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Does strength of phonological representations predict phonological awareness in preschool children?

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ABSTRACT
Previous research has shown a clear relationship between phonological awareness and early reading ability. This article concerns some aspects of spoken language skill that may contribute to the development of phonological awareness, as manifested in rhyme awareness and phoneme awareness. It addresses the hypothesis that phonological awareness abilities are associated with measures that purportedly tap into the strength of phonological representations. We examined rhyme awareness, phoneme awareness, articulatory skill, speech perception, vocabulary, and letter and word knowledge in 40 children, aged 4 to 6, who were just beginning to be exposed to formal reading experiences in private preschools. The children also received cognitive tests and tests of reading ability. The results did not validate strength of phonological representation as a unitary construct underlying phonological awareness more generally, but instead revealed a selective pattern of associations between spoken language tasks and aspects of phonological awareness. Speech perception was closely associated with rhyme awareness measures when age, vocabulary, and letter knowledge were controlled. Children with a less developed sense of rhyme had a less mature pattern of articulation, independent of age, vocabulary, and letter knowledge. Phoneme awareness was associated with phonological perception and production. Children with low phoneme awareness skills showed a different pattern of speech perception and articulation errors than children with strong abilities. However, these differences appeared to be largely a function of age, letter knowledge, and especially vocabulary knowledge.

It is now well established that early reading problems are associated with difficulties in phonological awareness – difficulties in phoneme awareness being the clearest case in point (for reviews, see Lyon, 1994; Mann, 1998; Stanovich, 1993; Wagner & Torgesen, 1987). Despite the strong relationship between phonological skills and reading, the nature of the phonological deficits that underlie poor reading remains to be elucidated. Differences in performance on various measures of phonological awareness have been attributed to educational experience (see Alegria, Pignot, & Morais, 1982; Mann & Wimmer, 2001; Morais, Cary, Alegria, & Bertelson, 1979), but this has not always been the case (see Bradley & Bryant, 1978; Lundberg, Oloffsson, & Wall, 1980; Mann, 1984, 1986). It may be that the development of phonological awareness is dependent on a complex interplay between individual differences in endowment and literacy-related experiences.

Noting that the link between reading and phonological skill encompasses rhyme awareness, phoneme awareness, speech perception, naming, and vocabulary, several investigators have proposed that the problem for poor readers may be traced back to a bottleneck reflecting inadequate phonological processing skills (see Mann, 1998; McBride-Chang, Wagner, & Chang, 1997; Watson & Miller, 1993), possibly due to ineffective or immature phonological representations in the mental lexicon (e.g., Elbro, 1996; Fowler, 1991; Walley, 1993). Since the literature to date has not reached a consensus as to whether adequacy, effectiveness, maturity, or distinctiveness of phonological representations is the source of the problem, in the present article we put aside this issue and refer to the hypothetical deficiency as one involving "strength of phonological representations." Our purpose is to examine whether the data support the position that a unitary construct underlies tasks that purportedly measure the qualitative aspects of phonological representations, and that this unitary construct relates to phonological awareness. For example, the qualities of a phonological representation that allow a child to perform a nonword repetition task may or may not be the same as those that are required to distinguish between pairs of words. These tasks, in turn, may or may not be equally well associated with tasks that measure phonological awareness.

In this study, we examine the relationship between performance on tasks that purportedly measure the strength of children's phonological representations and tasks that measure phonological awareness in the preschool years. We consider two different levels of phonological awareness: awareness of rhyme and awareness of phonemes. For children learning to read an alphabetic orthography such as English, phoneme awareness is the most widely replicated and accepted correlate of early reading skill (for reviews, see Adams, 1990; Brady & Shankweiler, 1991; Mann, 1998). While there is considerable evidence that phoneme awareness accrues as a consequence of exposure to letter knowledge and alphabetic print (Alegria et al., 1982; Barron, 1994; Mann, 1986; Mann & Wimmer, 2001), there is also evidence that individual differences can involve something above and beyond such exposure (Bradley & Bryant, 1978; Lundberg et al., 1980; Mann, 1986, 1991). The evidence linking rhyme awareness to reading is more controversial. Some studies reveal an association between levels of rhyme awareness and early reading skills (see Bryant, 1997; Bradley & Bryant, 1983, 1991), but others offer data that challenges this association (Duncan, Seymour, & Hill, 1997; Muter, Hulme, Snowling, & Taylor, 1998; Muter & Snowling, 1998). Likewise, some studies suggest that rhyme awareness is a developmental antecedent and a precursor of phoneme awareness (see Bradley & Bryant, 1983; Bryant & Goswami, 1987; Treiman & Zukowski, 1991), whereas others note that phoneme awareness can be independent of rhyme awareness (Duncan & Johnston, 1999). One result seems quite clear: rhyme awareness can –

and does – develop without exposure to a writing system (Liberman, Shankweiler, Fischer, & Carter, 1974; Morais, 1991; Treiman & Zukowski, 1991).

Our primary goal in the present study is to document the relation between children's performance on rhyme and phoneme awareness tasks and their performance on a variety of spoken language tasks that purportedly reflect the qualitative aspects of the phonological representation. These measures include speech discrimination, articulation, rapid naming, nonword repetition, and distinctness tasks. First, we review the evidence that supports the use of these tasks to measure the strength of phonological representation. We then offer a brief review of the evidence linking phoneme awareness to vocabulary and letter knowledge.

Measures of phonological strength

Speech discrimination. Several lines of evidence have suggested that poor reading ability (and, by implication, poor phonological awareness) relates to poor speech perception. For example, consonant perception in newborns is associated with language competence at 3 to 5 years, which, in turn, is predictive of reading achievement at 8 years (Scarborough, 1990). Children and adults with reading difficulties have difficulties perceiving speech in noise (Brady, Poggie, & Rapala, 1989; Brady, Shankweiler, & Mann, 1983), and children who are poor readers require a longer segment of a gated word in order to perceive it correctly (Metsala, 1997).

Following Walley (1993), Metsala (1997) suggested that the perceptual problem associated with poor readers and the concomitant difficulty these children show with phoneme awareness follow from the fact that phonemes are not preformed perceptual units whose conscious accessibility changes with literacy exposure. Instead, she argued, phonemes gradually develop over childhood, as the growth of spoken vocabulary causes lexical representations to become more segmental. Similarly, Manis and his colleagues (Manis et al., 1997) proposed that even small speech perception problems may be very important for learning to read, and that, in certain poor readers, the phonological categories may be "more prone to disruption under stress" (p. 214), such as perception in noise or gating conditions. In their view, another source of stress is the challenge of learning to read. As Manis et al. suggested, if children cannot perceive clear distinctions between phonemes, it will be hard for them to develop representations that can be easily accessed. Problems with accessing phonological representations, in turn, lead to difficulty in segmenting and manipulating phonemes and in learning grapheme–phoneme relationships.

Speech perception may also be studied by examining error patterns in tasks where children are asked to discriminate between words that vary along a single perceptual dimension. This is the strategy that we use in the present study. Speech discrimination errors often reflect perceptual distinctions that are particularly difficult for children (e.g., voicing, blends/clusters) (Treiman, 1985; Treiman, Broderick, Tincoff, & Rodriguez, 1998).

Additional support for a link between speech perception, phonological representations, and poor reading can be found in studies of children with specific language impairment (SLI). These children are six times more likely to have a reading disorder compared to children without the language difficulty (e.g., Ingram, Mason, & Blackburn, 1970), especially when the language delay has not resolved by the age of 5½ (Bishop & Adams, 1990). Children with SLI also have speech perception difficulties. Edwards and Lahey (1998) found that SLI children were less accurate than typically developing children, not because they missed stops or unstressed syllables, but because they made syllable structure, phoneme deletion, and phoneme substitution errors. These authors suggested that children with SLI have more holistic phonological representations than even younger typically developing children, who are able to utilize representations that are relatively distinctive (Edwards & Lahey, 1998). Thus, the speech perception differences between children with SLI and typically developing children have been interpreted as reflecting the difference between immature (holistic) and segmental (mature) representations (Edwards & Lahey, 1998; Manis et al., 1997).

Articulation. If we regard perceptual and awareness problems as the consequence of inadequate phonological representation, we might also look to problems with speech production as another possible consequence. Although young children's perception of speech may be superior to their production (Mann, Sharlin, & Dorman, 1985), speech perception and production are often found to be closely related. Thomas and Senechal (1998) found that 3-year-old children who cannot accurately produce /r/ perform less well on phoneme awareness tasks that require manipulation of that phoneme, thus providing a direct link between phoneme awareness and articulation. Speech production errors in typically developing young children often reflect a difficulty in mastering certain perceptual distinctions, such as those between /r/, /l/, and /w/ (Vihman, 1996, p. 162).

Children with SLI also present with abnormal speech production histories. These histories include less complex babbling (Whitehurst, Smith, Fischel, Arnold, & Lonigan, 1991), less productive use of complex syllables (Stoel-Gammon, 1989) and consonants (Roberts, Rescorla, Giroux, & Stevens, 1998), fewer vocalizations, and reduced phonetic inventories compared to controls (Paul & Jennings, 1992; Rescorla & Ratner, 1996). Like the findings about speech perception in children with SLI, findings about articulation suggest that they have delayed, rather than deviant, phonological development (Manis et al., 1997; Sussman, 1993).

Additional evidence that articulatory impairment could be a consequence of inadequate phonological representations comes from studies of children with speech production difficulties. Children with phonological disorders become resistant to changing incorrect production patterns, suggesting that it is somehow difficult for them to develop representations that are more distinct (Rvachew & Jamieson, 1995). In a lip-reading task, children who were unable to produce target consonants had greater difficulty integrating audible and visible speech than children who had productive control over these consonants (Desjardins, Rogers, & Werker, 1997). The authors interpreted their findings as suggesting that children who misarticulate phonemes have internal representations for these phonemes that lack critical distinguishing phonological features.

Naming speed. Naming speed, which involves both articulation and lexical access, has been shown to be strongly linked to reading ability. Children with reading disorders are slower in naming simple familiar items (e.g., colors, letters, words) than children without reading disorders (see Bowers & Wolf, 1993; Denckla & Rudel, 1976). Naming speed has also been linked to phonological deficits (e.g., Ben-Dror, Pollatsek, & Scarpati, 1991; Lundberg & Hoien, 1990; Manis, 1985; Murphy, Pollatsek, & Well, 1988). As naming problems in reading-disordered subjects have been associated with slower articulation rates, it has been suggested that lexical access in reading-disordered subjects may be associated with impaired access to individual phonological representations in the lexicon (e.g., Catts, 1989; James, Van Steenbrugge, & Chiveralls, 1994; Raine, Hulme, Chadderton, & Bailey, 1991; Wolff, Michel, & Ovrut, 1990). Katz (1986) suggested that the problem may in part stem from less phonologically complete lexical representations.

Nonword repetition. Nonword repetition, assessed during tasks that ask children to repeat novel phoneme sequences, is widely regarded as a measure of phonological processing (Brady et al., 1989; Edwards & Lahey, 1998; Manis et al., 1997). Studies have consistently found that children with reading and language difficulties are impaired in nonword repetition compared to children without such difficulties (Brady et al., 1989; Gathercole & Baddeley, 1993; Kamhi & Catts, 1986; Kamhi, Catts, & Mauer, 1990; Leonard, Schwartz, & Loeb, 1987; Manis et al., 1997), lending support for the view that nonword repetition is a promising predictor of reading difficulties, at least in some children (Edwards & Lahey, 1998; Manis et al., 1997). Several studies have offered the view that poor readers' difficulties with nonword repetition may reflect a problem with the distinctness or strength of the underlying phonological representations (Edwards & Lahey, 1998; Gathercole, Willis, Baddeley, & Emslie, 1994; Manis et al., 1997).

Distinctness. Distinctness – or the degree of separation between a phonological representation and similar-sounding words in the lexicon – appears to be an important factor in the development of language in general and phonological awareness in particular (Godfrey, Syrdal-Laskey, Millay, & Knox, 1981; Katz, 1986; Reed, 1989; Walley, 1993). In the distinctness task we used in this study (Elbro, Borstrom, & Petersen, 1998), children were presented with an imprecise label for a well-known object (e.g., *e-phant* for elephant) and were asked to provide the correct label. Such a task requires that the child accurately perceive the imprecise label, access the correct label, and execute the corrected response. The phonological distinctness of the representation of vocabulary items in kindergarten was found to contribute significantly to the prediction of phoneme awareness in grade 2 (Elbro et al., 1988).

Literacy-related skills linked to phonological processing

Vocabulary. Consistent findings show that vocabulary skills – especially productive vocabulary skills – have been related to the development of reading ability (for reviews, see Bowers & Wolf, 1993; Wolf, 1999). Vocabulary knowledge may interact with qualities of phonological representations. For example, dyslexic adults often confuse similar-sounding words in a vocabulary task (Elbro, Nielsen, & Petersen, 1994), suggesting that phonological distinctiveness may be an important factor. Others have noted that speech perception may contribute to literacy by facilitating vocabulary development (Sawyer & Butler, 1991; Walley, 1993). Gathercole and Baddeley (1989) showed that vocabulary was a significant predictor of nonword repetition accuracy, implying that existing lexical representations may facilitate nonword repetition abilities or that the factors that contribute to vocabulary development also affect nonword repetition skills. We included a vocabulary measure in our battery so that we could gauge whether vocabulary mediates any relationship between our spoken language tasks and phonological awareness.

Letter knowledge. Several lines of evidence point to the significance of letter knowledge in the acquisition of reading. Illiterate adults have poor phoneme awareness, supporting the position that phoneme awareness is a consequence of learning to read an alphabetic orthography (Morais et al., 1979). A refinement by Barron (e.g., 1991, 1994), termed the proto-literacy hypothesis, proposes that the critical level of literacy for the inducement of phonemic awareness is merely letter knowledge as opposed to decoding ability. Barron suggested that a child who, for example, learns that A is /ae/ may be aware of /ae/ as an invariant segment of words, yet may be unable to recover the sequence of phonemes that a sequence of letters transcribes. Consistent with this proposal, Mann and Wimmer (2001) showed that phoneme awareness is almost completely lacking among German kindergartners, who identified only 28% of the letters, whereas it is quite well developed among American children, who identified 94% of the letters. In their data, there was an even closer connection between reading ability (in particular, phonological recoding ability) and phoneme awareness than between letter knowledge and phoneme awareness. A similar observation was reported by Bowey (1994). Mann and Wimmer also observed substantial individual variation among the kindergarten children. For example, one German child without any letter knowledge exhibited perfect performance on the phoneme judgment task. Nevertheless, the data, on average, are consistent with the possibility that phonological awareness is related to letter knowledge and with Barron's (1994) suggestion that knowledge of letter names may actually induce phoneme awareness. Previous research findings are also consistent with a view that both the acquisition of letter names and the emergence of phonological awareness are aided by a change in the strength of phonological representation. This change may allow children to distinguish among letter names and other highly similar words in the lexicon (see Walley, 1993); it may be easier for them to map orthography onto phonological representations that are well specified (Elbro et al., 1994). These considerations led us to include measures of letter knowledge and reading so that we could account for any relationship that might emerge between the speech and phonological awareness tasks.

Objectives of the present study

The literature suggests that there is a strong relation between phonological awareness and performance on tasks that purportedly tap into the strength of phonological representations. Few studies, however, have examined this relation in children just beginning to be exposed to the alphabetic principle, few have examined multiple tasks, and few have considered whether the relation depends on the type of awareness being measured. We attempt to identify how rhyme awareness and phoneme awareness relate to several spoken language tasks that purportedly measure phonological strength. We also measure vocabulary and letter knowledge, given their link to phonological awareness as well as to some of the spoken language tasks we employ.

We examine the following hypotheses. First, tasks that purportedly measure the strength of the phonological representations should be related to each other and to the children's phonological awareness. Second, the relation between the strength of phonological representations and performance on phonological awareness tasks should be a function of the level of awareness being assessed (rhyme vs. phoneme), especially given that phoneme awareness is clearly tied to literacy experience. Third, levels of performance as well as error patterns on spoken language tasks should be related to level of phonological awareness. Errors for less aware children should reflect holistic phonological representations, resembling those previously observed in children with SLI.

METHOD

Participants

A total of 40 children from three private preschools in Southern California volunteered for the study; all served with the written consent of their parents. The children ranged in age from 4 to 6 years. The schools all had language-based programs, but only one provided formal literacy training in specific letter–sound combinations. All but one of the readers were from this school. One child left the preschool before all of the tests could be administered; this child's data was excluded.

Materials

Reading. A composite score for the Word Identification (real words) and Word Attack (nonwords) subtests of the Woodcock Reading Mastery Test–Revised (Woodcock, 1987) was obtained as a measure of reading.

Vocabulary. The Vocabulary subtest from the Wechsler Preschool and Primary Scale of Intelligence (Wechsler, 1992) was used as a measure of expressive vocabulary. In this test of receptive vocabulary, the children were asked to give definitions for words of increasing difficulty.

Letter knowledge. The Letter Identification and Letter–Sound subtests of the Concepts about Print Test (Clay, 1979) were administered. This test involved identifying and naming upper and lower case letters in random order. In addition, letter–sound knowledge in four blends (Singson & Mann, 1999) was assessed. The letter knowledge score was the summed scores on the Letter Identification and Letter–Sound subtests.

Phonological awareness tests

Phoneme awareness. The composite phonemic awareness score was calculated by summing the raw scores on six phoneme manipulation subtests adapted from Singson and Mann (1999). These tests each consisted of two practice items and, with the exception of the first test, 10 test items. The tests were administered in standard order: phoneme judgment (real words for initial and final positions: 20 items), phoneme deletion (real words for initial and final positions), and phoneme substitution (nonsense words for initial and final positions). In the phoneme judgment test, the children were told that Morpo, a Martian puppet, wanted them to help him play "the sound game." Following demonstration and practice, the examiner presented a stimulus word and then two test words; the children were to respond with the word that started (initial) or ended (final) with the same sound as the target word. In the phoneme deletion task, the children were told that Morpo wanted to see what happened to the words when the first (initial) or last (final) sound was taken out. After demonstration and practice, the children were to respond by indicating how the word would sound when the target sound was removed from each word. In the phoneme substitution test, the children were told that the examiner liked the letter /k/ and were invited to "change the words from Morpo's planet" by changing the first (initial) or last (final) sound to /k/. Following demonstration and practice, the children were to respond by changing the nonsense words into nonsense words that began (initial) or ended (final) with /k/.

Rhyme awareness. The composite rhyme awareness score was derived by summing the raw scores on two rhyming tasks (following Singson & Mann, 1999). In the rhyme recognition task, adapted from Chaney (1992), the children were shown three pictures of objects, two of which had names that rhymed. They were asked to name the three objects and to point to the pictures that sounded "the same." After a demonstration and three practice trials, the children indicated their responses for eight trials by pointing. In the rhyme production tasks, the children were asked to answer the question "What word rhymes with ______?" for five trials consisting of common words (e.g., *hop*).

Phonological strength measures

Articulation test. The Goldman–Fristoe Test of Articulation (Goldman & Fristoe, 1986) was administered to each child. The responses were transcribed phonetically on-line and later analyzed off-line according to phonological process errors, using the Khan–Lewis Phonological Analysis (1986). (The Kahn–Lewis procedure identifies developmental and nondevelopmental phonological processes.) A licensed and certified speech–language pathologist performed the transcription and phonological analyses using standard phonetic transcription. The score on the articulation test reflected the number of errors made on phonemes identified for testing in the Goldman–Fristoe Test of Articulation. All errors on the Goldman–Fristoe Test of Articulation were classified according to the criteria identified by Kahn and Lewis (1986). Error types that involved manipulation, addition, or deletion of syllables or phonemes were used in this analysis. These errors included syllable reduction, addition of a phoneme, cluster simplification, and deletion of final consonants.

Picture naming speed. A modified version (Singson & Mann, 1999) of Elbro's (1990) naming task was used. It is a simple naming task using color pictures taken from magazines; these names are within the vocabulary of 5-year-old children. Pictures from the same semantic category (e.g., chair, sofa, table) were presented, three at a time, on a single card; the child was asked to name the objects depicted in the pictures as quickly as possible. The test had two trial items and 15 test items. If the child failed to name a picture, misnamed a picture, or took longer than 15 seconds to name the items on the card, the data from that item was disregarded in the naming data. The individual score was the average naming time in seconds.

Nonword repetition. A modified version of Children's Test of Nonword Repetition (Gathercole et al., 1994) was used to assess nonword repetition ability. To shorten the task, only the first five nonwords from the two-syllable, three-syllable, and four-syllable lists were presented to the children (see Appendix 1). According to Gathercole and colleagues, the phoneme sequences in each stimulus nonword conformed to the phonotactic rules of English, and within each number of syllables the items were constructed to correspond to the dominant syllable stress patterns in English for words of that length (SW for two-syllable nonwords, SWW for three-syllable nonwords, and variable stress patterns for four-syllable nonwords). Thus, the phoneme sequences for the nonwords were phonotactically and prosodically legal. Test–retest reliability was reported at .77. Pronunciation was modified for the American sample according to pronunciation by 10 adults. On-line scoring was reported at agreement on 97% of the items. Deletions, substitutions, and additions were all scored as errors. In line with previous studies of nonword repetition accuracy (Edwards & Lahey, 1998; Gathercole et al., 1994), if a child used consistent substitutions/distortions, these errors were not scored as incorrect in the nonword repetition task. A consistent error pattern was operationally defined as occurring in at least two word positions (initial, medial, and/or final) in the articulation test. Percentage of correct words (after Gathercole, Willis, Emslie, & Baddeley, 1992) was calculated. The repetition errors were also scored in terms of error patterns on the syllables (Gathercole et al., 1994). Three types of error patterns were observed: deletions, substitutions, and additions. No children used transpositions. These error patterns were then classified according to whether the error occurred in a syllable that was stressed or unstressed (after Wood & Terrell, 1998). A certified speech–language pathologist who was highly trained in phonetic transcription transcribed the responses on-line. Scores consisted of the percentage of correct words.

Phonological distinctness test. This task, modified from Elbro (1990), used English words (see Appendix 2) to measure the distinctness of unstressed vocalic segments in multisyllablic words. The child was shown a hand-held puppet (the alien, Morpo) and was told that the puppet had some difficulties with our language: he did not pronounce the words well. The experimenter showed an object to the puppet and the child and pronounced it "the way Morpo usually says it." The pronunciation was at a level of distinctness below the level for the least distinct child. For example, the word *crocodile* was pronounced [ka:di]. The child was asked to teach the puppet the correct pronunciation. The accuracy score was based on standard pronunciation according to 10 adult speakers of standard American dialect. The words selected for the task were all within the active vocabularies of 5- and 6-year-old children. The children's score on this test reflected the number of correct responses.

Speech discrimination task. The Test of Auditory Discrimination (Goldman, Fristoe, & Woodcock, 1970) was used to assess the children's ability to discriminate phonemes in a forced choice paradigm. The child was asked to discriminate between four pictures representing words that differed by a single phoneme (e.g., *lake, make, rake,* and *wake*); the child was to point to the picture that matched the spoken word. The spoken words were tape-recorded under quiet conditions and played to the child via bilateral headphones. There were a total of 30 items; the score was the number of errors. In addition, errors were analyzed in terms of voicing/unvoicing and manner of articulation (plosives, continuants, nasals), according to criteria established by the authors of the test.

Design and procedure

The children were tested individually in two separate 45-minute sessions. They were rewarded with stickers. The tests were administered in a standard sequence, following procedures described in the manuals for the standardized tests or published procedures for the nonstandardized tests (e.g., administration of the phoneme and rhyme awareness tests utilized procedures and instructions developed from Chaney, 1992).

RESULTS

Mean scores on each of the experimental measures appear in Table 1. We wanted to know whether phonological awareness (phoneme and rhyme awareness) was related to measures of phonological strength (articulation, distinctness, nonword repetition, naming, and speech discrimination) and whether the relation depended on age, vocabulary, and/or letter knowledge. To this end, we conducted a principal components analysis of scores on all of the measures, ANOVAs, and correlational evaluations (including hierarchical regressions).

Table 1. *Summary information on the major variables*

Variable	Mean	Standard deviation	Range
Age	4.86	0.67	3.6–6.2
Vocabulary	11.65	7.94	0–32
Reading	3.95	11.15	0–62
Letter knowledge	41.27	31.06	0–108
Speech discrimination errors	10.59	5.28	0–24
Rapid naming speed (seconds)	6.58	2.50	3.13–14
Pronunciation distinctness	7.05	2.99	0–11
Articulation errors	8.10	9.43	0–45
Nonword repetition accuracy	57.54	22.54	6.67–100
Phoneme awareness	9.23	13.70	0–58
Rhyme awareness	6.48	4.70	0–13

Table 2. *Principal components analysis of the cognitive data*[a]

Factor name	Percentage of variance explained	Items contributing to factor (component loadings)
Literacy	24.49	reading (.86), phoneme awareness (.82), letter knowledge (.75), age (.56), vocabulary (.53)
Speech production	23.12	articulation errors (–.90), distinctness (.90), and nonword repetition accuracy (.82)
Speech perception	21.43	digit span (.87), speech discrimination errors (–.69), rapid naming speed (–.56), rhyme awareness (.53), vocabulary (.50)

[a]with varimax rotation.

Construct validity of the measures

Our first hypothesis was that tasks that purportedly measure the strength of phonological representations would be related to each other and to phonological awareness and reading skill. A principal components analysis of the cognitive data (i.e., the phonological awareness tests, the phonological strength measures, and the vocabulary, digit span, reading, and letter naming scores) revealed that three independent factors accounted for 69.03% of variance (see Table 2). The first component, accounting for 24.49% of the variance, reflected phoneme awareness, literacy exposure, and cognitive factors. The second component, accounting for 23.12% of the variance, reflected articulation and nonword repetition abilities. The third component, accounting for 21.43% of the variance, reflected digit span, speech perception, vocabulary, and rhyme awareness skills. The phonological strength measures did not all load on the same factor. Likewise, phoneme awareness and rhyme awareness loaded on different factors.

Table 3. *Summary of major variables in the reading ability/phoneme awareness (PA) groups*

Variable	Readers ($n = 10$)		Nonreaders/PA ($n = 11$)		Nonreaders/ No PA ($n = 18$)	
Age***	5.53	(.46)	4.88	(.66)	4.49	(.49)
Vocabulary***	19.90	(9.89)	8.64	(4.82)	9.06	(5.06)
Reading***	15.8	(18.20)	0	(0)	0	(0)
Letter knowledge***	84.11	(13.14)	30.55	(20.53)	25.53	(21.11)
Speech discrimination errors*	7.30	(3.47)	10.45	(5.41)	12.50	(5.35)
Rapid naming speed*	4.70	(.88)	6.99	(1.96)	7.37	(2.92)
Pronunciation distinctness	8.30	(1.89)	7.45	(2.66)	6.11	(3.46)
Articulation errors	2.70	(5.40)	7.54	(5.33)	11.44	(11.73)
Nonword repetition accuracy	9.50	(3.31)	8.30	(3.06)	8.11	(4.51)
Phoneme awareness***	24.80	(17.56)	10.18	(6.27)	0	(0)
Rhyme awareness*	9.40	(3.50)	7.00	(4.75)	4.56	(4.53)

*$p < .05$; ***$p < .001$.

Relation of phonological awareness measures to phonological strength measures

To investigate this question more fully, we considered the mean performance differences between children who possessed no demonstrable awareness, those who possessed a level of awareness but were not able to read, and those who possessed a level of awareness and were able to read at least one word. These analyses were driven by the realization that the pattern of scoring on the phonological awareness tests was discontinuous. On the phoneme awareness test, 18 children achieved a score of zero on the composite phoneme awareness measure; the 21 children who did achieve a positive score were subsequently divided into two groups on the basis of whether they were able to read at least one word (readers) or not (nonreaders). On the rhyme awareness test, participants were initially divided into a high or low awareness group on the basis of a median split ($Md = 3$) of the composite rhyme awareness measure. We then divided the high rhyme awareness group into readers and nonreaders. The readers group consisted of children who were able to read at least one word; the nonreaders group consisted of children who scored above the median. The low rhyme awareness group consisted of nonreaders who scored at or below the median. Mean scores for these groups appear in Tables 3 and 4. We conducted separate analyses for phoneme awareness and rhyme awareness, under the assumption that these types of phonological awareness may represent distinct skills; we were motivated to do this by the results of our factor analysis, which showed that these awareness measures loaded on separate factors.

Phoneme awareness. A multivariate one-way ANOVA revealed that the three groups who differed in phoneme awareness and reading ability also differed significantly in age, $F(2, 38) = 11.912$, $p < .0001$; letter knowledge, $F(2, 34) =$

Table 4. *Summary of major variables in the reading ability/rhyme awareness (RA) groups*

Variable	Readers ($n = 9$)		Nonreaders/ High RA ($n = 12$)		Nonreaders/ Low RA ($n = 18$)	
Age***	5.36	(.57)	4.80	(.64)	4.42	(.54)
Vocabulary***	19.67	(10.46)	10.48	(5.74)	6.67	(3.57)
Reading***	17.44	(18.49)	0	(.22)	0	(0)
Letter knowledge***	87.38	(9.36)	33.86	(20.54)	14.63	(16.17)
Speech discrimination errors*	7.33	(3.67)	9.38	(4.43)	16.67	(3.57)
Rapid naming speed*	4.67	(.93)	6.47	(2.14)	8.75	(2.84)
Pronunciation distinctness	8.22	(2.00)	7.76	(2.43)	8.75	(2.83)
Articulation errors	3.00	(5.63)	6.48	(4.72)	17.00	(14.49)
Nonword repetition accuracy	9.22	(3.38)	9.80	(2.80)	5.00	(4.36)
Phoneme awareness***	25.89	(18.26)	5.05	(7.04)	2.33	(4.80)
Rhyme awareness*	9.33	(3.70)	7.76	(3.95)	5.00	(4.36)

*$p < .05$; ***$p < .001$.

29.383, $p < .0001$; vocabulary, $F(2, 38) = 10.480$, $p < .0001$; speech discrimination, $F(2, 38) = 3.532$, $p < .05$; rapid naming, $F(2, 38) = 4.607$, $p < .05$; rhyme awareness, $F(2, 38) = 4.071$, $p < .05$; and phoneme awareness, $F(2, 38) = 22.549$, $p < .001$. Post-hoc tests (Tukey HSD) confirmed that all three groups differed from one another on phoneme awareness, as expected, and that the readers group differed from both nonreaders groups on age, letter knowledge, vocabulary, and rapid naming speed (Dunnett T3). However, for nonreaders, there were no significant differences between children with phoneme awareness skills and those with no awareness.

To explore the relation between phoneme awareness abilities and phonological strength measures, we conducted zero-order correlations. We found that phoneme awareness was significantly negatively correlated with rapid naming ability and overall speech discrimination errors (see Table 5). In a series of hierarchical regression analyses, controlling for age, vocabulary, and letter knowledge, none of the phonological strength measures accounted for additional variance in phoneme awareness (see Table 5) when age, vocabulary, and letter knowledge were partialed out. Age ($R^2 = .178$, $p < .01$) and, more strongly, letter knowledge ($R^2 = .373$, $p < .001$) and vocabulary ($R^2 = .418$, $p < .0001$) seemed to be the primary factors behind individual differences in phoneme awareness, mediating the relationship between phoneme awareness, naming, and speech discrimination. Consistent with this finding, phoneme awareness correlated with reading in zero-order correlations ($r = .604$, $p < .0001$), independent of age ($\Delta R^2 = .212$, $p < .001$), vocabulary ($\Delta R^2 = .235$, $p < .001$), and letter knowledge ($\Delta R^2 = .079$, $p < .05$).

Rhyme awareness. A multivariate one-way ANOVA conducted on the three groups who differed in rhyme awareness and reading ability (see Table 4) re-

Table 5. *Zero-order* (r) *and partial correlations* (β) *between phonological awareness measures and phonological strength measures when age* (*step 1*), *vocabulary* (*step 2*), *and letter knowledge* (*step 3*) *are partialed out*

Predictor variable	Phoneme awareness (β)				Rhyme awareness (β)			
	r	Step 1	Step 2	Step 3	*r*	Step 1	Step 2	Step 3
Articulation errors	.218	−.048	−.003	.074	−.423**	−.234	−.287	−.206
Pronunciation distinctness	.165	.039	−.074	−.158	.416**	.274	.271	−.158
Speech discrimination errors	−.407**	−.289	−.133	−.085	−.585**	−.422**	−.446**	−.367*
Nonword repetition accuracy	.192	.113	−.087	.056	.422**	.298*	.242	.302*
Rapid naming speed	−.436**	−.307	−.161	−.161	−.370*	−.152	−.165	−.185

*$p < .05$; **$p < .01$.

vealed significant group differences for age, $F(2, 39) = 5.969$, $p < .01$; vocabulary, $F(2, 38) = 9.234$, $p < .001$; speech discrimination, $F(2, 38) = 13.687$, $p < .0001$; rapid naming, $F(2, 38) = 8.295$, $p < .001$; pronunciation distinctness, $F(2, 38) = 6.980$, $p < .01$; articulation, $F(2, 38) = 7.583$, $p < .01$; nonword repetition, $F(2, 37) = 6.626$, $p < .0001$; phoneme awareness, $F(2, 38) = 15.429$, $p < .0001$; rhyme awareness, $F(2, 38) = 17.332$, $p < .0001$; and letter knowledge, $F(2, 36) = 37.240$, $p < .0001$. Post-hoc tests (Tukey HSD) revealed that all three groups were significantly different from one another ($p < .05$) on letter knowledge. The readers and nonreaders/high awareness groups were significantly different from the nonreaders/low awareness group, but were not significantly different from one another in vocabulary, speech discrimination, rapid naming, pronunciation distinctness, articulation, and rhyme awareness. We found significant differences between the readers and nonreaders/low awareness groups for age and between the nonreaders/low awareness and nonreaders/high awareness groups for phoneme awareness (see Table 6).

In zero-order correlations, rhyming ability was significantly negatively correlated with rapid naming speed, speech discrimination errors, and articulation errors and positively correlated to pronunciation distinctness and nonword repetition ability (see Table 5). Hierarchical regressions, separately removing the effects of age, vocabulary, and letter knowledge, were conducted to examine whether any of these variables mediated the relationship between rhyme awareness and these measures. Speech discrimination remained a significant predictor of rhyme awareness (see Table 5), independent of age, vocabulary, and letter knowledge. Rapid naming, pronunciation distinctness, and articulation did not account for significant additional variance when the effects of vocabulary ($R^2 =$

Table 6. *Articulation, speech discrimination, and nonword repetition error patterns in children grouped by reading ability and level of phoneme awareness (PA), indicated by means (SD)*

Error pattern	Readers		Nonreaders/PA		Nonreaders/ No PA	
Articulation errors						
Syllable reduction	0	(0)	.36	(.92)	.72	(1.59)
Phoneme addition	0	(0)	.18	(.60)	.22	(.55)
Final consonant deletion	0	(0)	.18	(1.78)	.89	(3.53)
Cluster simplification	.30	(.95)	.82	(1.78)	1.44	(3.71)
Speech discrimination errors						
Voiced*	4.50	(2.87)	6.09	(3.27)	7.72	(3.34)
Unvoiced	2.80	(1.14)	4.36	(2.58)	4.78	(2.65)
Plosives*	2.60	(1.35)	3.91	(2.26)	4.94	(2.58)
Continuants*	3.20	(1.75)	4.82	(2.52)	5.39	(2.48)
Nasals	1.33	(1.33)	1.73	(1.19)	2.17	(1.20)
Nonword repetition errors						
Stressed substitution	0	(0)	.22	(.44)	.11	(.47)
Unstressed substitution	.20	(.63)	.22	(.44)	.01	(.24)
Stressed deletion	.20	(.42)	.67	(1.00)	.11	(.32)
Unstressed deletion	.50	(.71)	1.22	(1.09)	1.17	(1.43)
Stressed addition	.10	(.32)	0	(0)	0	(0)
Unstressed syllable addition	.10	(.32)	0	(0)	0	(0)

$^*p < .05$.

.255, $p < .001$), age ($R^2 = .298$, $p < .0001$), and letter knowledge ($R^2 = .336$, $p < .0001$) were removed. The contribution of nonword repetition to rhyme awareness was independent of age and letter knowledge, but vocabulary apparently mediated the relation between rhyme awareness and nonword repetition. Like phoneme awareness, rhyme awareness predicted reading in zero-order correlations ($r = .311$, $p = .05$). However, hierarchical regression analyses, partialing out the effects of age, vocabulary, and letter knowledge, revealed that for rhyme awareness this effect was not independent of age ($\Delta R^2 = .007$, *ns*), vocabulary ($\Delta R^2 = .022$, *ns*), or letter knowledge ($\Delta R^2 = .007$, *ns*).

Error analysis

Our final hypothesis was that a pattern of speech production and speech perception errors would distinguish children with high phonological awareness abilities from those with low abilities. To this end, we examined the relation of error patterns to phonological awareness separately for phoneme awareness and rhyme awareness.

Phoneme awareness and articulation errors. When we divided the children into three groups on the basis of their reading ability and phoneme awareness com-

Table 7. *Zero-order* (r) *and partial correlations* (β) *between phonological awareness measures and speech production and perception error patterns when age* (*step 1*), *vocabulary* (*step 2*), *and letter knowledge* (*step 3*) *are partialed out*

	Phoneme awareness (β)				Rhyme awareness (β)			
Error pattern	*r*	Step 1	Step 2	Step 3	*r*	Step 1	Step 2	Step 3
Articulation errors								
Syllable reduction	–.205	–.220	–.062	–.025	–.419**	–.438**	–.331*	–.293*
Phoneme addition	–.098	–.079	.123	.040	–.129	–.106	.022	–.011
Final consonant deletion	–.118	–.045	–.044	.035	–.216	–.130	–.165	–.091
Cluster simplification	–.099	.029	–.020	.078	–.318	–.181	–.266	–.191
Speech discrimination errors								
Voiced	–.403*	–.289	–.160	–.078	–.593***	–.457**	–.463**	–.371*
Unvoiced	–.324*	–.208	–.049	–.066	–.443**	–.297*	–.275	–.240
Plosives	–.401*	–.292	–.090	–.088	–.561***	–.427**	–.410**	–.354*
Continuants	–.381*	–.249	–.132	–.095	–.520***	–.354*	–.373*	–.295
Nasals	–.249	–.184	–.114	–.005	–.416**	–.335*	–.322*	–.208

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

posite scores (see Table 6), it was apparent that none of the readers used the phonological processes of syllable reduction, addition of a phoneme, or deletion of a final consonant, whereas some children in the nonreaders groups did use these processes. Cluster simplification was the only error pattern used by readers in this analysis, and it was also the process most frequently used by children in the nonreaders groups.

Zero-order correlations revealed that there were no significant correlations between articulation error patterns and phoneme awareness scores (see Table 7). Hierarchical regression analyses, which predicted phoneme awareness from articulation error patterns by partialing out the effects of age, vocabulary, and letter knowledge, did not change this relationship.

Phoneme awareness and speech discrimination errors. A multivariate ANOVA followed by Tukey HSD tests revealed that readers made significantly fewer errors than nonreaders on voiced, plosive, and continuant sounds (see Table 6). Nonreaders with moderate or no phoneme awareness were not distinguished by their speech discrimination scores.

Voiced, unvoiced, plosive, and continuant errors on the speech discrimination task were all significantly correlated with phoneme awareness scores (see Table 7). To examine the relation between phoneme awareness and speech perception,

Table 8. *Articulation, speech discrimination, and nonword repetition error patterns in children grouped by reading ability and level of rhyme awareness (RA), indicated by means (SD)*

Error pattern	Readers ($n = 9$)		Nonreaders/RA ($n = 12$)		Nonreaders/ No RA ($n = 18$)	
Articulation errors						
Syllable reduction***	0	(0)	.1	(.31)	1.67	(1.94)
Phoneme addition	0	(0)	.15	(.49)	.33	(.71)
Final consonant deletion	0	(0)	0	(0)	1.78	(4.97)
Cluster simplification*	.30	(.95)	.35	(.59)	3.11	(5.18)
Speech discrimination errors						
Voiced***	4.50	(2.87)	5.71	(2.95)	10.00	(2.06)
Unvoiced***	2.80	(1.15)	3.67	(2.20)	6.67	(2.12)
Plosives***	2.60	(1.35)	3.57	(2.13)	6.67	(1.66)
Continuants***	3.20	(1.75)	4.24	(2.34)	7.00	(1.66)
Nasals	1.33	(1.33)	1.57	(1.03)	3.00	(.87)
Nonword repetition errors						
Stressed substitution	0	(0)	.22	(.44)	.11	(1.47)
Unstressed substitution	.20	(.63)	.22	(.44)	.01	(.24)
Stressed deletion	.20	(.42)	.67	(1.00)	.11	(.32)
Unstressed deletion	.50	(.707)	1.22	(1.093)	1.17	(1.43)
Stressed addition	.10	(.316)	0	(0)	0	(0)
Unstressed syllable addition	.10	(.316)	0	(0)	0	(0)

*$p < .05$; ***$p < .001$.

we conducted a series of hierarchical regression analyses, controlling for age, vocabulary, and letter knowledge. Hierarchical regression analyses, which predicted phoneme awareness from speech discrimination error patterns by partialing out the effects of age, vocabulary, and letter knowledge, showed that the relation between error patterns and phoneme awareness was mediated by age, vocabulary, and letter knowledge, confirming the results of the categorical analysis in the ANOVA (see Table 8).

Phoneme awareness and nonword repetition errors. There were no significant group differences between the reading ability/phoneme awareness groups for the various types of nonword repetition errors (see Table 6). However, it should be noted that nonreaders never made syllable (stressed or unstressed) additions, whereas a few readers did.

Rhyme awareness and articulation errors. Multivariate ANOVAs and subsequent Tukey HSD tests showed that children with low rhyme awareness scores made significantly more syllable reduction and cluster simplification errors (see Table 8) than children with higher rhyme awareness scores, regardless of whether they were readers.

Zero-order correlations revealed that syllable reduction errors significantly predicted the composite rhyme awareness score (see Table 7). Hierarchical regression analyses, which removed the effects of age, vocabulary, and letter knowledge, showed that the relation between syllable reduction errors and rhyme awareness was independent of age, vocabulary, and letter knowledge (see Table 7).

Rhyme awareness and speech discrimination errors. Multivariate ANOVAs with subsequent Tukey HSD tests revealed that the reading ability/rhyme awareness groups were significantly different from one another on each of the error types examined in the speech discrimination task (voiced, unvoiced, plosive, continuant, and nasal sounds) (see Table 8).

Zero-order correlations (Table 7) revealed that rhyme awareness was significantly correlated with all speech perception errors examined in the study, confirming the results of the ANOVA. Hierarchical regression analyses of the error types on the speech discrimination test revealed that the relation between rhyme awareness and voiced and plosive speech discrimination errors was independent of age, vocabulary, and letter knowledge (see Table 7). In addition, the relation between continuant and nasal sound discrimination errors and rhyme awareness was independent of age and vocabulary but not letter knowledge. The relation between rhyme awareness and unvoiced speech perception errors was mediated by vocabulary and letter knowledge but independent of age.

Rhyme awareness and nonword repetition errors. Paralleling the results for the reading ability/phoneme awareness groups, we found no significant group differences between the reading ability/rhyme awareness groups for the various types of nonword repetition errors we examined (see Table 8).

In summary, our analyses revealed that the speech tasks mapped onto more than one factor, challenging the notion that they measured a unitary factor relating to phonological strength. Moreover, the different tasks bore different relations to rhyme awareness and phoneme awareness. Additional analyses confirmed this in that the pattern of production and perception errors was directly linked to rhyme awareness but indirectly linked to phoneme awareness through the mediation of vocabulary and letter knowledge.

DISCUSSION

This study was designed to investigate the relationship between phonological awareness abilities and performance on measures of speech perception, speech production, and naming tasks. A primary objective was to address the hypothesis that phonological awareness abilities were associated with measures that purportedly tap into the strength of phonological representations. A second objective was to ask whether this relationship depended on the level of awareness being examined and the literacy and prereading skills. A third objective was to discern whether levels of awareness were associated with certain error patterns as well as levels of performance. Our results challenged a simplistic notion that strength of phonological representation is the common denominator underlying speech perception, speech production, naming, and phonological awareness. We discovered that phoneme awareness and rhyme awareness are differentially associated with speech perception, articulation, naming, vocabulary, and literacy skills. In this respect, our results are consistent with a view that phoneme and rhyme awareness skills represent separable components of phonological awareness (Hoien, Lundberg, Stanovich, & Bjaalid, 1995; Smith, Simmons, & Kameenui, 1998; Treiman & Zukowski, 1991).

Tasks that drew upon speech perception, speech production, and, to some extent, naming were more directly associated with rhyme awareness than phoneme awareness. The relation between these abilities and true phoneme awareness appeared to be mediated by age, vocabulary, and letter knowledge. The older children in our study, who undoubtedly had been exposed to more vocabulary and letter instruction than the younger children, had better phoneme awareness abilities. Phoneme awareness, in turn, was associated with reading ability, and error patterns in perception and articulation appeared to be a function of reading ability rather than phoneme awareness per se. This is consistent with previous findings that phoneme awareness skills are strongly associated with cognitive abilities that are relatively dependent on formal instruction (Lonigan, Burgess, Anthony, & Barker, 1998; Mann & Wimmer, 2001; McBride-Chang, Manis, & Wagner, 1996; McBride-Chang et al., 1997; Wagner et al., 1987). In contrast, the spoken language resources on which rhyme awareness tasks drew appeared to be less influenced by letter knowledge and vocabulary (see also Dale, Crain-Thoreson, & Robinson, 1995; Johnston, Anderson, & Holligan, 1996; Morais, 1991; Smith et al., 1998; Stahl & Murray, 1994). Our findings thus suggest that rhyme awareness tasks are better preschool measures of inherent differences in underlying phonological processing, and that phoneme awareness tasks are more determined by exposure to literacy.

In the correlational analyses, speech discrimination and nonword repetition stood out as the most significant correlates of rhyme awareness. Can reference to the concept of phonological representation explain this result? It is problematic that these skills loaded on different factors. It is also problematic that vocabulary was more tied to the association between rhyme awareness and nonword repetition than to that between rhyme awareness and perception. We might try to save the notion of "strength of phonological representation" by speculating that perception and repetition are different tasks with an important commonality: both require children to form stable, highly discriminable representations of spoken input. Children with SLI (Edwards & Lahey, 1998) and some dyslexic children (Manis et al., 1997) have been found to have holistic representations, as evidenced by their behavior in such challenging conditions as occur in nonword repetition and speech discrimination tasks. Perhaps a similar phenomenon might occur in young children with weak rhyme awareness skills; under stressed conditions, the acoustic signal may lead to a single holistic representation, as opposed to a discrete sequence of phonological representations. Initially, the holistic representation may be an entire word, whereas discrete analyses may involve onset–rime sequences, thus paving the way for rhyme awareness and superior performance on perception and nonword repetition.

In this view, then, perception, naming, and rhyme awareness are individually variable in the preschool years because children are undergoing a shift from holistic to segmental representation of incoming speech. A somewhat related view is that learning to read somehow changes the nature of the child's analysis of speech so that, once the alphabetic code is internalized by the child, a more discrete analysis would involve an analysis of phonemes (see Ehri & Wilce, 1980; Metsala, 1997; McBride-Chang & Ho, 2000). Our analysis of perception and production errors is consistent with this in showing a different pattern of errors among readers as compared to nonreaders with phoneme awareness. In this case, literacy exposure would have altered not only phoneme awareness, but also perception and production, and it would mediate the association between them. However, as parsimonious as it may be to think that reading changes the internal representation of speech, this view begs an explanation for why phoneme awareness can arise in the absence of literacy exposure (see, e.g., Bradley & Bryant, 1978; Lundberg et al., 1980; Mann, 1986, 1991). It also begs the issue of how orthographies arise in the first place. Puzzles such as this challenge a simplistic view that literacy acquisition is the impetus behind a change from holistic to segmental representations.

APPENDIX 1

PRONUNCIATION FOR THE NONWORD STIMULI IN THE NONWORD REPETITION TASK

Two syllables

ballop	/bæləp/
bannow	/bæno/
diller	/dɪlɚ/
glistow	/glɪsto/
hampent	/hæmpənt/

Three syllables

bannifer	/bænɪfɚ/
barrazon	/bɛrəzən/
brasterer	/bræstɚrɚ/
commerine	/kamərain/
doppelate	/dapəleit/

Four syllables

blonterstaping	/blantəsteipɪŋ/
commeecitate	/kəmisɪteit/
contramponist	/kəntræmpənɪst/
empliforvent	/ɛmpliforvənt/
fenneriser	/fɛnəraizɚ/

APPENDIX 2

STIMULI FOR THE PRONUNCIATION DISTINCTNESS TASK

Object	*Stimulus*
broccoli	bro-li
dinosaur	die-saur
battery	bat-ty
kangaroo	ka-roo
butterfly	bu-fly
crocodile	co-di
chocolate	cho-late
ambulance	am-lan
telephone	te-pho
camera	ca-ra

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