AN INVESTIGATION INTO THE PHONOLOGICAL AWARENESS SKILLS IN CHILDREN WITH AUTISM SPECTRUM DISORDER (ASD)

by

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Abstract

Phonological awareness is the reflection on or manipulation of speech sounds within words. Many studies have shown phonological awareness (PA) to be highly correlated with literacy skills, with children with language impairments often being delayed in acquisition of both. However, no research has been conducted to date describing the nature of PA skills for children with Autism Spectrum Disorder (ASD). Thus, the present study was designed to evaluate the phonological awareness skills of 11 children with ASD, ranging in age from 5 to 9 years. Five phonological awareness tasks targeting syllable, rime, and phoneme levels were administered, along with a pre-literacy (letter-sound identification) task. Four children scored above chance on all PA tasks, three were successful on two tasks, and four children did not complete any of the tasks. Four children achieved some success in subsequent teaching trials. Correlational analyses revealed significant relationships between performance on PA measures and language comprehension scores, percent consonant match (i.e., phonological production), and pre-literacy skills. According to a regression analysis, language comprehension scores and phonological production contributed most to the variance in performance on PA tasks. Children with ASD are thus similar to children with language impairment of other origins with respect to the interaction of language, phonology, and phonological awareness skills. Implications for future research and clinical intervention are discussed.
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Introduction

Although some studies have measured the remediation of phonological awareness (PA) skills in children diagnosed with Autism Spectrum Disorder (ASD) (Heimann, Nelson, Tjus, & Gillberg, 1995; Tjus, Heimann, & Nelson, 1998), no studies have focused specifically on the nature of PA ability in this clinical population. The objective of the current study was to characterize the phonological awareness skills of a small group of children with ASD in order to begin to address this gap in the literature.

Autism Spectrum Disorder

Autism is a neurodevelopmental disorder, characterized by qualitative impairments in social interaction and communication, and presence of restricted, repetitive, or stereotyped patterns of behaviour, interests, and activities (American Psychiatric Association, 2000). Because autism is behaviorally defined and ranges in severity and variability, the term “Autism Spectrum Disorder” or ASD is commonly used.

Language skills in children with ASD. Even though a deficit in communication is one of the main diagnostic features of ASD, there is a wide range of performance within this domain. Much of the research has focused on the social communication deficits in children with ASD. For example, individuals with autism may exhibit deficits in eye gaze and joint attention (for a review, see Bruinsma, Koegel, & Koegel, 2004), topic initiation (Tager-Flusberg, 1981a), topic maintenance (Hinerman & Channell, 1986), adjusting language based on context and listener needs (Baltaxe, 1977), and turn taking within a conversation (Loveland, Landry, Hughes, Hall, & McEvoy, 1988). Other difficulties in social discourse are exemplified through echolalia, perseveration, pronoun reversal, or off-topic speech (Rapin & Dunn, 2003).
Morphosyntactic deficits are variable across children with ASD. In an early study, Bartak, Rutter, and Cox (1977) found that children with autism were comparable to children with developmental language delay on measures of mean length of utterance (MLU) and grammatical complexity. In Kjelgaard and Tager-Flusberg’s (2001) study, it was found that some children with Autism Spectrum Disorder (ages 4 to 14 years) had essentially normal vocabulary and language skills, while others performed significantly below age expectations on a comprehensive battery of standardized tests. Considerable heterogeneity in syntactic development in children with ASD has also been noted in other studies (e.g., Roberts, Rice, & Tager-Flusberg, 2000).

Language comprehension can be particularly affected in children with ASD. Bartak, Rutter, and Cox (1977) found language comprehension in children with autism to be more severely compromised than that of children with specific impairments in language comprehension. Similarly, in Tager-Flusberg’s (1981b) study, children with autism had more severe sentence comprehension deficits than a matched control group of typically developing children. In a later large-scale study, Allen and Rapin (1992) found that none of their 229 subjects with ASD had normal comprehension skills, while 35% of a group of 262 children with developmental language disorders had comprehension skills within normal limits. Charman, Drew, Baird, and Baird (2003) found that 16 of 18 preschool children with ASD fell below the basal level (i.e., 12-month equivalent) on the comprehension scale of the Reynell Developmental Language Scales (Reynell, 1985). It has been suggested that language comprehension may appear more limited in children with ASD than would be expected based on their vocabulary production (Kjelgaard & Tager-Flusberg, 2001; Lord & Paul, 1997). However, impairments in language comprehension may be secondary to interacting social and/or cognitive factors also
manifested in Autism Spectrum Disorder (Lord, 1989; Tager-Flusberg, 1981b), or to lack of
effectiveness in the testing situation.

**Phonological skills in children with ASD.** Findings have differed regarding phonological
development of children with ASD. Some studies have suggested that phonological development
remains relatively intact. For example, from a review of the literature, Tager-Flusberg (1981a)
established that children with autism did not differ from children matched for cognitive delay in
terms of phonology, prosody, or syntax. In Kjelgaard and Tager-Flusberg (2001), scores on the
Goldman-Fristoe Test of Articulation (GFTA, Goldman & Fristoe, 1986) were in the normal
range for 72 children grouped into three categories based on language skills: impaired (n = 50),
borderline (n = 10), or normal (n = 12). However, the lowest-functioning group did show
significantly lower scores than the other two groups.

Other research reveals that some children with ASD do have phonological impairments.
In a sample of 229 children with ASD and 262 children with developmental language disorders,
Allen and Rapin (1992) found evidence for mixed phonology/syntax impairments in 63% of
children with ASD and 50% of the children with developmental language disorders. Wolk and
Edwards (1993) noted unusual sound substitutions (e.g., extensive glottal replacement and
segment coalescence) in one eight year-old boy with autism. Gibbon, McCann, Peppé, O'Hare,
and Rutherford (2004) found that 6 out of 30 children with high-functioning autism (aged 6 to 13
years) had articulation disorders that ranged from mild to severe, measured as standard scores
less than 85 on the GFTA-2 (Goldman & Fristoe, 2000). Children in their study also produced
more “atypical” substitutions than children in the normal articulation group. Information was not
provided regarding the exact nature of these substitutions, except for “phonetic realizations not
seen in normal development after 2;6 years of age” (p. 2).
Although some research has investigated the phonological development of children with ASD, as attested by the above studies, no research to date has examined the nature of phonological awareness skills in this population.

**Phonological Awareness**

Phonological awareness (PA) is the reflection on or manipulation of speech sounds and other phonological units (e.g., words, syllables, and sub-syllabic units such as onset and rime). Phonological awareness tasks require the child to adopt a metalinguistic perspective, that is, to treat language as an object of conscious reflection (Tunmer, 1991). Tests of phonological awareness vary in how much implicit and explicit knowledge they require (Cataldo & Ellis, 1988). A variety of tasks have been designed to assess phonological awareness, ranging from syllable, onset-rime, and phoneme judgments (e.g., Treiman & Zukowski, 1991) to rime and onset matching (e.g., Bird, Bishop, & Freeman, 1995) to syllable and phoneme segmentation (e.g., Catts, Fey, Zhang, & Tomblin, 2001). Verbal responses are often required, although some tasks allow pointing or other nonverbal responses.

A large amount of research has been conducted into the development of phonological awareness skills in typically developing children. Preschool, kindergarten, and Grade 1 children typically show the ability to segment speech at the word or syllable level earlier than at the phoneme level (e.g., Liberman, Shankweiler, Fischer, & Carter, 1974). Treiman and Zukowski (1991) revealed a developmental progression from syllable awareness, to onset-rime awareness, to awareness of single phonemes among children in preschool, kindergarten, and Grade 1, respectively.

**Phonological awareness and phonological skills.** PA skills have been found in some studies to correlate significantly with phonological production. In Bird et al.'s (1995) study, 31
children with phonological impairment scored lower on rime and onset matching, onset segmentation, and reading than a control group matched for age and nonverbal skills. Using similar tasks, Rvachew, Ohberg, Grawburg, and Heyding (2003) found that 13 children with moderate to severe delays in phonological production, but average language comprehension scores, scored lower on PA tasks than 13 typically developing children matched for chronological age (mean age of 4;7). There is not a one-to-one correspondence between phonological production and awareness skills, however. Some children in a study by Major and Bernhardt (1998) had severe phonological production delays but age-appropriate PA skills, whereas others had relatively mild phonological production impairments and minimal PA skills.

**Phonological awareness and language ability.** Language skills may also be correlated with phonological awareness skills. In a study by Kamhi, Lee, and Nelson (1985), children with delays of one year in language production and comprehension did not perform as well as typically developing children matched for mental and language age on sentence and word division PA tasks, showing particular difficulty dividing words into phonemes. Similarly, Warrick and Rubin (1992) found that 13 children with language delay, as measured on standardized tests of comprehension and production, performed significantly below 15 typically developing children on various tasks of phonological awareness (e.g., rhyming, phoneme segmentation, and initial phoneme isolation).

In summary, those children with phonological production impairments (e.g., Bird et al., 1995; Webster & Plante, 1992; Webster, Plante, & Couvillion, 1997) and language impairments (e.g., Catts, 1993; Warrick & Rubin, 1992) appear to be at increased risk for delays in acquisition of phonological awareness.
PA and links to literacy. Many studies have shown phonological awareness skills to be highly correlated with literacy development (Catts, 1993; Larrivee & Catts, 1999; Liberman & Liberman, 1990; Muter & Snowling, 1998). From the Report of the National Reading Panel (2000), "phonological awareness and letter knowledge are the two best school-entry predictors of how well children will learn to read during the first two years of instruction" (p. 1). Catts, Fey, Zhang, and Tomblin (1999) found that Grade 2 children with limited reading skills were four to five times more likely to have had delays in phonological awareness in kindergarten than grade-matched children with good reading skills. These authors also found that the group with limited reading skills in Grade 2 had lower scores on vocabulary, grammar, and narrative tasks in kindergarten, suggesting that early language factors, in addition to PA, may predict later reading scores (e.g., O'Connor & Jenkins, 1999).

Phonological Awareness in Children with ASD

Because many children with speech and language impairments have delays in PA development, children with ASD and communication deficits might also be expected to show delays in PA development. To date, however, no research has explored the nature of phonological awareness skills in children with ASD. A few studies have investigated PA as an outcomes measure after specific treatment strategies, suggesting that some children with ASD do show deficits in phonological awareness. In Heimann et al.'s (1995) study, 11 children with autism, 9 children with cognitive impairment, and 10 typically developing children showed an increase in vocabulary skills and word reading after participating in an interactive computer program aimed at teaching basic reading and writing vocabulary. Phonological awareness scores also improved, as measured by a Swedish standardized test that assesses phoneme segmentation, synthesis, and deletion (Tornéus, Taube, & Lundberg, 1984). In a related study, Tjus et al. (1998)
reported that 13 children with autism (aged from 4 to 11 years) showed gains in word and sentence reading and phonological awareness skills (e.g., phoneme synthesis and segmentation) after participating in a multimedia computer intervention. They also noted that children with the highest language comprehension levels showed the most improvement in phonological awareness during training and follow-up periods.

Research Question

The studies of Heimann et al. (1995) and Tjus et al. (1998) suggest that some children with Autism Spectrum Disorder can benefit from intervention for phonological awareness skills. However, no studies to date have characterized otherwise the phonological awareness development in children with autism, or the potential interaction of development in phonological awareness with other language development variables. The current study therefore set out to document phonological awareness skills in a group of verbal children with ASD with a range of language abilities, investigating potential relationships between PA skills, general language performance, phonological production and pre-literacy skills. It was hypothesized that children with ASD and communication deficits would have difficulty with phonological awareness tasks because communication impairments have been linked to delays to phonological awareness development. Based on the literature, it was further hypothesized that age, phonological production abilities, and language comprehension would be significantly correlated with performance on the PA tasks, with language ability perhaps contributing the greatest variance (Catts et al., 1993; Warrick & Rubin, 1992).
Method

Participants

Eleven children with ASD participated in the study. Selection criteria were (1) use of at least single-word utterances, (2) English as the dominant language, (3) no physical impairments, and (4) normal hearing. Children were between the ages of 5;0 and 9;0 years (M = 6.81, SD = 1.43) and included four girls and seven boys. Level of mother’s education ranged from 12 to 18 years of formal schooling (M = 16.18, SD = 2.60).

All children had diagnoses on the Autism Spectrum, as indicated by pediatrician and/or psychologist reports obtained via parent permission (see Table 1). Diagnoses were made based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, American Psychiatric Association, 2000), the Childhood Autism Rating Scale (CARS, Schopler, Reichler, & Renner, 1988), the Autism Diagnostic Interview-Revised (ADI-R, Rutter, Le Couteur, & Lord, 2003), or a combination of these measures. Some parents did not provide clinical reports and in these cases, parental reports of severity were utilized.

For five children, English was the only language in the home. In addition to English, three children spoke Cantonese; two spoke Mandarin; and one spoke Spanish. Of these six children, five were considered to be bilingual, based on parental report. All children were receiving therapy from either a school-based or private SLP for speech, language, and social skill intervention throughout the data collection, although phonological awareness was not a focus of intervention with any of the children. Seven children were enrolled in an Early Intensive Behavioral Intervention (EIBI) program with varying hours of intervention per week, and
individualized program goals. Parents reported that their children had normal hearing as assessed through formal audiological testing. (See Table 1 for details.)

**General Procedures**

Data collection occurred in three, one-hour sessions with each child over a series of three or four weeks. Parent(s) and/or the child's behavioural interventionist were also present during testing sessions, which aided the experimenter in learning the individualized needs, behavioural characteristics, and personalities of each of the children. A visual schedule constructed from Boardmaker® picture icons (Mayer-Johnson Co., 1994) was used during testing sessions to show the children the order of tasks and play breaks. Children were encouraged to assist the experimenter in organizing the visual schedule at the beginning of each session. A number of strategies were employed to maintain attention and motivation during the testing. Using the PowerPoint® animation feature, cartoon characters (shareware) were randomly displayed between test trials. Verbal reinforcement and encouragement were also given. For three children, edible reinforcers were utilized in order to maintain focus and compliance, because these children presented with attention and behavioural issues during testing. At the end of each session, children were given small toys for participating in the study (e.g., stickers, books, puzzles, bubbles, or coloring books).

All sessions were videotaped with a Canon Digital Video Camcorder ZR100 for later transcription and analysis. Phonological samples were also audiotaped with a Sony Recording Mini-Disc Walkman MZ-R900 with an external microphone.
Phonological awareness tasks. Similar to studies by Puolakanaho, Poikkeus, Ahonen, Tolvanen and Lyytinen (2003), Rvachew, Nowak, and Cloutier (2004), and Sutherland and Gillon (2005), PA tasks were presented by computer. Stimuli were prepared using Mayer-Johnson Boardmaker® pictures (Version 1.6 for Windows, 1994) and Microsoft PowerPoint® (2000 Edition), and displayed on a Toshiba Portable PC (Version 1.30, 2003). Table 2 displays the specific tasks (explained further below) administered within each testing session.

For all phonological awareness tasks, two training trials with corrective feedback were administered, followed by 10 test trials. If the child had three consecutive incorrect responses during a test trial, a second, 10-item training trial was subsequently administered. The objective of the second training trial was to teach the child the PA task, beginning with a high level of cueing support, and gradually fading the cues. (See Appendix A for specific levels of cueing and stimuli.) Cues consisted of verbal descriptions and visual supports in the form of highlighted text (size and colour) demonstrating the phonological awareness concept (e.g., pig and dig for the Rhyme Matching I task) and Boardmaker® picture icons (Mayer-Johnson Co., 1994) depicting a happy face with two ears for “sounds the same” and a red X for “doesn’t sound the same.” If the child had five consecutive incorrect answers on one of these training trials, the trial was abandoned. If the child was responding correctly on a secondary training trial (i.e., 5 or more consecutive right responses), the original test trial was re-administered, to determine whether the child could generalize knowledge from the more extensive training trial to the test trial.

The types of phonological awareness tasks designed and adapted for the current study have been used extensively in previous research with children with phonological production impairments (e.g., Bird et al., 1995; Rvachew et al., 2003), language impairments (e.g., Warrick & Rubin, 1992), and dyslexia (e.g., Swan & Goswami, 1997). The order and difficulty of the PA
tasks followed the developmental sequence in phonological awareness observed by Treiman and Zukowski (1991), i.e., syllable to onset-rime to phoneme awareness. Because nonverbal responses can enhance task completion in children who may not be familiar with test-like situations, who are shy or reluctant to speak (Gillon, 2004), or who have speech production difficulties (e.g., Rvachew et al., 2003), all of the phonological awareness tasks required only nonverbal responses from the children, such as pointing on the computer screen or selecting with the mouse.

Prior to data collection, the PA tasks were piloted with a typically developing child, aged 5;7, who performed at ceiling levels on all tasks. As a result of this pilot session, changes were made to the layout and design of the picture stimuli on the computer screen and instructions were simplified. A description of the individual PA tasks follows (see Appendix A for stimuli).

**Rhyme matching I (rime level).** The rhyme matching task was adapted from Vandervelden and Siegel’s (1999) Rhyme Judgment production task. The child was asked to select, from two pictures arranged side by side, the one that rhymed with a target picture situated above. For example, the child was asked, “Here are some pictures: ring, sun. Which one sounds the same/rhymes with king?” The children responded by either pointing with a finger or clicking the correct picture on the computer screen with the mouse. Wording and length of the instructions varied according to the individual needs of the children. For instance, some children did not understand “rhyme,” but understood “sounds the same” or “sounds different.” This task was chosen as the first task because rhyme matching has been found to be one of the earliest PA skills to develop (Treiman & Zukowski, 1991).

**Word segmentation (syllable level).** A word segmentation task was chosen in accordance with research suggesting that this type of PA task is predictive of reading achievement.
(Torgesen, Wagner, & Rashotte, 1994). Adapted from Catts et al.'s (2001) deletion production task, the word segmentation task required the child to delete a syllable from a compound word and point to the remaining word. For example, the child was shown a picture of a compound word at the top of the screen, plus the two pictures comprising the compound word and a semantically related distracter. Instructions were: “This is a cupcake. Here we have: cup, bowl, cake. If we take cup away from cupcake, which one is left behind/left over?” Again, terminology changed depending on the child. A semantic distracter (in the above example, bowl) was included to ensure that the child understood the task.

**Rhyme identification II (rime level).** The rhyme identification task was modified from the Rhyme Awareness subtest of the Pre-Reading Inventory of Phonological Awareness (PIPA, Dodd, Crosbie, McIntosh, Teitzel, & Ozanne, 2003), which is normed for children aged 5;0 to 6;11. The same words and procedures were used as described in the test manual, but stimuli were displayed on the computer screen. The child was asked to select which of four pictures did not rhyme with the other three. Instructions were: “Here are some pictures: clock, rock, sock, cat. Show me one that does not sound the same/does not rhyme/sounds different.” This task was considered to be more demanding than the previous tasks because of the resources required: the child had to remember four words, and then select the word that was different.

**Word-initial sound identification (phoneme level).** The word-initial sound identification task was modified from the Alliteration Awareness subtest of the PIPA (Dodd et al., 2003) by portraying stimuli on the computer screen. The child was shown four pictures and asked to select the one that did not begin with the same word-initial sound as the other three pictures. For example, “Here are some pictures: fish, feet, fork, boat. Show me the one that does not start with the same sound at the beginning/starts with a different sound at the beginning.” Because this task
and the Rhyme Identification I task are quite similar, they were administered in different testing sessions.

**Word-final sound matching (phoneme level).** The word-final sound matching task was modified from the Sound Matching-Last Sound subtest of the Comprehensive Test of Phonological Processing (CTOPP, Wagner, Torgeson, & Rashotte, 1999), a subtest normed for children aged 5;0 to 7;5. Using most of the same stimuli but with computer presentation and adapted instructions, the child was asked to select from three pictures, the one that ended with the same sound as a target word. For example, “Here is a *dog*. *Dog* ends in the /g/ sound. Here we have: *doll, pot, pig*. Show me the one that ends in the /g/ sound like *dog.*” This task was considered the most difficult phonological awareness task, because judgments about word-final phonemes have been found to be more difficult than judgments about word-initial phonemes (Treiman & Zukowski, 1991).

**Sound-Letter Correspondence: A Preliteracy Measure**

A sound-letter identification task was administered, adapted from the Letter-Sound Knowledge subtest of the PIPA (Dodd et al., 2003). Children were shown an array of six lowercase letters on the computer screen and were asked to identify the letter that corresponded to a particular sound. For example, the children were told, “Here are some letters. Show me the letter that makes the /m/ sound.” Given the vast amount of literature on the relationship between PA and pre-literacy skills (e.g., Catts et al., 1999; Muter & Snowling, 1998), this task was intended as a preliminary measure of the children’s literacy level, to determine if there were any relationships between performance on the previous five phonological awareness tasks and pre-literacy skills. Parents also completed a literacy questionnaire consisting of 12 questions
concerning the child's level and participation in reading and phonological awareness activities (Appendix B).

**Language Measures**

**Phonology.** The Phonemic Profile of the Computerized Articulation and Phonology Evaluation System (CAPES, Masterson & Bernhardt, 2001) was administered. For this task, children were presented with a series of 46 coloured pictures on a computer screen, which include a wide range of consonants in word-initial, medial, and final positions. Children were encouraged to say the words spontaneously; however, if a child did not respond, the experimenter provided a model for imitation. As noted above, this test was both videotaped and audiotaped to ensure adequate sound quality for phonetic transcription.

**Language comprehension.** The Sentence Structure subtest from the Clinical Evaluation of Language Fundamentals® - Preschool (CELF-P, Wiig, Secord, & Semel, 1992) or the Clinical Evaluation of Language Fundamentals® 4th Edition (CELF 4, Semel, Wiig, & Secord, 2003) was administered, depending on the child's age. The preschool version is suitable for children aged 3;0 to 6;11, and the CELF 4 for individuals aged 6;0 to 21;11. The Sentence Structure subtest evaluates children's ability to interpret spoken sentences of increasing length and complexity and select the picture that illustrates the meaning of the sentence. In accordance with the special testing considerations listed in the test manuals, two of the children (Child #7 and Child #8) received the preschool edition of the CELF because they appeared to be functioning at a 3- to 6-year old level in language development, although they were not in the chronological age range for the CELF-Preschool.

**Language production.** For the first session, the first author visited the child's home with the purpose of familiarizing the child with an unknown adult. Activities were chosen based on
the child's interests, pre-determined upon asking the parent(s). Because all sessions were videotaped, this play session contributed to some of the spontaneous language sample. The collection of the language sample continued in the second and third sessions, utilizing the experimenter's activities (e.g., Magna Doodle®, Perfection®, Play-Doh Fun Factory®, bubbles, an interactive dinosaur magnet book, and various other books). The goal was to obtain 100 spontaneous utterances per child across the three testing sessions. All language samples were later transcribed and entered into the *Systematic Analysis of Language Transcripts* (SALT, Miller, 2003) software program. All but Child #7 (who produced only 48 utterances) produced at least 100 utterances.

**Data Analysis**

**Phonology.** With CAPES (Masterson & Bernhardt, 2001), a phonological match/mismatch comparison to the adult targets (i.e., a relational analysis) was conducted to obtain the following measures: percentage of matching consonants (PCM), percentage of matching vowels (PVM), percentage of word shape match (WSM) in terms of CV sequences, and percentage of stress pattern match (SPM).

The author/experimenter transcribed the CAPES words for each child using the International Phonetic Alphabet (IPA) and narrow transcription after undergoing training by her research supervisor. Interrater reliability was 91.0% for consonants, 87.0% for vowels, and 60.0% for diacritics. The low match in terms of diacritics was due to abnormal voice quality and/or abnormal prosody of some of the children (e.g., devoicing, glottal fry, high and low tones, elongated vowels and consonants). (See Table 3 for a qualitative description of individual voice characteristics.)
**Language comprehension.** Raw scores from the Sentence Structure subtest of the CELF-Preschool (Wiig et al., 1992) and the CELF 4 (Semel et al., 2003) were initially transformed into standard scores and percentiles. However, because most of the children's standard scores were in a very low range and below the 5th percentile, raw scores were used for the statistical analyses.

**Language production.** For the language production data, 10% of the language samples were randomly selected for transcription by a second observer unfamiliar with the objectives of the research project. Morpheme by morpheme reliability was 85.2% (the number of agreements divided by the number of agreements plus disagreements).

Although a variety of measures can be derived from the Systematic Analysis of Language Transcripts (SALT, Miller, 2003), the following were used for the purposes of this study: mean length of utterance (MLU), MLU 2 (explained below), number of different words (NDW), and number of total words (NTW). MLU was chosen because it is a common measure of morphosyntactic development and has been used extensively in research with children with language impairments (e.g., Hewitt, Hammer, Yont, & Tomblin, 2005), and children with autism (Condouris, Meyer, & Tager-Flusberg, 2003; Tager-Flusberg et al., 1990). An alternative MLU measure, MLU 2, was also calculated as suggested by Johnston (2001), whereby answers to questions and yes/no responses are eliminated from the language sample. NDW and NTW were used because it has been suggested that NDW serves as a strong measure of semantic diversity and NTW provides an index of general vocabulary productivity (Miller, Freiberg, Rolland, & Reeves, 1992). NDW has become the preferred measure in child language studies (e.g., Goffman & Leonard, 2000) because it has been found to be a more sensitive estimate of children's lexical diversity than the Type-Token Ratio (TTR) (Watkins, Kelly, Harbers, & Hollis, 1995). NDW requires samples of equivalent length across subjects; thus, calculations were made based on the
first 100 utterances for all participants except Child #7 (who was not included in this analysis, due to lower output).

**Phonological awareness.** Both individual task scores and total scores across all PA tasks were used to evaluate the children's PA skills. A number of correlational analyses were done, using a non-parametric Spearman’s correlation coefficient (*rho*), due to the small sample size and the inability to assume a normal distribution with the children with ASD in this study. All statistical analyses were computed using SPSS for Windows 95, Version 10.0. Correlations were performed between the various language measures, between total phonological awareness scores and various language measures and between individual PA tasks and language measures.

**Results**

**Phonology**

Although the children were encouraged to produce the Phonemic Profile words spontaneously, percentage of the samples imitated ranged from 6.5% to 63.0% (*M* = 30.0%, *SD* = 16.6%). (See Table 3 for individual results). The mean percentage of consonant match (PCM) was 68.8% (*SD* = 19.5%), mean percentage of vowel match (PVM) was 71.5% (*SD* = 17.9%), mean percentage word shape match (WSM) was 73.9% (*SD* = 26.7%), and mean percentage stress pattern match (SPM) was 87.0% (*SD* = 9.3%). Table 3 displays individual data regarding consonant, vowel, word shape, and stress pattern matches.

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Insert Table 3 About Here
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Due to the unforeseen difficulty in achieving reliability for diacritics, an additional analysis was conducted whereby diacritics were omitted and only matches for consonants and vowels were analyzed. For example in the above analysis, if a child produced the word *pig* as
[pʰɪɡ], the devoiced /ɡ/ would be considered a mismatch. However, in the second analysis, the [ɡ] would be considered a match for /ɡ/ because the child did produce the correct phoneme (i.e., broad transcription). With diacritics omitted, PCM ranged from 21.9% to 93.3%, with the mean increasing to 76.2% (SD = 21.3%). Mean values in PVM increased to 83.6% (SD = 9.6%), with a range from 58.8% to 91.2% accuracy. Even with diacritics omitted from this analysis, there were still low values in percentage of matching vowels. This was attributed to the children with abnormal prosody and the five children who spoke Mandarin and Cantonese, which may have affected vowel quality.

Severity of phonological impairment was estimated by comparing the children’s Percent Consonant Match (PCM) on the CAPES single word naming task to Austin and Shriberg’s (1997) lifespan reference data for Percent Consonants Correct in connected speech samples. Three children (#5, #7, #11) had relatively severe phonological impairments (48.6%, 21.0%, 70.5%, respectively); three children (#6, #8, #9) had moderate impairments (60.0%, 79.1%, 73.3%, respectively); three children (#1, #2, #10) had mild impairments (76.2%, 74.2%, 90.5%, respectively); and Child #3 had normal phonological production (PCM of 82.9%). (See Table 3).

Language Comprehension

Mean raw scores for the eight children that received the Sentence Structure subtest from the CELF-Preschool (Wiig, et al., 1992) were 13.6 (SD = 5.7). Scores ranged from 4 to 22, out of a possible 22. For the three children given the CELF 4 (Semel et al., 2003), mean raw scores were calculated at 15.3 (SD = 4.0), and ranged from 11 to 19 out of a possible 26 correct. Based on the percentile range of performance scale, eight children had scores below the 5th percentile. Child #3 performed in the ‘superior’ range (between the 95th and 99th percentile), Child #1
scored in the 'average' range (between the 25\textsuperscript{th} and 74\textsuperscript{th} percentile), and Child #8 scored in the 'borderline average range' (between the 6\textsuperscript{th} and 15\textsuperscript{th} percentile). (See Table 4).

Language Production

For all but Child #7 (who produced 48 utterances), the average number of utterances for 10 children was 104.2 (SD = 2.70, range of 101 to 109). (See Table 4). For all participants, the average Mean Length of Utterance (MLU) in morphemes was 2.80 (SD = 1.03), with a range of 1.31 to 4.66. The alternative measure, MLU 2, was also calculated, in which answers to questions and yes/no responses were omitted (Johnston, 2001). The mean for MLU 2 values was slightly higher (M = 3.05, SD = 1.11, range of 1.37 to 5.06). The small difference between the two MLU measures suggests that the low MLU values were not a consequence of the experimenter's interactional style or question asking.

Excluding Child #7, who produced 48 utterances, Number of Different Words (NDW) in the first 100 utterances ranged from 57 to 128 (M = 100.9, SD = 23.8). For all participants, mean Number of Total Words (NTW) in 100 utterances was 253.6 (SD = 81.5). NTW values ranged from 121 to 411, revealing considerable between-subject variability. (See Table 4).

Phonological Awareness Tasks

At-chance performance on the phonological awareness tasks is a score of 4 or less (p > .05). Four children (# 5, #6, #7, #11) scored below chance levels on one or two of the PA tasks. Children #1 and #8 scored above chance levels on two of the tasks (Rhyme Matching I and Word Segmentation), Child # 4 scored above chance on three of the tasks (Rhyme Matching I, Word Segmentation, and Rhyme Identification II), and four children (#2, #3, #9, #10) scored above
chance on all five tasks. For the remainder of the results and discussion, the four children who had difficulty with the PA tasks will be referred to as the “Low PA” group, the three children who were successful with some of the tasks will be referred to as the “Middle PA” group, and the four children who were able to do all five PA tasks will be referred to as the “High PA” group. Table 5 shows results from the phonological awareness tasks.

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**Individual phonological awareness tasks.** Rhyme Matching I was the only task administered to all participants. Raw scores on the Rhyme Matching I task were highly correlated with all language measures. (See Table 8). Seven children attempted all five phonological awareness tasks. For Child #6 and #7, testing was discontinued after administering the first PA task (Rhyme Matching I), because it was believed the remaining PA tasks would be too difficult, given the children’s lower language comprehension levels. Attention and behavioral issues also interfered with testing for these two children. For Child #5 and Child #11, testing was discontinued after attempting the Rhyme Matching I and Word Segmentation tasks. Based on the children’s responses during testing, it appeared that these four children did not understand what was meant by “rhyme,” even when the instructions were simplified (e.g., “sounds the same”) and visual cues were added with the second set of training trials. As mentioned, children in the Middle PA group either completed two (Rhyme Matching I, Word Segmentation) or three (Rhyme Matching I, Word Segmentation, and Rhyme Identification II) of the PA tasks. See Table 5 for individual PA task results.
Secondary training trials. If the child obtained three incorrect responses in a row during the test trials, the test trials were discontinued and a secondary training trial (maximum 10 tokens) was presented. Secondary training trials were administered to the children in the Low PA and Middle PA groups only, because the four children in the High PA group did not require these trials. Three of the children in the Low PA group scored below chance on the training trials. Child #11 scored 7/10 and 8/10 on the secondary training trials of the Rhyme Matching I and Word Segmentation tasks, respectively. However, when the test trials were re-administered, Child #11 scored below chance on both tasks, revealing that generalization had not occurred.

The three children in the Middle PA group were able to obtain near-perfect scores on the secondary training trials, but only one showed any generalization to the test trials. Child #8 scored 10/10 on Rhyme Identification II, 8/10 on Word-Initial Sound Identification, and 9/10 on Word-Final Sound Matching secondary training trials, but scored below chance levels during re-administration of the test trials. Child #4 scored 8/10 on the Word-Initial Sound Identification secondary training trials, but scored below chance on the re-administration of the test trials. Child #1 scored 10/10 on the secondary training trials of the Word-Initial Sound Identification task, and then scored 8/10 when the test trials were re-administered, revealing some generalization of this particular PA skill. However, with the Rhyme Identification II task, Child #1 scored 10/10 on the secondary training trials, but below chance on re-administration of the test trials.

Observations during the secondary training trials revealed that the introduction of the picture icons helped the children in the Middle PA group learn the teaching stimuli. Some children even used some of their own strategies. For example, Child #1 used his own fingers and made them in the shape of an “X” when two words did not rhyme, and pointed to his own ears
when words rhymed or had the same initial sound. It is important to note that Child #1 and Child #4 used the picture icons more than the text during the secondary training trials, because they were still developing literacy skills, as indicated by parental report during testing.

**Letter-Sound Identification: Pre-Literacy Measure**

All children were able to complete the Letter-Sound Identification task. Out of a possible 10 correct responses, mean scores were calculated at 7.91 ($SD = 2.39$), and ranged from 3 to 10. Table 5 displays the individual results for this pre-literacy task.

From the literacy questionnaires that were returned by the parents (for all but Child #2), parents reported that their child enjoyed reading or looking at books. Parents also commented on their child’s current reading level. For children in the Low PA group, all parents reported a one-year difference in grade and reading level, except for one Grade 3 student reported to be two years behind in reading. For the Middle PA group, both parents of kindergarten children reported their children on par with grade level expectations, while one parent reported her Grade 2 child to be one year behind. There was variability among the children in the High PA group. One parent reported a kindergarten child to be two years ahead in reading ability (this appeared to be confirmed according to experimenter observation). One Grade 3 child was reported to be on par with reading expectations, and another Grade 3 student to be one year behind (this was also the participant reported not to enjoy reading activities).

**Statistical Analyses**

**Correlations between total PA scores and language measures.** Table 6 displays all correlations for total PA scores versus external variables (e.g., age, mother’s level of education, home language), and language measures; only significant results will be discussed in this section.
There was a high correlation between performance on phonological awareness tasks and the phonological measure, Percent Consonant Match: $\rho = 0.83, p = 0.001$. Word Shape Match (WSM) was moderately correlated with performance on PA tasks: $\rho = 0.68, p = 0.021$.

Performance on phonological awareness and language comprehension raw scores were also highly correlated: $\rho = 0.71, p = 0.014$. For production, MLU 2 in morphemes and PA were moderately correlated, but approached significance: $\rho = 0.57, p = 0.067$.

Performance on phonological awareness tasks and the Letter-Sound Identification task revealed a high correlation: $\rho = 0.84, p = 0.001$. There was also a high correlation between reported reading level from the parent literacy questionnaire and performance on PA tasks: $\rho = 0.76, p = 0.01$ ($n = 10$ because data was missing for one child).

To portray the individual variability across participants, one measure of phonological production (PCM), one measure of language production (MLU 2), and language comprehension raw scores are displayed in Table 7 as a function of how the child performed on all five phonological awareness tasks (total PA scores). Raw scores on the Letter-Sound Identification task are also included.

Correlations between individual PA tasks and language measures. Individual correlational analyses were conducted between each of the phonological awareness tasks and all language measures. However, only significant correlations or moderate correlations that approached significance will be discussed in this section. Only three of the five PA tasks
revealed significant correlations: Rime Matching I, Word Segmentation, and Word-Final Sound Matching. For the Rime Matching I task, there were moderate to high correlations among all language measures (e.g., phonology, comprehension, and production) and scores on the Letter-Sound Identification task (see Table 8 for specific results).

For the Word Segmentation task, only two significant correlations arose. Scores on Word Segmentation and language comprehension raw scores were highly correlated: \( \rho = 0.77, p = 0.016 \). Word Segmentation was also highly correlated with scores on the Letter-Sound Identification Task: \( \rho = 0.72, p = 0.030 \). Although approaching significance, performance on the Word Segmentation task and Percentage Consonant Match (PCM) were moderately correlated: \( \rho = 0.66, p = 0.055 \). Note that \( n = 9 \) for this analysis, because Child #6 and Child #7 were not given the Word Segmentation task.

For the Word-Final Sound Matching PA task, age was highly correlated with performance on this task, but not significant: \( \rho = 0.75, p = 0.084 \). Performance on Word-Final Sound Matching and the Letter-Sound Identification was also highly correlated: \( \rho = 0.89, p = 0.017 \). For this analysis, \( n = 6 \) because the Word-Final Sound Matching task was not administered to Children #4, #5, #6, #7, #11.

Correlations among various language measures. An analysis was also conducted among the different language measures to determine any significant relationships (see Table 9). There was a moderate, but insignificant relationship between language comprehension raw scores and MLU 2: \( \rho = 0.57, p = 0.067 \). For language production, there were very high, significant correlations between MLU 2 and Number of Difference Words (NDW): \( \rho = 0.981, p = 0.001 \).
(n = 10 because Child #7 did not have 100 utterances); and MLU 2 and NTW: \( \rho = 0.982, p = 0.001 \) (n = 11). There was also a moderate, significant correlation between Percentage Consonants Match (PCM) and other scores: (a) language comprehension raw scores \( \rho = 0.64, p = 0.034 \), (b) Mean Length of Utterance (MLU): \( \rho = 0.69, p = 0.019 \); (c) MLU 2: \( \rho = 0.71, p = 0.015 \); (d) Number of Total Words (NTW): \( \rho = 0.71, p = 0.015 \); and (e) PCM and Letter-Sound Identification performance: \( \rho = 0.72, p = 0.012 \).

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Regression Analysis

Even though it is a parametric method, a regression analysis was conducted to evaluate the potential relationship of the significantly correlated variables with phonological awareness. It is recommended that the number of participants be 5 or 10 times the number of variables entered into the regression analysis (Norman & Streiner, 1998). Therefore, using the minimum recommendation of five participants, two variables was the maximum that could be entered. The variables entered into the analysis were percentage consonant match (PCM) and raw scores on the language comprehension subtest. In Model 1, language comprehension contributed significantly to the model \( F[1, 9] = 8.31, p = 0.018 \), explaining 48% of the variance \( (r^2 = 0.48) \). However, when language comprehension and Percentage Consonant Match were entered into the model, both variables explained approximately 52% of the variance in PA performance \( (r^2 = 0.524) \), essentially reaching significance \( F[2, 8] = 4.40, p = 0.051 \). MLU 2 was also entered into the regression for descriptive purposes, even though this did exceed the recommended number of variables (Norman & Streiner, 1998). MLU 2 did not contribute any change in variance when it was added to the model. Table 10 displays the regression analysis results.
Discussion

This study endeavored to describe the phonological awareness (PA) skills of 11 children diagnosed with Autism Spectrum Disorder (ASD). Five tasks targeting different levels of linguistic knowledge were designed to measure phonological awareness: one task at the syllable level (Word Segmentation), two tasks at the rime level (Rhyme Matching I and Rhyme Identification II), one task at the initial phoneme level (Word-Initial Sound Identification), and one task at the final phoneme level (Word-Final Sound Matching). In contrast to the original hypothesis, not all children had difficulty with the PA tasks. Four children scored above chance performance on all five PA tasks (i.e., the High PA group), three children were successful with two or three tasks (i.e., the Middle PA group), and four children had difficulty with even the simplest PA task (i.e., the Low PA group).

For the Middle PA group, tasks that children had some success with were rhyme matching and word segmentation. For Child #1 (5.0 years) and Child #4 (5.8 years), this is consistent with the literature on the development of phonological awareness. Typically developing preschool and Kindergarten children develop knowledge of the syllable level and the onset-rime level, respectively, but usually do not develop phoneme awareness until Grade 1 (Treiman & Zukowski, 1991). For the children in the Middle PA group, the introduction of secondary training trials also had some positive effects, especially for Child #1 who showed some generalization with the Word-Initial Sound Identification task. (See further discussion below).
Chronological age was not related to total PA performance (unlike what has been found in other studies), or any on the individual phonological awareness tasks, except the Word-Final Sound Matching task. This particular finding supports the developmental progression of phonological awareness skills as proposed by, e.g., Treiman & Zukowski (1991) for this one task. In general, older children found this task less difficult. It was not too surprising that age did not correlate with performance on phonological awareness tasks for the children in this study. Because no research has been conducted on the PA skills in this population, the PA tasks were designed following previous research with typically developing children (e.g., Treiman & Zukowski, 1991), children with phonological production impairments (e.g., Bird et al., 1995), and children with language impairments (e.g., Warrick & Rubin, 1992). From the results of this study, other factors such as language ability seem to affect performance on PA, more so than age. Because all children were diagnosed with Autism Spectrum Disorder, variability and severity in autistic characteristics may have been a more prominent factor than age, and thereby have affected phonological awareness. (See discussion regarding severity of autism below.)

From the three language measures entered into a regression analysis (percentage consonants match for phonology, language comprehension raw scores, and MLU 2 for language production), language comprehension and phonological production contributed most to the variance in PA performance. Overall, results from this preliminary investigation reveal that some children with ASD have the ability to perform metalinguistic tasks requiring conscious manipulation of phonological information.

Phonological Awareness Tasks and Other Language Performance

Results from this study reveal heterogeneity in phonological production, language comprehension, and language production across the 11 participants. (See also Table 7). This
supports previous findings indicating a large amount of variability in the language skills of children with ASD (e.g., Kjelgaard & Tager-Flusberg, 2001). In spite of the variability, there were certain consistent patterns in the data, which are discussed below.

**Individual phonological awareness tasks and overall findings.** Results from the correlational analyses reveal that raw scores on the Rhyme Matching I task were highly correlated with all language measures. (See Table 8). Rhyme Matching I was designed as the easiest PA task, given the reduced demands on language comprehension and memory this task entailed. This was the only task that could be administered to all participants.

Findings for other tasks could be an artifact of performing statistical analyses with small sample sizes. However, scores on the Word Segmentation task and the Letter-Sound Identification task were highly correlated. This finding suggests that word segmentation may be related to sound-letter correspondence teaching. The remainder of the discussion describes performance on various language and speech tasks and the total score for PA tasks.

**Phonological production and total phonological awareness scores.** Based on Austin and Shriberg’s (1997) lifespan data, children in this study ranged from having severe to mild phonological impairment, with only one child (#4) having normal phonological production for his chronological age. These deficits in phonological production are contrary to the literature suggesting that children with ASD have spared articulation skills (e.g., Tager-Flusberg, 1981a) or a delay in phonological development (e.g., Bartolucci & Pierce, 1977). Nine of the 11 children presented with atypical voice and/or prosodic characteristics, which made phonetic transcription difficult. However, these findings support previous research suggesting that suprasegmental characteristics of speech, such as lexical and syntactic stress, pitch, and intonation may be affected in individuals with ASD (Lord & Paul, 1997; Tager-Flusberg, 2001).
There was a significant, high correlation between performance on phonological awareness tasks and percentage consonants match (PCM), thereby confirming one of the initial hypotheses that children with more severe phonological production impairments may have more difficulty with the PA tasks than children with milder or no phonological impairment. This finding is similar to other studies in the literature in which children with phonological production impairment often show reduced skill on phonological awareness tasks (Bird et al., 1995; Rvachew et al., 2003; Webster & Plante, 1992).

Language comprehension and total phonological awareness scores. From the percentile scores of the Sentence Structure subtest, children's scores ranged from the superior range to a very low level in language comprehension. Due to problems with converting raw scores into meaningful standardized scores, descriptive labels (e.g., severe, moderate, high) were assigned based on raw scores (see Table 7). Regardless, both percentiles and raw scores reveal that children in this study had considerably low comprehension skills compared to typically developing children on whom the CELF-Preschool (Wiig et al., 1992) and the CELF 4 (Semel et al., 2003) were standardized. This finding validates previous studies suggesting some children with ASD have difficulties with language comprehension (e.g., Bartak, Rutter, & Cox, 1977; Tager-Flusberg, 1981b).

The language comprehension scores were surprisingly lower than expected and possibly not representative of the children's actual understanding of language. For example, Child #1 refused to do any test items that contained "boys" or "girls" or the pronouns, "he" or "she," which affected the total raw score. It should also be noted that raw scores from the CELF-Preschool and the CELF 4 were combined together in the analyses. It is possible that the Sentence Structure subtest on the preschool version is simpler to understand than that of the
CELF 4. However, after examining the raw scores and taking the experimenter’s impression of the children into account, the difference in scores for the three children given the CELF 4 was considered to be minor. Limitations of using standardized tests to assess language skills in children with ASD have been noted (e.g., Tager-Flusberg, 2000). Because only one subtest was used to assess language comprehension in this preliminary study, more comprehensive formal and informal testing should be conducted in future studies to obtain a more accurate portrayal of language comprehension in children with ASD.

There was a high, significant relationship between performance on phonological tasks and raw scores from the language comprehension subtest. Based on Catts (1993) and Warrick and Rubin (1992), language comprehension was a possible strong predictor of phonological awareness performance. Thus, this study adds to that body of research, but with a small group of children with ASD now included. The language comprehension findings also confirm one of the initial research hypotheses that children with impairments in language comprehension tended to have more difficulty with the phonological awareness tasks. Findings from this study are also related to Tjus et al.’s (1998) study that found that children with ASD and higher language comprehension levels showed improvement in phonological awareness after a language-based computer intervention. Two studies now reveal a possible link between PA skills and language comprehension in children with ASD.

Language production and total phonological awareness scores. From the language sample analysis, there was a wide range in mean length of utterance (MLU), number of different words (NDW), and number of total words (NTW) across the participants. However, all measures were considerably lower compared to what has been suggested in the literature for typically developing children. For instance, a typically developing 5 year-old should have an MLU of
approximately 5.5 (Brown, 1973; Johnston & Ammon, 1985). For a typically developing 5 year-old producing 100 utterances, NDW should range from 156-206 and NTW should range from 439-602 (Leadholm & Miller, 1992). From examining Table 4, none of the children met criterion for even the lowest “typical” values for NDW or NTW. However, the language production results were not necessarily unexpected for children with ASD. It was expected that children in this study would possibly have lower levels of language output because one of the defining characteristics of autism is the delay or absence of spoken language (American Psychiatric Association, 2000).

From the correlational analyses, the alternative measure of Mean Length of Utterance (MLU 2, Johnston, 2001) and performance on phonological awareness tasks were moderately, but not significantly related, revealing a moderate trend that some children with lower morphosyntactic skills had more difficulty with the PA tasks. There was no significant correlation between total phonological awareness scores and Number of Different Words (NDW). This reveals that semantic diversity was not related to performance on phonological awareness tasks for the 11 children in this study. There was a moderate, but insignificant relationship between Number of Total Words (NTW) and phonological awareness scores, suggesting that some children with higher vocabulary production measures had less difficulty with the PA tasks. This finding validates previous research suggesting that as children’s vocabularies increase, so does their ability to perform phoneme awareness tasks (Metsala, 1999). However, vocabulary was informally assessed only through language sample analysis in this study. Future research should include standardized measures of vocabulary comprehension and production to confirm this finding.
Regression analysis variables

The regression analysis showed that phonological production, as measured by percentage consonants match, and language comprehension raw scores were the two strongest predictors of PA performance. This finding supports the results from the correlation analyses; percentage consonants match and language comprehension were two of the language measures highly correlated with PA. This finding also confirms the original hypothesis in that language ability, especially language comprehension and phonological production, contributed the most to performance on PA. However, caution must be warranted when interpreting regression models based on relatively small sample sizes (Norman & Streiner, 1998). This preliminary investigation suggests a trend in that language comprehension and phonological production may be strong predictors of PA in children with ASD. Larger scale studies should be conducted to confirm this finding.

Secondary Training Trials

One child in the Low PA group and all children in the Middle PA group used the visual supports during the secondary training trials. For example, with the Word-Initial Sound Identification task, Child #1 initially scored 0/10 on the test trials, achieved a score of 10/10 with the secondary training trials, and then scored 8/10 when the test trials were re-administered, revealing that some generalization of this particular phonological awareness skill had occurred. However, when the Rhyme Identification II task was given in the next testing session, Child #1 scored 10/10 on the secondary training trials, but below chance levels when the test trials were re-administered. This shows the variability within one child’s performance, across testing days, and between different PA tasks. Interesting results from the secondary training portion of this study, however, was that the children in the Middle PA group used the picture icons, and to a
lesser extent, the highlighted text. This became apparent as support was gradually faded out; one child asked, “Where are the ears?” There is a growing body of literature describing the benefits of using visual strategies to teach children with ASD (e.g., Dettmer, Simpson, Myles, & Ganz, 2000; Tiscott & Evans, 2003).

Even though the secondary training trials were administered to all children in the Low PA group, the additional visual supports may have been detrimental to learning. One parent commented that she thought her child was confused because there were too many distracters on the computer screen. This may be important information to note for children with developing PA skills and lower language comprehension skills.

A limitation to the secondary training trials may have been in the initial design. Support may not have been faded as quickly as possible; the least amount of support (i.e., without the picture icons) only involved Trial 8 and 9. (See Appendix A.) In hindsight, the picture icons could have been removed after the first five trials to determine if the children could achieve success on Trials 6 to 10 without the use of visual supports. Such an alteration in cue reduction could be attempted in future studies. Alternatively, a longer set of secondary trials might be included.

**Literacy**

**Pre-literacy.** All participants, except for one child in the Low PA group, scored above chance levels on the Letter-Sound Identification task, revealing that most children had adequate sound-letter correspondence, despite having some deficits in phonological awareness. There was also a significant relationship between performance on phonological awareness tasks and letter-sound recognition skills, providing additional evidence for the link between phonological awareness and performance on pre-literacy measures, such as sound-symbol correspondence
Informal observation during data collection revealed that six letters on the computer screen might have been too many for some participants. Scores for this task may have been higher if there had been fewer letters from which to choose.

**Literacy questionnaire.** There was a significant relationship between reading level as reported by parents from the literacy questionnaire and performance on phonological awareness tasks. This study could potentially add to the literature linking phonological awareness to literacy skills (e.g., Catts et al., 1999; Larrivee & Catts, 1999), but for a group of children with autism. However, caution must be warranted regarding the anecdotal nature of this literacy measure. Parents may not have known their child’s reading level and could have rendered a guess when completing the literacy questionnaire. Also, results should be interpreted with caution because literacy expectations increase as children enter higher grade levels; it is difficult to compare reading expectations in kindergarten with literacy skills in Grade 3. To alleviate this, future studies investigating literacy in children with ASD should include standardized measures of reading ability.

**Interactions Between Language Measures**

There was a moderate, but insignificant, correlation between language comprehension and morphosyntactic production (i.e., MLU 2) for the 11 children in this study. This supports some previous findings proposing that comprehension skills can be similar to production skills in children with ASD (e.g., Jarrold, Boucher, & Russell, 1997). However, most literature has suggested that language comprehension is more impaired than production (Bartak et al., 1975; Lord & Paul, 1997). Given the small sample size in this study and the wide range in variability, the moderate relationship between language comprehension and production is merely a trend and
not representative of all the children in the group. For example, Child #2 had a “moderate” impairment in language comprehension, but a relatively high MLU 2 (e.g., 4.17), compared to the other children. (See Table 7 for more individualized results).

Explaining the Variability in Phonological Awareness Performance

**Individual variation.** Even though results from the correlational analyses suggest potential relationships between phonology and language comprehension and PA skills, there is a considerable amount of variability in the language ability and phonological awareness skills across the 11 participants (See Table 7). For instance, given the trends from the correlations, one might expect children in the Low PA group to have “low” skills in phonological production, language comprehension, and language production, and so on for the children in the Mid and High PA groups. This is depicted in Table 7 with left arrows (e.g., ←), however this was only a general trend for some of the children.

The asterisks in Table 7 portray certain “anomalies” in the data. For example, given that Child #8 is 7;5, with “moderate” phonological impairment and “high” language comprehension, one might expect to see this child in the High PA group. However, this child was successful with only the first two PA tasks; therefore factors other than age, phonology, and language comprehension might better explain performance on PA tasks, such as characteristics and severity of Autism Spectrum Disorder. With respect to Child #9 with “moderate” phonological impairment and “high” language comprehension skills, one might expect to see PA performance at the intermediate level. However, Child #9 spoke Cantonese and had a lateral lisp characterized by ungrooved sibilants (e.g., [θouz] for toes and [haus] for house), which contributed to the “moderate” impairment in phonological production. Therefore, phonetic details, not a phonological characteristic, lead to the assignment of “moderate” impairment. Child #2 and
Child #10, both in the High PA group, showed anxiety with some of the testing. As previously mentioned, Child #2 refused to answer any questions pertaining to boys, girls, or their respective pronouns (e.g., he, she) with the CELF-Preschool, and became visibly upset (e.g., covering his ears and verbally protesting) during administration of this test. Child #10 also showed anxiety in that he would not respond unless absolutely sure of the correct answer when given the CELF 4.

Exclamations of “I don’t know” were common throughout language and phonological awareness testing with this child. For both Child #2 and #10, anxiety factors lead to lower raw scores and the subsequent assignment of “moderate” language comprehension skills. In summary, there did not seem to be a one-to-one relationship between PA skills, phonology, and language comprehension for most of the participants. Some of the “anomalies” in the data can be explained by idiosyncrasies in behavior, revealing the individualistic nature of the children in this study.

**Severity of autism.** Because there was missing data concerning the level and severity of autism, and because a variety of autism diagnosis scales lead to inconsistent results, severity of autism could not be entered as a variable into the analysis. Based on the diagnoses that were obtained, parental reports, and experimenter observations during testing, severity of autism did seem to be a contributing factor in how children performed on the phonological awareness and language testing. However, this cannot be confirmed without a standardized assessment. Future research should include a formal measure of autism, for example, the Childhood Autism Rating Scale (Schopler et al., 1988), to validate these observations.

**Home language.** Because the children’s home language revealed little or no correlations with performance on phonological awareness tasks or any of the language measures, it can be assumed that the presence of a second language did not affect the variability observed in
phonological awareness tasks. Again, however, a more formal assessment should be conducted to determine this. Two of the children in the Low PA group had a different home language, as did two children in the High PA group, either of which could have influenced their ability to do phonological awareness tasks.

**Literacy development.**

Children in this study may have been at different points in the developmental phonological awareness sequence (Treiman & Zukowski, 1991), and therefore at different stages in literacy development. The reciprocal nature of literacy and phonological awareness has been noted in the literature, in that phonemic awareness may develop as a result of learning to read. It has also been suggested that the ability to identify rime and onset is usually present before children learn to read (Bird et al., 1995).

This may or may not have been the case for children in this study. Children in the Low PA group, who were one to two years behind in reading level in school, performed poorly on all phonological awareness tasks. For children in the Middle PA group, two of the three children were on par with reading level, but all were successful with at least two of the PA tasks. Children in the High PA group varied, in being either above, at the same level, or below reading expectations, but able to complete all five PA tasks. Caution must be used when interpreting the children's literacy skills from parental report. However, these findings contribute to the variability in phonological awareness and literacy skills observed for this group of children with autism.

**Limitations**

Because of the small sample size, this study reveals trends in the relationships between language, phonology, and phonological awareness skills in children with autism. Generalization
to the general population of children with ASD is limited. Future studies should include more
participants to confirm the findings of this preliminary study.

To limit the amount of testing carried out with the participants, neither a test of non-
verbal intelligence nor a formal assessment measuring severity of autism were administered.
Also, only one pre-literacy measure was administered, because exploration of literacy skills was
not the main objective of the study. Future research should consider such factors.

Due to the investigative and descriptive nature of this study, a control group of typically
developing children was not included. The phonological awareness tasks were piloted with a
typically developing 5-year old, who performed at above chance on all tasks. From the literature
on phonological awareness and typically developing children (e.g., Liberman et al., 1974;
Treiman & Zukowski), it could be assumed that the same results may have been obtained with
other typically developing children, with some variability. However, future research should
include a control group to validate this assumption.

Clinical Implications and Future Research

This study has possible implications for children with ASD with phonological and
language comprehension deficits. The four children in the Low PA group scored at or below the
1st percentile on the language comprehension measure and had moderate to severe phonological
impairment. Based on the premise that children with phonological production difficulties
(Rvachew et al., 2003) and language comprehension deficits (Warrick & Rubin, 1992) may be at
risk for problems with phonological awareness and later literacy skills, the children in the Low
PA group may also be at risk for future literacy and academic problems. Concern for these
children increases once they enter higher grades in school when language demands become
increasingly more complex. Their low scores on language comprehension suggest that
intervention focusing on more general language development remains important for those children.

Given the results from the children in the Middle PA group, this study has positive implications for children with autism who may be at the stage of developing phonological awareness skills and who have adequate language comprehension skills in order to understand more abstract concepts such as “rhyme.” When provided with additional cues, such as picture icons and written words, these children were able to learn the teaching stimuli and one child was able to generalize initial-phoneme identification. Given the results from the secondary training trials and possible emerging PA skills, these children may be prime candidates for phonological awareness intervention; however, more research is needed in this area.

Ultimately, this is a preliminary study that has started to bridge the gap in the literature concerning phonological awareness skills in children with autism, showing that these children may be similar to children with language impairment of other origins with respect to the interaction of language and phonological awareness skills. This study also shows that some children with ASD are capable of performing metalinguistic tasks and may be capable of being taught certain phonological awareness concepts, provided with appropriate teaching stimuli.
Table 1
Participant demographics

<table>
<thead>
<tr>
<th>Child</th>
<th>Age</th>
<th>Grade</th>
<th>Gender</th>
<th>Diagnosis</th>
<th>Diagnostic Measure</th>
<th>Home Language</th>
<th>Bilingual</th>
<th>Mother's education</th>
<th>EIBI program</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>5.0</td>
<td>K</td>
<td>M</td>
<td>PDD-NOS</td>
<td>ADI-R, CARS</td>
<td>Spanish</td>
<td>Yes</td>
<td>Bachelor degree</td>
<td>Yes</td>
</tr>
<tr>
<td>#2</td>
<td>5.2</td>
<td>K</td>
<td>M</td>
<td>HF Autism</td>
<td>n/a</td>
<td>English</td>
<td>No</td>
<td>High school diploma</td>
<td>Yes</td>
</tr>
<tr>
<td>#3</td>
<td>5.6</td>
<td>K</td>
<td>M</td>
<td>HF Autism</td>
<td>DSM-IV, CARS</td>
<td>English &amp; Japanese</td>
<td>No</td>
<td>Bachelor degree</td>
<td>Yes</td>
</tr>
<tr>
<td>#4</td>
<td>5.8</td>
<td>K</td>
<td>M</td>
<td>Moderate Autism</td>
<td>n/a</td>
<td>Cantonese</td>
<td>Yes</td>
<td>College diploma</td>
<td>Yes</td>
</tr>
<tr>
<td>#5</td>
<td>5.9</td>
<td>K</td>
<td>F</td>
<td>ASD</td>
<td>DSM-IV</td>
<td>English</td>
<td>No</td>
<td>Bachelor degree</td>
<td>Yes</td>
</tr>
<tr>
<td>#6</td>
<td>6.7</td>
<td>1</td>
<td>M</td>
<td>Autistic disorder</td>
<td>DSM-IV</td>
<td>English</td>
<td>No</td>
<td>Bachelor degree</td>
<td>Yes</td>
</tr>
<tr>
<td>#7</td>
<td>7.2</td>
<td>2</td>
<td>F</td>
<td>Severe Autism</td>
<td>n/a</td>
<td>Cantonese</td>
<td>Yes</td>
<td>College diploma</td>
<td>No</td>
</tr>
<tr>
<td>#8</td>
<td>7.5</td>
<td>2</td>
<td>F</td>
<td>Moderate Autistic range</td>
<td>DSM-IV, CARS</td>
<td>English</td>
<td>No</td>
<td>Bachelor degree</td>
<td>No</td>
</tr>
<tr>
<td>#9</td>
<td>8.4</td>
<td>3</td>
<td>M</td>
<td>HF Autism</td>
<td>DSM-IV</td>
<td>Cantonese</td>
<td>Yes</td>
<td>High school diploma</td>
<td>No</td>
</tr>
</tbody>
</table>
Table 1 (Continued)

<table>
<thead>
<tr>
<th>#</th>
<th>Age</th>
<th>Sex</th>
<th>Functioning</th>
<th>Autism</th>
<th>Mandarin</th>
<th>Education</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>8.6</td>
<td>M</td>
<td>HF Autism</td>
<td>n/a</td>
<td>Mandarin</td>
<td>Yes</td>
<td>Two college diplomas</td>
</tr>
<tr>
<td>#11</td>
<td>9.0</td>
<td>F</td>
<td>Mod-Severe</td>
<td>Autism</td>
<td>n/a</td>
<td>Mandarin</td>
<td>No</td>
</tr>
</tbody>
</table>

Note. 1PDD-NOS: Pervasive Developmental Disorder - Not Otherwise Specified; ASD: Autism Spectrum Disorder; HF: High Functioning.


3EIBI: Early Intensive Behavioural Intervention program.
Table 2

Procedure: Test types and order

<table>
<thead>
<tr>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Language sample</td>
<td>1. Language sample</td>
<td>1. Language sample</td>
</tr>
</tbody>
</table>
| 2. Language comprehension measure
tested for reading 
comprehension | 2. CAPES phonology measure | 2. Rhyme Identification II PA task |
| 4. Word-Initial Sound Identification PA task | | 4. Letter-Sound Identification task |

Note. 1Sentence Structure subtest from the CELF-Preschool (Wiig et al., 1992) or the CELF 4 (Semel et al., 2003).


3Order was randomized across children for these particular PA tasks before each testing session.
Table 3

Phonological production measures across children

<table>
<thead>
<tr>
<th>Child</th>
<th>% Sample Imitated</th>
<th>PCM</th>
<th>PVM</th>
<th>WSM</th>
<th>SPM</th>
<th>Voice/Speech Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>19.6</td>
<td>76.2</td>
<td>89.7</td>
<td>89.1</td>
<td>93.5</td>
<td>Abnormal prosody; breathy</td>
</tr>
<tr>
<td>#2</td>
<td>30.4</td>
<td>74.3</td>
<td>82.4</td>
<td>87.0</td>
<td>97.8</td>
<td>Breathy; pharyngealization</td>
</tr>
<tr>
<td>#3</td>
<td>6.5</td>
<td>82.9</td>
<td>75.0</td>
<td>86.9</td>
<td>82.6</td>
<td>Glottal fry</td>
</tr>
<tr>
<td>#4</td>
<td>21.7</td>
<td>81.0</td>
<td>83.8</td>
<td>89.1</td>
<td>87.0</td>
<td>Glottal fry; fast rate</td>
</tr>
<tr>
<td>#5</td>
<td>41.3</td>
<td>48.6</td>
<td>35.3</td>
<td>43.5</td>
<td>76.1</td>
<td>Breathy; low volume</td>
</tr>
<tr>
<td>#6</td>
<td>41.3</td>
<td>60.0</td>
<td>57.4</td>
<td>60.9</td>
<td>91.3</td>
<td>Cantonese accent; lateral lisp</td>
</tr>
<tr>
<td>#7</td>
<td>63.0</td>
<td>21.0</td>
<td>44.1</td>
<td>8.7</td>
<td>69.6</td>
<td>Mandarin accent; nasality</td>
</tr>
<tr>
<td>#8</td>
<td>6.5</td>
<td>79.1</td>
<td>75.0</td>
<td>93.5</td>
<td>89.1</td>
<td>Abnormal prosody</td>
</tr>
<tr>
<td>#9</td>
<td>30.4</td>
<td>73.3</td>
<td>85.3</td>
<td>84.8</td>
<td>93.5</td>
<td>Breathy; low volume</td>
</tr>
<tr>
<td>#10</td>
<td>28.3</td>
<td>90.5</td>
<td>76.5</td>
<td>95.7</td>
<td>78.3</td>
<td>Breathy; low volume</td>
</tr>
<tr>
<td>#11</td>
<td>41.3</td>
<td>70.5</td>
<td>82.4</td>
<td>73.9</td>
<td>97.8</td>
<td>Breathy; low volume</td>
</tr>
</tbody>
</table>

Note. PCM: percentage consonant match; PVM: percentage vowels match; WSM: percentage word shape match; SPM: percentage stress pattern match.
Table 4

Language comprehension and production measures across participants

<table>
<thead>
<tr>
<th>Child</th>
<th>Language Comprehension</th>
<th>Language Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Score</td>
<td>Percentile</td>
</tr>
<tr>
<td>#1</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>#2</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>#3</td>
<td>22</td>
<td>91</td>
</tr>
<tr>
<td>#4</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>#5</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>#6</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>#7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>#8</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>#9</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>#10</td>
<td>16</td>
<td>0.1</td>
</tr>
<tr>
<td>#11</td>
<td>11</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Table 4 (Continued)

**Note.** MLU: Mean Length of Utterance; MLU 2: alternative Mean Length of Utterance measure (Johnston, 2001); NDW: Number of Different Words in the first 100 utterances; NTW: Number of Total Words in the first 100 utterances.

1 Participants #1 to #8 received the *CELF-Preschool* (Wiig et al., 1992); participants #9 to #11 received the *CELF 4* (Semel et al., 2003). Child #7 and #8 were administered the *CELF-Preschool*, even though their chronological ages were not within the age range for this test.
Table 5

Phonological awareness results across children and PA tasks

<table>
<thead>
<tr>
<th></th>
<th>Rhyme Matching I</th>
<th>Word Segmentation</th>
<th>Initial Sound Identification</th>
<th>Rhyme Identification II</th>
<th>Final Sound Matching</th>
<th>Total PA</th>
<th>Letter-Sound Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low PA Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#5</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>#6</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>#7</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>#11</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td><strong>Mid PA Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#1</td>
<td>10</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>#4</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>7</td>
<td>n/a</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>#8</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td><strong>High PA Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>46</td>
<td>9</td>
</tr>
<tr>
<td>#3</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>48</td>
<td>10</td>
</tr>
<tr>
<td>#9</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>9</td>
<td>46</td>
<td>10</td>
</tr>
<tr>
<td>#10</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>48</td>
<td>10</td>
</tr>
</tbody>
</table>
Table 5 (Continued)

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>6.27</td>
<td>6.78</td>
<td>5.43</td>
<td>6.57</td>
<td>5.67</td>
<td>22.5</td>
<td>7.91</td>
</tr>
<tr>
<td>SD</td>
<td>4.98</td>
<td>3.93</td>
<td>5.13</td>
<td>4.61</td>
<td>4.50</td>
<td>21.8</td>
<td>2.39</td>
</tr>
<tr>
<td>n</td>
<td>11</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

Note. n/a: Not applicable because Child #4 chose not to do this PA task, not because the task was considered too difficult.
Table 6

Correlations between total scores on PA tasks and external variables and language measures

<table>
<thead>
<tr>
<th>Variables</th>
<th>Spearman rho coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age and total PA</td>
<td>-0.12</td>
<td>0.73</td>
</tr>
<tr>
<td>Mother’s education level and total PA</td>
<td>-0.23</td>
<td>0.49</td>
</tr>
<tr>
<td>Home language and total PA</td>
<td>-0.02</td>
<td>0.97</td>
</tr>
<tr>
<td><strong>Phonology measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent consonant match (PCM) and total PA</td>
<td>0.83</td>
<td>0.001**</td>
</tr>
<tr>
<td>Percent vowel match (PVM) and total PA</td>
<td>0.39</td>
<td>0.23</td>
</tr>
<tr>
<td>Word shape match (WSM) and total PA</td>
<td>0.68</td>
<td>0.021*</td>
</tr>
<tr>
<td>Stress pattern match (SPM) and total PA</td>
<td>0.04</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>Language comprehension measure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw scores and total PA</td>
<td>0.71</td>
<td>0.014*</td>
</tr>
<tr>
<td><strong>Language production measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLU and total PA</td>
<td>0.51</td>
<td>0.11</td>
</tr>
<tr>
<td>MLU 2 and total PA</td>
<td>0.57</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Table 6 (Continued)

<table>
<thead>
<tr>
<th>Measure</th>
<th>NDW and total PA (n=10)</th>
<th>NTW and total PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDW and total PA (n=10)</td>
<td>0.44</td>
<td>0.21</td>
</tr>
<tr>
<td>NTW and total PA</td>
<td>0.54</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Literacy measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter-sound identification scores and total PA</td>
<td>0.84</td>
<td>0.001**</td>
</tr>
<tr>
<td>Reported reading level (parent questionnaire)</td>
<td>0.76</td>
<td>0.01*</td>
</tr>
</tbody>
</table>

*Note.* *p* < 0.05 two-tailed; **p* < 0.01 two-tailed.
Table 7

Pre-literacy and language measures as a function of PA group

<table>
<thead>
<tr>
<th>Low PA Group</th>
<th>Age</th>
<th>Phonology: PCM</th>
<th>Severity&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Comprehension: Raw Scores&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Severity&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Production: MLU 2</th>
<th>Letter-Sound</th>
<th>Total PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5</td>
<td>5.9</td>
<td>48.6</td>
<td>Severe</td>
<td>10/22</td>
<td>Moderate</td>
<td>1.37</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>#6</td>
<td>6.7</td>
<td>60.0</td>
<td>Moderate</td>
<td>12/22</td>
<td>Moderate</td>
<td>2.46</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>#7</td>
<td>7.2</td>
<td>21.0</td>
<td>Severe</td>
<td>4/22</td>
<td>Severe</td>
<td>1.44</td>
<td>3</td>
<td>0 &lt;</td>
</tr>
<tr>
<td>#11</td>
<td>9.0</td>
<td>70.5</td>
<td>Severe</td>
<td>11/26</td>
<td>Moderate</td>
<td>2.82</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Mid PA Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#1</td>
<td>5.0</td>
<td>76.2</td>
<td>Mild</td>
<td>18/22</td>
<td>High</td>
<td>5.06</td>
<td>5</td>
<td>17 &lt;</td>
</tr>
<tr>
<td>#4</td>
<td>5.8</td>
<td>81.0</td>
<td>Normal</td>
<td>11/22</td>
<td>Moderate</td>
<td>3.60</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>#8</td>
<td>7.5</td>
<td>79.1</td>
<td>Moderate*</td>
<td>18/22</td>
<td>High</td>
<td>3.25</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>High PA Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td>5.2</td>
<td>74.3</td>
<td>Mild</td>
<td>14/22</td>
<td>Moderate*</td>
<td>4.17</td>
<td>9</td>
<td>46</td>
</tr>
<tr>
<td>#3</td>
<td>5.6</td>
<td>82.9</td>
<td>Normal</td>
<td>22/22</td>
<td>High</td>
<td>3.77</td>
<td>10</td>
<td>48 &lt;</td>
</tr>
<tr>
<td>#9</td>
<td>8.4</td>
<td>73.3</td>
<td>Moderate*</td>
<td>19/26</td>
<td>High</td>
<td>2.55</td>
<td>10</td>
<td>46</td>
</tr>
<tr>
<td>#10</td>
<td>8.6</td>
<td>90.5</td>
<td>Mild</td>
<td>16/26</td>
<td>Moderate*</td>
<td>3.10</td>
<td>10</td>
<td>48</td>
</tr>
</tbody>
</table>
Table 7 (Continued)

Note. PCM: Percentage Consonants Match; MLU 2: alternative Mean Length of Utterance measure (Johnston, 2001); Letter-Sound: raw scores on Letter-Sound Identification task; Total PA: sum of raw scores across all five phonological awareness tasks; Left arrow (←): depicts children with “low” PA skills has also having “low” ability in phonological production and language comprehension, children with “middle” PA skills as having “average” ability, and children with “high” PA skills as having “high” ability in phonology and language comprehension; Asterisk (*): depicts certain “anomalies” in the data.

1Severity of phonological impairment based on Austin and Shriberg’s (1997) reference data.

2Raw scores out of a possible 22 correct for the CELF-Preschool (Wiig et al., 1992); out of a possible 26 correct for the CELF 4 (Semel et al., 2003).

3Severity of language comprehension impairment determined by distribution of percentages from the raw scores (i.e., “High” = above 73%; “Moderate” = 40-65%; “Severe” = below 30%). Note that due to problems with standardization, these descriptive labels were arbitrarily assigned based on the raw scores.
Table 8
Correlations between rhyme matching I task and language measures

<table>
<thead>
<tr>
<th>Raw scores on Rhyme Matching I versus:</th>
<th>Spearman $rho$ coefficient</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent consonant match (PCM)</td>
<td>0.79</td>
<td>0.004**</td>
</tr>
<tr>
<td>Percent vowel match (PVM)</td>
<td>0.70</td>
<td>0.017*</td>
</tr>
<tr>
<td>Word shape match (WSM)</td>
<td>0.72</td>
<td>0.013*</td>
</tr>
<tr>
<td>Language comprehension raw scores</td>
<td>0.68</td>
<td>0.022*</td>
</tr>
<tr>
<td>MLU</td>
<td>0.73</td>
<td>0.011*</td>
</tr>
<tr>
<td>MLU 2</td>
<td>0.76</td>
<td>0.007**</td>
</tr>
<tr>
<td>NDW (n=10)</td>
<td>0.67</td>
<td>0.035*</td>
</tr>
<tr>
<td>NTW</td>
<td>0.76</td>
<td>0.007**</td>
</tr>
<tr>
<td>Letter-sound identification task</td>
<td>0.67</td>
<td>0.024*</td>
</tr>
</tbody>
</table>

Note. *$p < 0.05$ two-tailed; **$p < 0.01$ two-tailed. All participants were administered the Rhyme Matching I task.
<table>
<thead>
<tr>
<th>Variables</th>
<th>Spearman rho coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language comprehension versus:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLU 2</td>
<td>0.57</td>
<td>0.067</td>
</tr>
<tr>
<td>PCM</td>
<td>0.64</td>
<td>0.034*</td>
</tr>
<tr>
<td>Percentage consonants match (PCM) versus:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLU</td>
<td>0.69</td>
<td>0.019*</td>
</tr>
<tr>
<td>MLU 2</td>
<td>0.71</td>
<td>0.015*</td>
</tr>
<tr>
<td>NTW</td>
<td>0.71</td>
<td>0.015*</td>
</tr>
<tr>
<td>Letter-sound identification task</td>
<td>0.72</td>
<td>0.012*</td>
</tr>
<tr>
<td>MLU 2 versus:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDW (n = 10)</td>
<td>0.981</td>
<td>0.001**</td>
</tr>
<tr>
<td>NTW</td>
<td>0.982</td>
<td>0.001**</td>
</tr>
</tbody>
</table>

Note. *p < 0.05 two-tailed; **p < 0.01 two-tailed.
Table 10

Regression analysis for variables predicting performance on phonological awareness tasks

<table>
<thead>
<tr>
<th>Model</th>
<th>Variables Entered&lt;sup&gt;1&lt;/sup&gt;</th>
<th>$r^2$</th>
<th>Change in $r^2$</th>
<th>$F$-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1) Lang. comp. raw scores</td>
<td>0.48</td>
<td>n/a</td>
<td>8.31</td>
<td>0.018*</td>
</tr>
<tr>
<td>2</td>
<td>1) Lang. comp. raw scores</td>
<td>0.52</td>
<td>0.04</td>
<td>4.40</td>
<td>0.051</td>
</tr>
<tr>
<td></td>
<td>2) PCM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1) Lang comp. raw scores</td>
<td>0.52</td>
<td>0.00</td>
<td>2.57</td>
<td>0.137</td>
</tr>
<tr>
<td></td>
<td>2) PCM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3) MLU 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. *Significance = $p < 0.05$.

<sup>1</sup>PCM: percentage consonant match; MLU 2: alternative Mean Length of Utterance measure (Johnston, 2001).
References


Appendix A

Test Trials and Secondary Training Trials Stimuli Lists

1. Rhyme Judgment I Task
   
   Test Trials
   1. snake: corn, cake
   2. clock: cat, rock
   3. car: star, fan
   4. bat: hose, hat
   5. king: ring, sun
   6. dog: log, feet
   7. rose: cup, nose
   8. mouse: house, chair
   9. box: fox, bed
   10. van: pear, man

   Secondary Training Trials
   Most Support: Boardmaker picture icons & color-coded text
   1. dig: pig, stove
   2. mat: bear, rat
   3. tail: shirt, pail
   4. sun: fun, shoe
   5. lick: light, stick

   Intermediate Support: Picture icons; text without color-coding
   6. coat: orange, goat
   7. rug: stop, mug
   8. bag: flag, glove

   Least Support: No picture icons, text without color-coding
   9. cook: book, brush
   10. sand: hand, bird

2. Word Segmentation Task
   
   Test Trials
   1. hotdog: mouse, hot, dog
   2. blackboard: board, black, school
   3. cowboy: boy, cow, sheep
   4. toothbrush: tooth, brush, comb

   Secondary Training Trials
   Most Support
   1. pancake: pan, cake, bowl
   2. ice cream: cookie, cream, ice
   3. playground: ground, rope, play
5. haircut: comb, cut, hair
6. doughnut: muffin, nut, dough
7. duck pond: duck, pond, fish
8. junk food: food, fork, junk
9. baseball: run, ball, base
10. baby: crib, bay, bee

4. sunset: set, sun, clock
5. beanbag: bag, carrot, bean

Intermediate Support

6. headlight: head, tire, light
7. bedroom: room, chair, bed
8. horseshoe: horse, cow, shoe

Least Support

9. popcorn: pop, corn, salt
10. firetruck: truck, fire, rain

---

3. Word-Initial Sound Identification Task

**Test Trials**

1. /d/: duck, door, dog, cake
2. /t/: table, balloon, turtle, toothbrush
3. /b/: baby, button, hammer, balloon
4. /f/: fish, feet, fork, boat
5. /k/: cage, cup, sun, cow
6. /s/: hat, seat, sock, sun
7. /p/: pig, bike, pin, pea
8. /k/: feet, key, kite, corn
9. /k/: kangaroo, telephone, computer, camera
10. /b/: bone, bed, cup, bike

**Secondary Training Trials**

**Most Support**

1. /b/: book, bird, ball, leaf
2. /h/: head, house, bird, hat
3. /m/: map, mask, pot, moon
4. /f/: fox, fall, cat, fish
5. /l/: man, light, leg, leaf

**Intermediate Support**

6. /y/: juice, coat, jump, jam
7. /g/: goat, boot, game, gum
8. /l/: lemon, leopard, laundry, popcorn

**Least Support**

9. /k/: table, castle, cupcake, canoe
4. Rhyme Identification II Task

Test Trials
1. corn, snake, cake, rake
2. clock, rock, sock, cat
3. car, jar, fan, star
4. hose, cat, hat, bat
5. swing, ring, king, sun
6. feet, frog, log, dog
7. rose, nose, clock, hose
8. bed, shoe, head, bread
9. key, bow, pea, tree
10. bear, chair, hair, kite

Secondary Training Trials

Most Support
1. pink, sink, wink, pot
2. pie, tie, toe, lie
3. van, dog, man, can
4. goat, coat, fish, boat
5. shoe, tail, pail, mail

Intermediate Support
6. hand, ship, lip, zip
7. bug, mug, rug, house
8. pan, ape, tape, grape

Least Support
9. rat, fat, gum, bat
10. tree, bee, see, pail

5. Word-Final Sound Matching Task

Test Trials
1. /l/ bowl: doll, hat, cup
2. /p/ cap: car, lip, fan
3. /g/ dog: pear, pot, pig
4. /t/ cat: sit, comb, back

Secondary Training Trials

Most Support
1. /m/ gum: goat, bear, mom
2. /g/ leg: leaf, rug, pen
3. /k/ book: cat, rain, duck
Letter-Sound Identification Task

Test Trials

1. b: /b/
2. l: /l/
3. a: /æ/
4. sh: /ʃ/
5. z: /z/
6. i: /ɪ/ 
7. th: /θ/
8. o: /ə/
9. d: /d/
10. k: /k/

Note. Underlined words refer to correct responses.
Appendix B

Parent Literacy Questionnaire

1. Does your child like to read or look at books?

2. Does your child like to read with adults or siblings, or does he/she prefer to read alone?

3. Has your child been exposed to phonological awareness tasks (e.g., rhyming, beginning sounds of words, final sounds of words, tapping out syllables of words, etc.) before this research project?

4. Have you worked on phonological awareness tasks with your child?

5. Have others, such as behavioral interventionists or a Speech-Language Pathologist, worked on phonological awareness with your child?

6. About how often are phonological awareness tasks worked on?

7. Can your child identify letters and numbers (e.g., “Where's the letter B”)?

8. Does your child sound out words when he/she reads (i.e., does your child decode the sounds of the words)?

9. What method of teaching was used when your child was learning to read, either at school or at home? (Circle all that apply).
   1. Phonics (i.e., teaching individual letter sounds)
   2. Whole word (e.g., teaching the entire word and/or core vocabulary)

10. Does your child understand the majority of what he/she reads?

11. What grade is your child in?

12. What grade level is your child currently reading at?