Journal of Research in Reading, ISSN 0141-0423 *DOI: 10.1111/j.1467-9817.2006.00323.x*
Volume 30, Issue 2, 2007, pp 169–183

Rhythm and reading development in school-age children: a longitudinal study

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Rhythm production in 53 children in grade 1 was investigated as a predictor of reading ability in the same children in grades 1–5. This paper reports the results of correlations and hierarchical regression analyses, controlling for shared variance between phonological awareness and naming speed. Rhythm was correlated significantly with both phonological awareness and naming speed. Rhythm predicted significant variance in reading ability at each grade level. Once phonological awareness was controlled, however, rhythm was a significant predictor only in grade 5. When naming speed was controlled, rhythm predicted unique variance in reading ability in grades 2, 3 and 5. Implications for the relationship between rhythm and the development of reading skills are discussed.

Recent research has concentrated on finding the underlying cognitive processes related to reading in order to determine possible predictors of reading ability (e.g. Schatschneider, Fletcher, Francis, Carlson & Foorman, 2004; Wagner & Torgesen, 1987). This is important because children who are poor readers in the primary grades have been found to remain poor readers in later grades (Francis, Shaywitz, Stuebing, Shaywitz & Fletcher, 1996). Currently, the most thoroughly researched cognitive processes are phonological awareness and naming speed, both of which are considered to be robust predictors of reading ability (Wolf & Bowers, 1999).

Phonological awareness has to do with the understanding that language can be broken down into smaller units of sound and manipulated (Shankweiler & Fowler, 2004). Furthermore, there are many levels at which this awareness can be realised. Children first develop awareness for syllables, followed by awareness for onset and rime (the onset is the initial consonant phonemes in any syllable, while the rime is the vowel plus the consonants that follow), and lastly, awareness for the smallest unit of speech, the phoneme (Goswami, 2002). Phonological awareness tasks include manipulations at all three levels.

There is a strong relationship between phonological awareness and reading ability as children who are poor readers are significantly worse than their peers on tests of phonological awareness (Wagner & Torgesen, 1987; Wagner, Torgesen & Rashotte, 1999). Children who demonstrate difficulty on tests of phonological awareness prior to formal schooling are at risk of becoming poor readers while those who do well on such tests are likely to become stronger readers (Bradley & Bryant, 1983). Even more, researchers have shown that the relationship between phonological awareness and reading continues throughout the school years (Shankweiler et al., 1995). A research consensus agrees that, with letter knowledge, phonological awareness is the strongest predictor of reading ability (Rayner, Foorman, Perfetti, Pesetsky & Seidenberg, 2001).

Another robust predictor of later reading is rapid automatised naming (RAN). Tests of RAN involve presenting a subset of familiar visual symbols from a certain category (i.e., alphanumeric, colours, objects) in a randomised serial array and having individuals name the items across the rows as quickly as possible (Savage, 2004). It has been argued that both naming speed and reading involve matching visual stimuli to phonological codes and saying them out loud in a specific timed manner (Wolf & Bowers, 1999). Not only has naming speed been found to relate directly to reading ability, but it has also been suggested that it plays a causal role in reading disability (Wolf & Bowers, 1999). There is no consensus on the fundamental nature of RAN, and why dyslexic readers are often slower than typical readers at rapid naming tasks. One hypothesis is that RAN is a linguistic process that is primarily phonological in nature (e.g. Bowey, McGuigan & Ruschena, 2005; Wagner & Torgesen, 1987), and therefore the slow naming speed observed in dyslexics is an expression of a larger phonological deficit. An alternative account has it that slow naming speed in dyslexics reflects a linguistic manifestation of a more general speed of processing deficit. Related to this is the notion that processing two or more stimuli presented sequentially, especially with short interstimulus intervals, is particularly problematic for dyslexics (Overy, Nicolson, Fawcett & Clarke, 2003; Tallal, Merzenich, Miller & Jenkins, 1998). Evidence for such a deficit has been observed in the auditory (Tallal et al., 1993), visual (Farmer & Klein, 1993) and motor (Nicolson & Fawcett, 1994; Wolff, 1993) domains.

Researchers have debated whether naming speed and phonological awareness are fundamentally part of the same construct, in that naming speed is primarily a phonological task that can be seen as the 'retrieval of phonological codes from a long-term store' (Wolf & Bowers, 1999). Evidence supporting a relationship between naming speed and phonological awareness is somewhat inconsistent, as some researchers have found strong correlations (e.g. Wagner, Torgesen & Rashotte, 1994), while the majority have found only moderate ones (e.g. Morris et al., 1998; Savage, 2004). Nonetheless, Wagner et al. (1994) found that the strong correlations between phonological awareness and naming speed disappeared over time. Evidence supports the notion that naming speed and phonological awareness measure different constructs as both uniquely predict and contribute to reading ability (Morris et al., 1998; Savage, 2004; Wolf & Bowers, 1999). Functional magnetic resonance imaging has shown that both phonological awareness and naming speed activate neurological networks in the brain that are related to reading, and yet different from each other (Misra, Katzir, Wolf & Poldrack, 2004).

Despite the substantial literature showing the power of phonological awareness and RAN to predict reading performance, research continues to investigate the nature of these factors and to search for other factors that can explain the remaining variance in reading that these factors cannot account for. A candidate for further investigation is rhythm. There are a number of reasons for us to consider rhythm as a potentially influential factor in reading development.

Rhythm is an important part of language, becoming salient almost from birth, as evidenced by newborns' ability to discriminate languages based on their rhythmic class (i.e., English, Dutch [stress-based] vs Japanese [mora-based], Nazzi, Bertoncini & Mehler, 1998). Researchers suggest that the strong–weak pattern of stressed syllables typical of English is used by infants as young as 7.5 months to segment words in continuous speech (Jusczyk, Houston & Newsome, 1999). Verbal communication with an infant has been termed musical speech as it consists of high pitch, slow tempo, repetition and changes in tone (Anvari, Trainor, Woodside & Levy, 2002), and newborn infants tend to respond better to the inviting rhythm of musical speech (Balkwill & Thompson, 1999). Linguistic rhythm manifested through stress is also used as a cue to facilitate speech segmentation in adults, especially in stress-timed languages such as English and Dutch (e.g. Cutler & Norris, 1988). Rhythmic information can also be lexically contrastive, as can be seen in the minimal pair *dessert/desert*, which differ only in the relative emphasis of the syllables. There is increasing interest in the notion that rhythm may play a role in reading development.

A handful of studies have investigated the role of rhythm in reading directly. Wood and Terrell (1998) conducted a study investigating relationships among a variety of speech perception tasks and reading ability. They had three groups in their study: poor readers (mean age = 9 years), age-matched controls (mean age = 9 years) and reading-age-matched controls (mean age = 6.4 years). The authors examined children's ability to match a low-pass-filtered sentence to a sentence with the same stress pattern. A low-pass-filtered sentence is one where the phonemic and lexical characteristics of the sentence are removed and only the prosodic contour of the utterance remains. The participants were presented with a low-pass-filtered sentence, followed by two regular sentences with the same number of syllables, one of which also matched in terms of metrical stress pattern. Wood and Terrell found that the poor readers had the lowest scores on this task, followed by the reading age controls and then the age-matched controls. After controlling for vocabulary, a significant difference still remained between the poor readers and the age-matched controls, but not between the poor readers and reading-age-matched controls, thus suggesting that a maturational lag might exist. Wood and Terrell concluded that sensitivity to lexical rhythm in speech is necessary before progressing to phonemic awareness and reading. In addition, Wood (2004) found that children's sensitivity to changes in stress was related to reading ability.

Goswami and her colleagues have also demonstrated that sensitivity to rhythm is related to reading ability in good and poor readers. This work suggests that, in order to achieve phonological awareness, children must be sensitive to the rise time of the amplitude envelope in speech (Goswami et al., 2002). Rise time is associated with the perceptual centre (p-centre) of the syllable; for the speaker/hearer, it captures the 'subjective moment of occurrence' (Scott, 1998) of syllabic rhythm. In the studies conducted by Goswami and her colleagues (e.g. Goswami et al., 2002; Muneaux, Ziegler, Truc, Thomson & Goswami, 2004; Richardson, Thomson, Scott & Goswami, 2004), the percept associated with changes in rise time was variation in rhythmic beat. The beat detection task used in Goswami's studies was associated with significant amounts of variance in a variety of literacy and literacy-related tasks including word reading, spelling and phonological awareness (rime oddity). Poor readers were significantly less sensitive to changes in rise time than their chronological- and reading-age-matched peers, and precocious readers were the most sensitive of all groups to beat variation (Goswami et al., 2002). Interestingly, this phenomenon does not appear to be restricted to stress-timed languages like English; the effect was also observed in French, a syllable-timed language (Muneaux et al., 2004).

A more common approach to the study of rhythm and reading is mediated through musical tasks. Peynircioglu, Durgunoglu and Oney-Kusefoglu (2002) found that musical aptitude has a strong link with phonological awareness in children between the ages of 3 and 6 years, as they further proposed that having a high musical aptitude appears to enhance children's ability to manipulate sound. Adult musicians with dyslexia report particular difficulties with rhythm (Ganschow, Lloyd-Jones & Miles, 1994).

Anvari et al. (2002) presented preschool children with two computer-generated rhythmic patterns with instructions to determine whether the two rhythms were the same or different and also had children orally reproduce rhythmic patterns (e.g. la la LA la), among other tasks measuring melody discrimination, chord discrimination and chord analysis. Factor analysis revealed a single music factor for 4-year-old children, and two factors relating to pitch perception and rhythm perception for the 5-year-old children. In terms of reading ability, factor analysis revealed one factor for phonemic awareness tasks in both 4- and 5-year-olds. Overall, Anvari et al. found that reading awareness and phonological awareness were correlated, as were the musical factors with phonemic awareness in both age groups. However, the music factor was related to reading in the 4-year-olds, while in the 5-year-olds, pitch perception was related to reading while rhythm perception was not. Furthermore, a hierarchical regression revealed that music was predictive of reading ability beyond phonological awareness in 4-year-olds as was pitch perception in 5-year-olds (rhythm was not entered in the 5-year-olds' regression analysis as it was not correlated with reading ability). The researchers noted that within the context of their study, it is unclear as to why rhythm was not related to the latter age group. We suggest that one possibility for this negative finding is the nature of the reading outcome measures. Anvari et al. measured reading ability with the WRAT-3, which begins with a string of 15 letters to be identified before moving on to word identification. That is, even though there is variability on the measure, the majority of scores represent letter identification as opposed to actual word-reading ability. Therefore, it might be the case that rhythm ability plays a stronger role in relation to reading ability when the task involves decoding or word recognition rather than letter identification. This notion is supported by the findings of Atterbury (1985) and Douglas and Willats (1994). In the former, studying children between the ages of 7 and 9 years, the authors found that poor readers, compared with normal readers, were impaired in rhythm production, measured by the ability to clap back a set rhythm. Also, Douglas and Willats (1994), using the same task later used by Anvari et al. (2002), found that rhythm discrimination correlated with reading ability in 7- and 8-year-old children. Similarly, Overy et al. (2003) found that dyslexic children were significantly less able to perform musical rhythm tasks than age-matched controls, although they were significantly better than control children at tasks involving musical pitch.

In sum, evidence supports the notion of a relationship between rhythm and reading, but little attention has been paid to the question of whether sensitivity to rhythm can predict reading development beyond the contribution of more traditional variables. The present research seeks to determine whether rhythm does uniquely predict young children's reading, beyond phonological awareness and naming speed, through a 5-year longitudinal study. No known study has investigated such a longitudinal relationship controlling for, and examining the relationships with, phonological awareness and naming speed. Therefore, an original contribution of this study is the ability to track the contribution of rhythm to reading as it develops over 5 years of school, and the role of rhythm as a predictor in combination with the more traditional variables of phonological awareness and RAN. Of interest is whether a relationship exists between rhythm in grade 1 and concurrent tasks of phonological awareness, naming speed, word reading and pseudoword reading. Based on current research evidence supporting a link between rhythm and both phonological awareness and RAN, it is hypothesised that correlations between these factors will be observed in the present study. We also expect to uncover a relationship between rhythm and reading, consistent with the findings of the studies reviewed here.

Method

Participants

Fifty-three children (31 males, 22 females; mean age = 76.1 months, *SD* = 3.4 months) began the study in the fall of grade 1. The children were tested again in the fall of grades 2–5. Over the last 3 years, attrition reduced the sample to 47, 44 and 38. The participants were drawn from three schools in Eastern Ontario, Canada, representing a range of socioeconomic backgrounds. The majority of the participants were Caucasian, which is in line with the population residing in the region that was investigated. All participants had informed parental consent and were able to understand task instructions.

Measures and procedure

All tests were administered at a time convenient to the classroom teacher. The researcher worked one on one with the participant in a quiet place so as to ensure minimal distraction. All tests involved practice trials and no test was administered until the researcher was positive that the participant fully understood the instructions.

Phonological awareness. In grade 1, five measures of phonological awareness were administered (Sound Oddity was taken from Bradley & Bryant, 1983, and the remaining four were taken from Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993). *Sound Oddity* requires the participant to listen to three words, two of which share a phoneme, and to identify which word out of the three was the 'odd one' (e.g. *pig*, *pen*, *hall*). There were six practice items and 30 test items. *Blending Phonemes* requires the participant being asked to combine individual phonemes together to form a complete word (e.g. 'What word does /ch/ - /ai/ - /r/ say?'). This task consisted of six practice items and 15 test items. For *Blending Onset and Rime*, the participant is presented with the first consonant in a word (onset) and then the rime with the instructions to put the two together to form one complete word (e.g. 'What word does /d/ - /og/ say?'). This task consisted of six practice items and 15 test items. *Phoneme Elision* requires the participant to repeat a word without a specific phoneme. All the phonemes that were to be deleted were consonants and the remaining phonemes formed a new word (e.g. 'Say the word /bat/. Now say the word /bat/ without the /b/'). The location of the deleted phoneme varied. This task consisted of six practice items and 15 test items. For *Sound Isolation*, the participant identifies the first, middle or last sound in a word. The task consisted of six practice items and 15 test items. With the exception of Sound Oddity, each of the phonological awareness tasks was discontinued after four mistakes were made in the last seven items. The number of items that were correctly answered became the score.

Naming speed. Two tests of naming speed were administered in grade 1. These measures were developed based on colour naming and picture-naming tasks described in Wolf, Bally and Morris (1986). Colours and pictures were chosen over alphanumeric stimuli as the predictors were measured in the fall of grade 1 before children had much formal reading instruction and the researchers were not confident that all the children would be familiar with the letters and digits. Each task consisted of a series of 32 randomly ordered colours or pictures, each taken from a set of four (colours: blue, green, red and yellow; pictures: bird, horse, pig and cat). The participants had time to practise and to make sure that they were familiar with the colours and pictures. Stimuli items were presented in two four-by-four matrices. The number of seconds it took the child to name the stimuli correctly was the child's score. If an error was made, the experimenter pointed to the incorrect stimulus immediately, with the child having to start again from that spot as the time continued to be recorded without stopping.

Reading ability. Two subtests from the Woodcock Reading Mastery Tests – Revised (Woodcock, 1987) were used in all grades. Word Identification requires that the participant read aloud words in isolation (e.g. *is*, *you*, *and*) that continuously increase in difficulty, with a total of 106 possible items. Word Attack measures participants' ability to read pseudo-words through the application of phonic and structural analysis skills (e.g. *dee*, *apt*, *ift*), with a total of 45 items.

Rhythm. In Grade 1, Weikart's (1989a) Rhythmic Competency Analysis test was used. The instrument is reported to have an internal consistency (alpha) ranging from .70 to .79 (Weikart, Schweinhart & Larner, 1987). This test includes five different rhythmic production tasks, which are conducted to two different sets of music. The first musical selection was 'Soldier's Joy' from the recording *Rhythmically Moving 2* (Weikart, 1989b) and the second musical selection was 'Oh, How Lovely' from *Rhythmically Moving 1* (Weikart, 1989a). The second musical selection was slower in tempo. Task one requires that the child tap the beat of the musical selection on his/her lap using both hands simultaneously. Task two requires that the child tap on his/her lap to the beat using alternating hands. Task three requires that the child move his/her legs in a walking manner to the beat while seated. Task four requires that the child walk the beat while standing in one place. Task five requires that the child walk the beat in a forward direction. If the child accurately produced at least eight consecutive beats in unison with the underlying steady beat of the music, one point was given. This provided for an 11-point scale with the range from 0 to 10, as up to 1 point could be achieved on each task for both musical selections. Two raters, proficient in this test, marked all participants.

Results

Alpha was set to .05 for all analyses. Because the scores were not dichotomous (right vs wrong), but instead represented a range of values from 1 to 10, inter-rater reliability for the rhythm task was calculated using the split-half method, with each rater's scores representing alternating halves of the total score for each participant. Reliability was determined to be high and acceptable at .92. Given that both raters also had similar means ($M = 5.38$ and 5.08) and standard deviations ($SD = 2.97$, 3.11), both raters' scores were combined for a possible total of 20 points on the task. Preliminary analyses were performed to determine whether there were any gender differences on the measures used. *T*-tests revealed no significant differences, so the data for males and females were combined.

The means and standard deviations for all the measures used across grades 1–5 are presented in Table 1. All five phonological awareness test scores were significantly correlated with one another (see Table 2), so they were converted to *z*-scores and averaged into a single score, PA ($M = 0.0$, $SD = 0.83$). Both colour-naming and picture-naming scores were significantly correlated ($r = .55$, $p < .001$), so they were converted to *z*-scores and averaged into a single score ($M = 0.0$, $SD = 0.88$). These composite scores for phonological awareness and RAN are used for all further analyses.

T-test analyses were run to determine that no differences existed between the participants who remained in the study until grade 5 and those who were lost to attrition on their performance on the PA, RAN and rhythm tasks taken in grade 1. No significant differences were found on any of the three measures between the two groups (*t*-values ranged from .01 to 1.45, and *p*-values ranged from .15 to .99).

Simple correlations among rhythm, phonological awareness, naming speed and reading were examined and are reported in Table 3. Concurrent correlations showed grade 1 rhythm correlated significantly with RAN, phonological awareness and Word Identification. The lack of significant relation between rhythm and Word Attack is likely due to the fact that the majority of the participants scored 0 on Word Attack, thereby causing the distribution to be extremely skewed and resulting in a restriction of range. Longitudinal correlations showed that each of the three predictors measured in grade 1, RAN, phonological awareness and rhythm, maintained a significant relationship with both Word Identification and Word Attack over the following 4 years. The strength of these relationships ranged from $r = .63$ to .73 for phonological awareness, from $r = .39$ to .53

Table 1. Means and standard deviations of all measures used across grades 1 and 2.

Measure	*N*	*M*	*SD*
Rhythm – Grade 1	53	10.45	5.96
Sound Oddity – Grade 1	53	14.91	5.71
Sound Isolation – Grade 1	53	6.30	4.59
Blending Phonemes – Grade 1	53	8.85	4.45
Blending Onset and Rime – Grade 1	53	9.49	4.73
Phoneme Elision – Grade 1	53	4.89	4.69
Phonological Awareness – Grade 1	53	0.00	0.83
Naming Speed Colours – Grade 1	53	32.70	9.52
Naming Speed Pictures – Grade 1	53	35.66	11.27
Naming Speed – Grade 1	53	68.40	18.34
Word Identification – Grade 1	53	7.19	11.60
Word Attack – Grade 1	53	1.68	4.25
Word Identification – Grade 2	53	35.19	16.50
Word Attack – Grade 2	53	10.04	9.51
Word Identification – Grade 3	47	52.09	14.60
Word Attack – Grade 3	47	17.21	10.48
Word Identification – Grade 4	44	59.09	12.25
Word Attack – Grade 4	44	22.27	10.44
Word Identification – Grade 5	38	69.05	11.99
Word Attack – Grade 5	38	28.24	9.30

Table 2. Intercorrelations between all five phonological awareness tasks in grade 1 ($N = 53$).

Measure	1	2	3	4	5
1. Sound Oddity	–	.55**	.45**	.64**	.58**
2. Sound Isolation		–	.77**	.63**	.67**
3. Blending Phonemes			–	.48**	.57**
4. Blending Onset and Rime				–	.69**
5. Phoneme Elision					–

**$p < .01$.

Table 3. Intercorrelations between rhythm, phonological awareness (PA), naming speed (NS) and reading across grades ($N = 53$).

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13
1. MR		–.41**	–.30*	.28*	.26	.42**	.39**	.37**	.41**	.31*	.37*	.40*	.50**
2. PA		–	–.57**	.55**	.48**	.70**	.73**	.69**	.67**	.67**	.68**	.63**	.64**
3. NS			–	–.36**	–.28*	–.52**	–.46**	–.50**	–.39**	–.53**	–.49**	–.49**	–.48**
4. WID – Grade 1				–	.86**	.62**	.62**	.53**	.55**	.47**	.47**	.38*	.44**
5. WA – Grade 1					–	.58**	.65**	.50**	.53**	.44**	.43**	.38*	.44**
6. WID – Grade 2						–	.89**	.92**	.80**	.86**	.78**	.78**	.74**
7. WA – Grade 2							–	.82**	.84**	.77**	.78**	.70**	.71**
8. WID – Grade 3								–	.86**	.94**	.87**	.87**	.83**
9. WA – Grade 3									–	.84**	.91**	.82**	.88**
10. WID – Grade 4										–	.89**	.96**	.88**
11. WA – Grade 4											–	.87**	.88**
12. WID – Grade 5												–	.89**
13. WA – Grade 5													–

Notes: MR = Musical Rhythm, WID = Word Identification, WA = Word Attack.
*$p < .05$, **$p < .01$.

for RAN and from r =.31 to .50 for rhythm. Overall, these relationships among the variables support the prediction that rhythm would show a sustained relation with reading.

Regression analyses were conducted in order to determine rhythm's predictive power with respect to reading. Of interest was whether rhythm has enough power to predict reading ability uniquely, or whether its ability to predict reading is a result of shared variance with phonological awareness and/or naming speed. Hierarchical regressions were performed first with the two grade 1 reading scores as the dependent variables and then with the two reading scores from grades 2–5 as the dependent variables. The first 10 regressions examined the predictive ability of rhythm on its own (see Table 4). Overall, the regression analyses here demonstrate that rhythm in grade 1 significantly predicts both word reading and pseudo-word reading as far as grade 5 (with the exception of grade 1 Word Attack), and that the longitudinal measurements account for more variance than do the concurrent measurements.

The next 10 regressions looked at the predictive ability of rhythm, removing any shared variance with phonological awareness (see Table 5). Overall, rhythm did not account for unique variance in reading, with one exception in grade 5. In grade 5, rhythm predicted nearly 9% of variance in Word Attack, after the contribution of phonological

Table 4. Percentage of variance in word identification and word attack in grades 1–5 accounted for by Grade 1 rhythm.

Measure	*N*	% Variance rhythm accounted for in Word Identification	% Variance rhythm accounted for in Word Attack
Grade 1	53	7.5*	6.5
Grade 2	53	17.3**	15.1**
Grade 3	47	13.8**	16.8**
Grade 4	44	9.7*	13.4*
Grade 5	38	15.9*	24.6**

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

Table 5. Hierarchical regression predicting reading in grades 1–5 from phonological awareness (PA) and rhythm.

	Step	Predictor variable	β	R^2 change	*F*	Significant *F* change
Grade 1 WID	1	PA	.55	.30	21.57	<.001
	2	PA	.52			
		Rhythm	.06	.00	10.73	.64
Grade 1 WA	1	PA	.48	.23	15.62	<.001
	2	PA	.46			
		Rhythm	.07	.00	7.82	.62
Grade 2 WID	1	PA	.70	.49	49.41	<.001
	2	PA	.64			
		Rhythm	.15	.02	26.20	.16
Grade 2 WA	1	PA	.73	.53	57.19	<.001
	2	PA	.68			
		Rhythm	.11	.01	29.16	.31
Grade 3 WID	1	PA	.69	.48	41.49	<.001
	2	PA	.64			
		Rhythm	.14	.02	21.70	.23
Grade 3 WA	1	PA	.67	.45	37.15	<.001
	2	PA	.60			
		Rhythm	.19	.03	20.65	.11
Grade 4 WID	1	PA	.67	.44	33.49	<.001
	2	PA	.64			
		Rhythm	.07	.00	16.61	.59
Grade 4 WA	1	PA	.69	.47	37.05	<.001
	2	PA	.64			
		Rhythm	.12	.01	19.05	.32
Grade 5 WID	1	PA	.63	.40	24.18	<.001
	2	PA	.56			
		Rhythm	.21	.04	13.78	.13
Grade 5 WA	1	PA	.64	.41	24.53	<.001
	2	PA	.53			
		Rhythm	.32	.09	17.12	.02

Notes: $N = 53$ in grades 1 and 2, 47 in grade 3, 44 in grade 4 and 38 in grade 5; WID = Word Identification, WA = Word Attack.

awareness. For Word Identification, rhythm never survived control for phonological awareness.

Shared variance in reading between naming speed and rhythm was also examined. The next 10 regression analyses look at the predictive ability of rhythm, removing any shared

Table 6. Hierarchical regression predicting reading in grade 1 and grade 2 from naming speed (NS) and rhythm.

	Step	Predictor variable	β	R^2 change	*F*	Significant *F* change
Grade 1 WID	1	NS	−.35	.13	7.30	<.05
	2	NS	−.30			
		Rhythm	.19	.03	4.66	.18
Grade 1 WA	1	NS	−.28	.08	4.28	<.05
	2	NS	−.22			
		Rhythm	.19	.03	3.10	.18
Grade 2 WID	1	NS	−.52	.27	18.66	<.001
	2	NS	−.43			
		Rhythm	.29	.08	13.10	.02
Grade 2 WA	1	NS	−.46	.21	13.81	<.001
	2	NS	−.38			
		Rhythm	.28	.07	9.88	.03
Grade 3 WID	1	NS	−.50	.25	15.07	<.001
	2	NS	−.44			
		Rhythm	.26	.07	10.14	.05
Grade 3 WA	1	NS	−.39	.15	8.17	<.01
	2	NS	−.31			
		Rhythm	.33	.10	7.62	.02
Grade 4 WID	1	NS	−.53	.28	16.63	<.001
	2	NS	−.49			
		Rhythm	−.19	.03	9.49	.17
Grade 4 WA	1	NS	−.49	.24	13.05	<.001
	2	NS	−.42			
		Rhythm	.26	.06	8.74	.06
Grade 5 WID	1	NS	−.49	.24	13.05	<.001
	2	NS	−.41			
		Rhythm	.27	.07	7.83	.08
Grade 5 WA	1	NS	−.48	.23	10.5	<.01
	2	NS	−.35			
		Rhythm	.38	.13	9.76	.01

Notes: $N = 53$ in grades 1 and 2, 47 in grade 3, 44 in grade 4 and 38 in grade 5; WID = Word Identification, WA = Word Attack.

variance with naming speed (see Table 6). Overall, once the shared variance from naming speed is removed, rhythm does play a significant role in explaining variance in grade 1 reading and predicting reading in subsequent grades. Specifically, rhythm predicts unique variance in grades 2 and 3 Word Identification and in grades 2, 3 and 5 Word Attack.

In summary, grade 1 rhythm on its own significantly predicts reading ability in grades 1–5. However, once the shared variance with phonological awareness is removed, rhythm only predicts a significant amount of variance in grade 5 Word Attack. When the shared variance with naming speed is removed, rhythm does not account for a significant amount of variance in grade 1 reading, and yet it still predicts a significant amount of variance in grades 2 and 3 Word Identification and Word Attack, as well as in grade 5 Word Attack.

Discussion

This study investigated the relations among rhythm, phonological awareness, naming speed and reading in a longitudinal sample of children in grades 1–5. The correlations indicate that rhythm in grade 1 is significantly related to not only the two main predictors of reading ability, phonological awareness and naming speed but also to reading ability in the same year and up to 4 years later. Furthermore, once shared variance with phonological awareness was removed, rhythm uniquely predicted Word Attack in grade 5. When naming speed was controlled, rhythm predicted variance in Word Identification in grades 2 and 3, and in Word Attack in grades 2, 3 and 5.

An essential primary finding in the present study is that rhythm and reading, both real words and pseudo-words, are related in a sample of typically developing readers. This is noteworthy because the majority of studies demonstrating such a relationship have involved poor readers of different ages, and the evidence has rested primarily on comparisons of good and poor readers on rhythm tasks (e.g. Atterbury, 1985; Overy et al., 2003; Wood & Terrell, 1998). Studies that have not selected out poor readers have often used measures of literacy, which, while appropriate for the age of the participants, are perhaps inadequate in scope to allow the relationship with rhythm to emerge. For example, Anvari et al. (2002), which did not find a significant correlation between reading and rhythm for their older children, measured primarily letter knowledge in preschoolers. One notable exception is the study by Whalley and Hansen (2006), which found significant relationships between word-level rhythm and decoding, and between sentence-level rhythm and reading comprehension. Our findings are broadly consistent with those of Atterbury (1985), Douglas and Willats (1994), Goswami (2002), Overy et al. (2003) and Wood and Terrell (1998), who found significant reading–rhythm correlations in older children. What is new is the evidence that this relationship is sustained over 5 years of schooling, and its strength does not diminish substantially. Indeed, the simple correlations between rhythm and word reading show that the concurrent reading–rhythm relationship is the weakest ($r = .28$), while the strongest is in Grade 5 ($r = .40$). A similar trend is seen for pseudo-word reading; the concurrent relationship does not reach significance, while the strongest relationship is seen between rhythm and Word Attack measured in grade 5 ($r = .50$).

What could account for the increase in the strength of such a relationship? In grade 1, the demands of reading are fairly simple as children are mostly reading monosyllabic words. Indeed, a glance at the Woodcock Word Identification items shows that there are only two polysyllabic words within the first 30 items (*little*, item 17, and *after*, item 30). As children progress, however, reading increasingly requires the ability to tackle polysyllabic words, which involve the rhythmic alternation of strong and weak syllables. As the participants advanced in grade, the average number of words they were reading, and the complexity of those words, increased. Metrical and rhythmic intonation is necessary for reading polysyllabic words, as it is required in order to assign stress properly and achieve the proper alternation (in English) of full and reduced (schwa) vowels in words. Therefore, one possibility is that those children who were more sensitive to the demands of the rhythm task in grade 1 were also those who developed a greater facility for using the linguistic rhythm of stress to help decode more difficult words.

Another important finding is that much of the variance in reading ability provided by rhythm overlaps almost completely with that provided by phonological awareness. Only in the case of grade 5 Word Attack does rhythm predict significant variance in excess of that explained by phonological awareness. While this is in keeping with an account that sees rhythm as developmentally more important as the demands of reading increase, we are reluctant to overinterpret this result in the light of the other nonsignificant regression results involving phonological awareness and rhythm. In this study, therefore, it appears that rhythm is not related to reading beyond the cognitive, auditory and linguistic skills required by phonological awareness. This contrasts with Goswami et al. (2002), who found that the beat detection task predicted a significant 9% of variance in reading after the contribution of phonological awareness. However, at least two points make direct comparisons impossible; first, there are vast methodological differences between the rhythm tasks used in Goswami et al. and the current study; and second, the phonological awareness task in Goswami et al. was a rime oddity task, where four of the five phonological awareness tasks in this study required phoneme-level manipulation. Lamb and Gregory (1993) have suggested that some auditory skills used in language processing are also related to music perception skills (i.e. blending and segmenting sounds, and melodic and rhythmic discrimination). As Anvari et al. (2002) point out, these abilities require temporal sequencing abilities, which may be the key factor common to the reading, rhythm and phonological awareness tasks used in this study.

A final interesting finding relates to the role of rhythm in reading once naming speed was removed. In these analyses, rhythm proves to have relatively robust predictive power. Although it was no predictor of reading in grade 1, rhythm still predicted a modest but significant amount of unique variance in grades 2 and 3 Word Identification and grades 2, 3 and 5 Word Attack. Unlike the case observed for phonological awareness, the results indicate that, overall, rhythm is related to reading beyond the cognitive demands of rapid naming. One challenge to this interpretation may lie in the choice of RAN task administered in grade 1. Several studies have shown that alphanumeric RAN is more predictive of reading development than colour and object RAN. Therefore, the robust role played by rhythm in the presence of RAN may have been attenuated, had alphanumeric RAN measures been employed. Although Scarborough's (1998) meta-analysis found that naming speed for colours and pictures was comparable to naming speed for alphanumeric stimuli for children who are learning to read (median $r = -.39$ for colours and pictures, median $r = .38$ for letters and digits), this is clearly an area for future research.

While both phonological awareness and naming speed have been shown to predict reading development in many studies, they do not predict all the variance in reading development. It would be valuable to discover a process that added to the amount of variance accounted by phonological awareness and naming speed. Finding that rhythm is correlated with reading development over 5 years is interesting, but in order to be useful for theory building, it is necessary to determine whether the variance contributed by rhythm is unique, or whether it is shared by other, more traditional predictors. Many studies that have investigated the role of rhythm in reading have failed to consider the role of rhythm in combination with rapid naming or phonological awareness, and none have considered the contribution of these variables over time. The findings from this study suggest that rhythm plays a role that is largely distinct from naming speed, but is subsumed by phonological awareness. This is interesting when considered in light of previous research linking rhythm to phonological awareness (e.g. Goswami, 2002). We also observe that the contribution of rhythm appears to increase over time, when it is considered alone, and also in the context of naming speed.

There are several limitations within the context of this study that require acknowledgment and constrain the interpretation of our data. First, the rhythm task measured rhythm production only; a measure of rhythm discrimination would have allowed a more comprehensive analysis and integration of these findings relative to the literature. For example, the conflicting findings of Atterbury (1985) and Douglas and Willats (1994) regarding the relationship between reading and rhythm may be due to the fact that the former measured only rhythm production and the latter measured only rhythm discrimination. Relatedly, the score on the rhythm task was a combined score of the participants' abilities to tap the rhythm with both hands, alternating hands, march the rhythm while seated, standing and walking. Insofar as the tasks involve different amounts of coordination and balance beyond that of rhythm production, scores may reflect these extraneous influences. A measure of the participants' exposure to music would have allowed for a discussion of whether rhythm related to reading is heightened by musical experience. A further limitation is the relatively small sample size; attrition lowered the sample size from 53 to 38, which may have prevented some of the regression analyses from reaching conventional levels of significance in the later grades.

Overall, our findings provide evidence that rhythm is a factor that deserves greater research attention. The present study focuses on non-speech rhythm; given the importance of speech rhythm in oral language, especially in stress-timed languages such as English and Dutch, perhaps speech rhythm, such as stress or prosody, would be a productive area of investigation (Wade-Woolley & Wood, 2006). This is particularly true for older readers, as the results of this study show that the strongest correlations between reading and rhythm are in the older grades. Further research is required to determine whether the greatest impact of rhythm is domain general, or more tightly constrained within the linguistic system.

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Received 15 February 2006; revised version received 3 September 2006.

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