant clusters. Words such as *nest* (produced by MAE speakers as /nɛst/) are often produced by AAE speakers as /nɛs/. When asked which word rhymes with *nest*, AAE-speaking children frequently indicated *dress* rather than *best*. When identifying the individual sounds in words, AAE speakers were more likely to indicate that *nest* contained three sounds (/n, ɛ, s/), while MAE speakers indicated four (/n, ɛ, s, t/). The AAE and MAE groups performed similarly on phonological awareness when the stimuli did not contain phonological structures that were infrequent in MAE (Shollenbarger et al., 2017), suggesting that stimuli must reflect the phonological features of the child's dialect. On phonological memory tasks, AAE-speaking children's performance on nonword repetition may reflect *dialect density*, or the extent of using features of AAE in spoken language (Moyle et al., 2014; see also McDonald & Oetting, 2019).

## Phonological Memory

The SRT developed by Shriberg et al. (2009) may be a useful tool for assessing phonological memory in multilingual children. This assessment includes sounds that are present in many languages, making it an appropriate measure for a wide range of first languages (see McLeod et al., 2017). A systematic review conducted by Ortiz (2021) found that nonword repetition tests can be successfully used as an assessment tool for multilingual children. Thus, these assessments may support a clinician in identifying difficulties related to phonological memory or encoding among multilingual children.

## Phonological Awareness

When assessing phonological awareness in a multilingual child, as when assessing a monolingual child, clinicians should use word stimuli that are familiar to the child. Depending on the child's experience in English, these stimuli may be words from the child's first language. To target more specific areas of strength and weakness within phonological awareness and to track progress over time in response to intervention, clinicians may create a criterion-referenced assessment using words the child knows from their first language. Clinicians can work with the child and/or their caregiver(s) to generate this list of words, potentially using resources like the MacArthur–Bates Communicative Development Inventory (Fenson et al., 1993). Word lists in multiple languages are available at Wordbank (Frank et al., 2017; tool can be accessed at Frank et al., n.d.). Clinicians working with Spanish-speaking children can refer to Gorman and Gillam (2003), who provide specific guidelines for assessing phonological awareness among this population.

When planning intervention for phonological awareness, clinicians should consider incorporating target words from all of a child's languages (Stewart, 2004). One way to do this would be to record an interpreter producing target words in the child's first language(s) and to pair these audio recordings with appropriate images. For example, clinicians could choose words based on their phonological characteristics. If the clinician wanted to target sound blending or segmentation, then the clinician might begin with words in the target language with very few phonemes. Once the clinician identifies appropriate words, then the clinician could insert an image that represents each word on PowerPoint slides. PowerPoint has an audio recording feature (Insert > Audio > Record audio), which the clinician could use to record the interpreter saying each word, as well as saying the separate sounds in the word (e.g., p…e…z for *pez*). The clinician would then have a list of words with images that they could use to target phonological awareness skills. If working on blending, the clinician could play the recording with the individual sounds first, then allow the child to attempt to blend the sounds into a word. After the child's response, the clinician could play the full word. On the other hand, if the child is working on segmenting, then the clinician could play the full word first and give the child an opportunity to segment the word into its individual sounds. The clinician could then play the recording with the individual sounds to provide a model of the target response. These same images and recordings could be used for first-sound matching, first-sound identification, syllabification, and rhyming. Clinicians could use the format of the PowerPoints from J. L. Preston (n.d.) for example structures.

## Phonological Retrieval

When assessing RAN, there are a few considerations for multilingual children that must be taken into account. First, some children may be more familiar with a writing system that does not use an alphabet or that uses a different alphabet than English does. If this is the case, then the clinician should consider using colors or shapes to assess

RAN, supplementing with English letters to identify how familiarity with the English alphabet might affect future reading skills in English-speaking schools. Second, if the child is already familiar with the English alphabet, whether because their first language uses the same alphabet or because they have been taught the English alphabet, then the child should say the letter names in the language in which they are most comfortable. For some multilingual children, this may be English due to learning letter names at school. Therefore, the first step of the RAN assessment should involve an untimed task where the child is asked to name all the letters (or colors, or shapes). During this task, clinicians should note how each letter is named by the child and whether any letters could be confused due to the child's specific speech patterns. If so, then those letters could be omitted from the timed assessment to facilitate accurate scoring.

Overall, modifying phonological processing assessment tasks for multilingual children with SSD involves similar procedures to modifying these tasks for monolingual children, though the clinician needs to take additional factors into account. By making these modifications, clinicians could improve their ability to interpret the results of these tests without having to decide whether the child's spoken responses represent phonological transfer from the child's primary language, SSD, or difficulties with phonological processing skills.

## Case Study

Allison is a 6-year, 4-month-old girl with an SSD affecting intelligibility and participation in home and school contexts. She is a monolingual speaker of MAE. Her mother reports no history of hearing difficulties, but there is a family history of SSD and suspected dyslexia that was not formally diagnosed.

### Speech Sound Abilities

The SLP conducted a standardized single-word speech sound assessment and identified the following patterns of errors:

- Most fricatives produced as /h/ (e.g., *shoe* as /hu/, *finger* as /hɪŋgɚ/)
- Backing of alveolar stops in word-final position (e.g., *plate* as /pleɪk/)
- Consonant cluster reduction (e.g., *spider* as /paɪdɚ/)
- Gliding of liquids (e.g., *ring* as /wɪŋ/, *lion* as /waɪən/)

In addition to the error patterns above, Allison also produced a number of errors with only one or two occurrences. Because Allison was a monolingual speaker of MAE, matching the standardization sample of the standardized speech test, a standard score was calculated. Her standard score on the single-word speech sound assessment was below 40. The clinician noted that fricatives produced as /h/ and backing of alveolars are both atypical speech sound errors for English-speaking children; atypical errors are a potential indicator of underlying phonological awareness difficulties (J. Preston & Edwards, 2010).

The clinician then used the Diagnostic Evaluation of Articulation and Phonology inconsistency subtest (Dodd et al., 2002) and found that Allison produced 60% of the target words inconsistently. The clinician used an oral mechanism examination and the Dynamic Evaluation of Motor Speech Skill (Strand & McCauley, 2019) to rule out motor speech difficulties, and based on the results of the inconsistency subtest, Allison was diagnosed with inconsistent phonological disorder.

### Language Abilities

After completing speech sound testing, the clinician conducted language testing, since speech and language disorders frequently co-occur (Shriberg et al., 1999). On the Structured Photographic Expressive Language Test–Third Edition, which tests morphosyntax, Allison obtained a standard score of 76. However, given Allison's difficulties with fricatives, word-final stops, and consonant clusters, the clinician was not confident on the scoring of specific items requiring word-final morphemes, such as possessive *'s*, third-person *–s*, and past tense *–ed*. The clinician thought that perhaps Allison's speech errors may have negatively impacted her score.

On a standardized receptive vocabulary assessment, Allison obtained a standard score of 80. The clinician knew that vocabulary is closely related to phonological awareness (Walley et al., 2003) and also to oral language abilities, which both are related to later reading success.

Because Allison exhibited many potential indicators of phonological processing or later reading difficulties (atypical speech sound errors, variable speech sound errors, possible language difficulties, small receptive vocabulary size), the SLP completed phonological processing assessments the next session. The SLP needed to prepare the testing materials to ensure that speech errors would not affect performance on these assessments, as they had for the language test.

### Phonological Awareness

The SLP assessed phonological awareness using a receptive task, given the child's extensive speech sound production errors that could impact scoring. The SLP used the phonological awareness assessment probes from Gillon (2005). While Allison did well on the rhyme detection subtest, she performed below chance level on the phoneme-matching subtest. Based on the information in Schuele and Boudreau (2008), rhyming and alliteration (which requires phoneme matching skills) are often acquired by the middle of the kindergarten year, while segmenting and blending are typically acquired by the end of kindergarten or beginning of first grade. Allison was at the beginning of first grade. Based on this information, the SLP concluded that Allison was likely delayed in phonological awareness. The SLP decided to probe blending and segmentation (the phonological awareness skills most closely related to reading success) by using the probes from J. L. Preston (n.d.). Allison performed below chance on those tasks as well, despite being at the age where these skills should be emerging. The overall evidence indicated that Allison had delayed phonological awareness skills.

### Phonological Memory

Next, the SLP assessed phonological memory using the SRT (Shriberg & Lohmeier, 2008). The SLP confirmed that Allison was able to produce all of the target consonant phonemes (/b/, /d/, /m/, /n/) in syllable-initial position by reviewing her single-word speech assessment. The SLP downloaded the PowerPoint presentation from Shriberg (n.d.), played the sounds in the PowerPoint presentation, and transcribed how Allison repeated the word. The SLP calculated the competence score as the percentage of consonants correct at each syllable length. At two syllables, competence was 93.75%. At three syllables, competence was 61.1%. At four syllables, competence was 56.25%. The SLP noted a decrease in performance from two to three syllables, which she confirmed by calculating the memory score (3:2 syllables), 57.2. Allison's encoding score was 62. The SLP noted the low encoding score and made a plan to assess Allison's speech perception for misarticulated sounds in a future session (see Brosseau-Lapré & Roepke, 2022). Allison's transcoding score was 88. Since scores below 80 on transcoding are often associated with childhood apraxia of speech (Shriberg et al., 2012), this transcoding score supported the SLP's findings that Allison did not have childhood apraxia of speech. Overall, Allison's performance on the SRT indicated difficulties affecting phonological memory.

### Phonological Retrieval

Finally, the SLP assessed phonological retrieval using an RAN task. After reviewing Allison's speech errors, the SLP selected the letters *B*, *M*, *N*, *O*, *T*, and *Y* to include. The clinician first asked Allison to name the letters to check that Allison already knew these letter names. Allison was able to name all of the letters correctly. The SLP then created the following RAN field:

B M N O T Y

N B Y T M O

T O M Y N B

M Y B N O T

O B M Y N T

Y T B O M N

Allison made only one naming error on the RAN task, which she self-corrected. Allison completed the task of 30 items in 52 s. The clinician did not note any significant inter-item pauses that would indicate difficulty retrieving the name of the letter. Based on this assessment, the clinician concluded that Allison's phonological retrieval skills were developing as expected.

### Intervention Goals

Allison presented with several factors indicating higher risk of later reading difficulties. These included atypical speech sound errors, small vocabulary size, phonemic awareness difficulties, and phonological memory difficulties. In addition, Allison may have DLD, though further testing is required to verify the diagnosis. Therefore, the SLP decided to include goals related to preliteracy skills in Allison's intervention plan.

The SLP considered the following facts while developing Allison's intervention goals.

1. Phonemic awareness can be taught (Schuele & Boudreau, 2008).
2. Phonemic awareness intervention can facilitate reading acquisition (Gillon et al., 2019).
3. Phonological awareness is related to vocabulary knowledge (Walley et al., 2003).
4. Phonological memory improves following phonological awareness intervention (van Kleeck et al., 2006).

The SLP decided to incorporate phonological awareness intervention into speech sound production tasks (Brosseau-Lapré & Roepke, 2022). The SLP used the phonological awareness intervention from Gillon (n.d.-b). The clinician also incorporated vocabulary and oral language skills into intervention sessions by collaborating with Allison's teacher to identify thematic vocabulary targets.

The SLP worked on Allison's inconsistent word productions using the Core Vocabulary approach (Dodd et al., 2006). As an element of the Core Vocabulary

**Table 4.** Summary of recommended assessment tasks and intervention approaches.

| Phonological processing area | Assessment task | Intervention |
|---|---|---|
| Phonological awareness | Receptive awareness tasks:<br>• Rapid Online Assessment of Reading (n.d.)<br>• Access to Literacy (ATLAS-PA, n.d.)<br>• Appendix in the study of Bird et al. (1995)<br>• PowerPoint files (Preston, n.d.)<br>• Silent Deletion of Phonemes (Appendix A in the study of Claessen et al., 2010)<br>• Phonological awareness probes (Gillon, n.d.-b)<br>• Dynamic assessment (Appendix A in the study of Gillam et al., 2011)<br>• Sound matching subtest of Comprehensive Test of Phonological Processing–Second Edition | Integrated phonological awareness (Gillon, n.d.-b) |
| Phonological memory | Syllable Repetition Task (Shriberg, n.d.) | Integrated phonological awareness (Gillon, n.d.-b) |
| Phonological retrieval | Rapid automatized naming with modified targets | Low speed: holistic reading intervention<br>Low accuracy: letter naming |

approach, the clinician and Allison worked together to segment words into single sounds and blend them into a word after segmenting. Allison's family participated by practicing her Core Vocabulary words at home each day.

The SLP monitored Allison's progress throughout intervention by using probes for both speech sound production and the phonemic awareness skills of blending and segmenting. Five probe words for each target were administered at the end of each session, and these words were not targeted during intervention sessions.

## Conclusions

Children with SSD are at increased risk for reading difficulties if they have phonological processing difficulties (Tambyraja et al., 2023). Therefore, clinicians should consider assessing phonological processing skills in children with SSD, no matter which subtype of SSD the child presents with. Accurate assessment considers the individual's specific speech production profile when selecting assessment instruments. Nonword repetition, phonological awareness, and RAN tasks can all be modified to be more appropriate for children with SSD. The SRT (Shriberg et al., 2009) is a measure of phonological memory that is appropriate for children with SSD because it includes only early-developing syllable structures and speech sounds. There are multiple options for phonological awareness assessments using receptive tasks where a child's speech production errors will not impact the scoring. Finally, stimuli for RAN can be selected to avoid letter names with sounds that a child cannot produce correctly. Clinicians can also select and/or modify phonological processing tasks when working with multilingual children to maximize the likelihood that results reflect a child's processing abilities rather than the extent to which they speak MAE. A complete assessment of the child's phonological processing skills is the first step in developing individualized intervention targets to address both speech output and input processes.

### *Limitations*

The purpose of this tutorial was to provide practical recommendations for clinicians to assess phonological processing skills in children with SSD. Therefore, much of the theoretical background for the relationship between these skills, SSD, and reading was not discussed in detail. Clinicians interested in learning more about how phonological processing is related to reading are referred to articles such as Schuele and Boudreau (2008), Sutherland and Gillon (2007), Hogan et al. (2005), Gillon (2005), Farquharson (2019), and Coady and Evans (2008).

In addition, reading ability is multifactorial and cannot be fully explained by phonological processing skills. Other risk and protective factors (see Pennington, 2006), such as vocabulary size and language ability, were not covered in this tutorial, but they should be considered as part of the child's profile. Furthermore, there is no single test or single cutoff score that can accurately identify which children are at risk for later reading difficulties. Therefore, many of the suggestions in this tutorial must be used to develop a profile of strengths and weaknesses for a child, rather than a diagnosis of phonological processing deficits. While the absence of norms for these tasks may make interpretation more difficult, it also allows clinicians to evaluate the weight of the evidence for the child. If a child presents with atypical speech sound errors (see Brosseau-Lapré & Roepke, 2019; J. Preston & Edwards, 2010), difficulty with nonword repetition, difficulty with phonological awareness, and a limited vocabulary size, then that child has a high risk of reading difficulties and would likely benefit from more intensive intervention.

### Clinical Implications

SLPs can use this tutorial as a guide to identify and/or modify phonological processing assessment tasks when working with children with SSD. Table 4 contains a summary of recommended assessment and treatment approaches within each area of phonological processing. Many of the tasks are freely available for clinical use and can be quickly administered, making these tasks appropriate for school-based clinicians with time restrictions. Clinicians should consider conducting phonological processing skill assessments as part of their assessment battery when working with children with SSD. The results of these assessments could inform intervention approaches to maximize a child's preliteracy skills. For example, children with SSD who are identified as having phonological awareness difficulties may benefit from integrated phonological awareness intervention to target both speech production and phonological processing. The intervention guide and materials for this approach are freely available from Gillon (n.d.-b) and are evidence based for children with multiple subtypes of SSD (Gillon, 2005; McNeill et al., 2009). Since early identification and intervention for phonological processing is associated with improvements in reading ability (Gillon et al., 2019), clinicians may consider integrating phonological awareness into their speech production interventions to strengthen children's knowledge of the sounds of their language and set them up for later reading success.

## Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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