Sensitivity to Speech Rhythm Explains Individual Differences in Reading Ability Independently of Phonological Awareness

Andrew J. Holliman

Open University

Clare Wood

Coventry University

Kieron Sheehy

Open University

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Author Note:

Andrew J. Holliman, Faculty of Education and Language Studies; Clare Wood, Faculty of Education and Language Studies now at (Faculty of Health and Life Sciences, Coventry University); Kieron Sheehy, Faculty of Education and Language Studies.

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Correspondence concerning this article should be addressed to Andrew J. Holliman at the Faculty of Education and Language Studies, Open University, Walton Hall, Milton Keynes, MK7 6AA. Email: a.holliman@open.ac.uk.

Abstract

This study considered whether sensitivity to speech rhythm can predict concurrent variance in reading attainment after individual differences in age, vocabulary and phonological awareness have been controlled. Five to six-year-old English-speaking children completed a battery of phonological processing assessments and reading assessments, along with a simple word stress manipulation task. The results showed that performance on the stress manipulation measure predicted a significant amount of variance in reading attainment after age, vocabulary, and phonological processing had been taken into account. These results suggest that stress sensitivity is an important, yet neglected aspect of English-speaking children's phonological representations, which needs to be incorporated into theoretical accounts of reading development.

Introduction

Most theories acknowledge that successful reading development is marked by successful phonological awareness development, and reading difficulties are associated with deficits in phonological awareness (e.g. Ehri, 1999; Frith, 1985; Goswami & Bryant, 1990; Snowling, 2000). The evidence linking poor phonological representations to reading difficulties is so strong that Stanovich (1986) proposed that dyslexia should be defined in terms of a core phonological deficit. The “phonological core-variable difference model” suggests that those with poor reading abilities differ from those with normal reading abilities on all skills which tap into the phonological core deficit, such as phonological awareness tasks. However, as Chiappe, Stringer, Siegel, and Stanovich (2002) noted, despite the consensus for a core phonological deficit hypothesis, a growing amount of research is investigating the possibility that the phonological core deficit itself may in fact be secondary to another underlying deficit; thus, we do not know exactly what causes poor phonological representations.

Some researchers have suggested that reading difficulties and phonological awareness difficulties are caused by deficits in basic speech processing abilities (McBride-Chang, 1996). For example, Manis et al. (1997) found that poor phonemic awareness was related to poor performance on a speech perception task. McBride-Chang also found phonological awareness to be substantially correlated with speech perception. These studies are suggestive of a link between speech perception and literacy development. According to Wood and Terrell (1998, p. 399) “speech perception demands the development of skills which promote implicit segmental awareness of sounds (i.e. words in speech)”. One of the skills that Wood and Terrell refer to is that of spoken word recognition.

Spoken word recognition refers to a more specific process of speech perception and is concerned with how we recognise words in fluent speech or in isolation. The speech stream is continuous with few audible pauses between words, so the question of how we identify where each word begins is central to spoken word recognition. Some researchers suggest that sensitivity to speech rhythm is one of the skills that an infant needs for spoken word recognition (e.g. Cutler, 1994). In English, which is a stress-timed language, speech rhythm is metrical: it is characterised by strong and weak syllables. A strong syllable contains a 'full' vowel sound (e.g. /u:/ in two). It is also louder and articulated more forcefully, but more importantly, it is characterised by its higher pitch and longer duration. In contrast, a weak syllable does not carry stress and often contains a reduced or abbreviated vowel, such as a 'schwa' /ə/. Cutler and Norris (1988, p. 114) suggest that "we hear six times as many lexical items beginning with strong syllables as with weak syllables…this in turn implies that a recogniser that started lexical access at strong syllables would actually miss very few word beginnings". Similarly, Cutler and Carter (1987) estimated that in English approximately 85% of lexical words (excluding function words) begin with strong syllables, and in a corpus of 190,000 words, 90% were found to begin with strong syllables. Therefore, metrical stress seems to be a relatively good indicator of potential word boundaries. Consequently, Cutler and Norris proposed the Metrical Segmentation Strategy (MSS), which suggests that for the speech stream to be successfully segmented the infant uses the rhythmic characteristics of their first language to predict potential word boundaries. Sensitivity to the rhythmical properties of native language develops during the first year of life (Morais, 2003) and Jusczyk, Cutler, and Redanz (1993) found that by nine-months-old children show sensitivity to boundaries of major phrases. It has been suggested by Cutler that it is the rhythmic characteristics of our native language that enable us to hypothesise about breaking the speech stream down into interpretable units, and in English metrical stress sensitivity seems to play a crucial role in this process.

In the literature a clear, but perhaps indirect relationship between stress sensitivity and reading development is beginning to emerge although few papers have directly examined this relationship. Wood and Terrell (1998) looked at speech rhythm in relation to reading development because they claimed that sensitivity to speech rhythm (as measured by sensitivity to metrical stress) may help achieve spoken word recognition, and later facilitate the development of phonological awareness. Wood and Terrell suggested that phonological awareness may be facilitated by sensitivity to speech rhythm in at least two ways. Firstly, the ability to manipulate stress and apply it to unstressed syllables may help to clarify ambiguous phonemes and enhance phoneme identification, which may facilitate phonological representations of words. Secondly, because the peak of loudness in a syllable corresponds to vowel location, sensitivity to speech rhythm may facilitate the identification of onset-rime boundaries and enhance rhyme awareness.

Wood and Terrell (1998) used a rhythm matching task, which measured how sensitive children were to metrical stress in speech. Children were played a sentence with a particular arrangement of stress patterns (strong and weak syllables) which had been low-pass filtered to leave only the intonation pattern of the sentence and no phonemic information. The children were then read two further sentences, one of which shared the stress pattern of the filtered sentence. The children had to decide which of the two spoken sentences was the one that had been filtered. Wood and Terrell found that those with reading difficulties performed significantly worse than their age-matched controls on the rhythm matching task, even after accounting for differences in vocabulary.

These findings suggest that sensitivity to speech rhythm is related to reading development. However, there was a very broad age range in the poor readers group and this means that the poor readers group represents a highly diverse group of children. Also, the rhythm matching task used was memory intensive, which could have confounded the subsequent findings. However, Wood (2006a) has since revisited the data that was obtained in Wood and Terrell (1998) and examined it to see if there were any associations between phonological awareness and stress sensitivity later in reading development. Wood found that stress sensitivity was able to account for variance in phoneme deletion, rhyme detection, and reading ability. This provides strong evidence of an association between metrical stress sensitivity and segmental phonological awareness.

To overcome some of the methodological limitations of the Wood and Terrell (1998) task, Wood (2006b) further investigated the association between stress sensitivity and reading development in 4-5 year-old children using a task which was less memory intensive and is more fun and appropriate for children of this age range. Rhythmic sensitivity was measured by a task in which children were required to find objects in a pretend house. All of these objects had two syllable names and carried primary lexical stress on the first syllable with a weak syllable in the second syllable (e.g. “sofa”). The children were required to find the objects when the words were spoken incorrectly. The ‘mispronunciation’ involved systematically manipulating three of the syllable-based elements that are necessarily changed when such words have their metrical stress pattern altered: vowel reduction, vowel change, and lexical stress change. In one of these conditions the metrical stress pattern of the word was reversed, which required the children to manipulate the stress of the word in order to retrieve the correct object name. Here, the first vowel became a reduced vowel and the second vowel became fully articulated; for instance the word “sofa” was pronounced “s’far”. Wood found that performance on this reversed metrical stress condition was significantly associated with reading attainment, whereas the other manipulations to the words, each one changing related elements, including changing the lexical stress of the word without reducing the vowel, were not. However, of the phonological awareness battery, only the rapid automatised naming test, which is a measure of phonological production, was found to be significantly associated with metrical stress sensitivity. In a second study, Wood assessed school aged children (5-7 year olds) and also found evidence of a relationship between performance on the stress manipulation task and measures of word reading, non-word reading, spelling, letter sound knowledge and rhyme detection ability. However, Wood did not use vocabulary as a covariate, which is problematic given that vocabulary may mediate the relationship between spoken word recognition and phonological awareness (Walley, 1993). In spite of this, this study has provided promising insights suggesting that metrical stress sensitivity may play a role in the development of literacy; one that warrants further investigation.

Since the publication of Wood and Terrell (1998) the role of speech rhythm in the development of phonological awareness has been discussed further (see Wade-Woolley & Wood, 2006). Indeed, Goswami (2003, p. 465) commented that “once we consider that speech rhythm is one of the earliest cues used by infants to discriminate syllables, a link with the development of phonological awareness becomes plausible”. Goswami (2003) has suggested that perception of the auditory signals in rhythm and prosody can be important for the segmentation of words and for representing words themselves because the acoustic beats in speech (where there is a peak in the amplitude of the speech signal) correspond to the articulation of vowels, which in turn mark the boundaries between onset and rhyme. Goswami (2002) found that children with dyslexia were significantly less sensitive to beat detection and associated auditory characteristics than their non-dyslexic counterparts. After controlling for age, nonverbal IQ, and vocabulary, it was further found that individual differences in sensitivity to these parameters accounted for 25% of the variance in reading and spelling ability. These findings support the suggestion that sensitivity to the rhythmic properties of speech influence literacy development.

The associations between stress sensitivity, phonological awareness and literacy are under-researched and this has been acknowledged by researchers in the field. For example, Morais (2003, p. 146) observed that “more work of course is needed to support the idea that inaccurate segmental processing in dyslexics may be related to poor rhythmical speech sensitivity”. Similarly, Protopapas, Gerakaki and Alexandri (2006, p. 428-9) comment: “if stress assignment is an important and necessary step in reading aloud, then cognitive models of reading must be extended to include it”. The purpose of this study is therefore to go some way to demonstrating whether stress sensitivity represents an ‘important and necessary’ skill in reading performance. The study employed a stress sensitivity task based on that used in Wood’s (2006b) study, along with reading and phonological assessments to investigate further the relationship between metrical stress sensitivity and the development of phonological awareness and reading ability. It addressed the research question of whether performance on the stress manipulation measure can predict reading attainment after age, vocabulary, and phonological awareness have been taken into account.

Method

Participants

All participants in this study (n = 44) were recruited from a single primary school in Buckinghamshire, UK. Children were aged between 5 and 6-years-old (mean age 6;1) and were in either Reception (n = 16) or Year-One (n = 28) classes. 27 children were female and 17 were male. The mean standardised vocabulary score of the sample was 103.34 (SD = 11.92), which was slightly above the average score of 100, in the 'average score range - high'. The mean word reading score of the sample was 21.64 (SD = 18.56), which equates to a reading age equivalent of 6 years 7 months.

Test battery

The phoneme deletion task (Wood, 1999). The phoneme deletion task provides a measure of children’s ability to isolate individual phonemes in a word, delete them, and then re-blend the remaining letters to form a new word. In one subtest the first phoneme was deleted e.g. ‘try to say “car” without the /k/ sound’. In the other subtest the last phoneme was deleted. Both subtests began with four practice items followed by the twelve test items, and the order of these subtests was counterbalanced. Corrective feedback was provided to children during the practice items to ensure they understood the instructions, but no feedback was provided to children during the test items. Children received one point for each correct deletion made, giving a maximum score of 24. Cronbach’s Alpha reliability coefficient was α=.94.

The rhyme detection task (Frederickson, Frith & Reason, 1997). The rhyme detection task was included to provide a measure of children’s sensitivity to rhyme. Children heard three words and had to verbally identify the two rhyming words out of the three provided e.g. of the words “sail”, “boot”, and “nail”, “sail” and “nail” would be a correct response. The task began with three practice items followed by up to twenty-one test items of increasing difficulty. Corrective feedback was provided to children during the practice items, but no feedback was provided to children during the test items. Children received one point for each pair of words named correctly. It was reported in the phonological assessment battery that Cronbach's Alpha reliability coefficient for this task was α=.92.

The British Ability Scales Word Reading subtest (Elliot, Smith & McUlloch, 1996). The British Ability Scales Word Reading subtest simply assessed the number of words that a child could accurately read out loud. There were a total number of ninety items (nine blocks of ten words) and each block became increasingly difficult. Thirty-two of the ninety words were monosyllabic and fifty-eight of the words were polysyllabic. If a child made eight or more failures in any block of ten the test was discontinued and a total score was obtained. Children received one point for every word named correctly.

The non-word reading test (Frederickson et al., 1997). The non-word reading test was included to provide a measure of children's decoding ability by assessing the number of non-words that a child could accurately read out loud. As the non-words in this test were made-up nonsense words, e.g. the word "fot", they could not be read as a result of having that word in their sight vocabulary and remembering what word it represented without decoding it phonologically. There were three practice items where corrective feedback was provided. There were a total number of twenty test items (two blocks of ten) with items increasing in difficulty. Ten of the twenty non-words were monosyllabic and ten of the non-words were polysyllabic. If a child made six or more failures in a block the test was discontinued and a total score was obtained out of twenty. Children received one point for every non-word named correctly. It was reported in the phonological assessment battery that Cronbach's Alpha reliability coefficient for this task was α=.95.

British Picture Vocabulary Scales II (Dunn, Dunn, Whetton & Burley, 1997). This task provided a measure of the vocabulary that a child understands, but may not actually use. A word is read out loud by the administrator and the child has to select from a choice of four the picture which best illustrates that word. Children begin the test in a particular section dependant on their age and the series of words become increasingly unfamiliar as they progress through the test. The test is terminated when a child scores 8 or more incorrect in a set of 12. A total score for the number of correct answers is then obtained. It was reported in the British Picture Vocabulary Scales II that Cronbach's Alpha reliability coefficient for this task was α=.94.

The stress manipulation ('mispronunciations') task (Wood, 2006b). In this task it was initially checked that children could accurately identify 17 common words in a line drawing of a cartoon house to obtain a baseline score (one practice item and 16 test items). All of the object names had two syllables and carried primary lexical stress on the first syllable, and the vowel in the second syllable included a reduced vowel (i.e. sofa). However, in the experimental condition the words were mispronounced. The metrical stress of each word was reversed so that the first vowel became reduced and the second vowel became fully articulated. For example, instead of the normal pronunciation of the word "sofa" it was pronounced "s'far". An overall score out of 16 (as the first word was a practice item) was calculated. The practice item in this task is important as it indicates to the child that stress manipulation is necessary to solve this task. That is, the children that have a greater sensitivity to speech rhythm should recognise that the metrical stress pattern of the word has been changed, and will also be more able to reverse the stress pattern to identify the correct item. Children received one point for every item correctly pointed to on the line drawing of a house. The metrical stress sensitivity task was used twice for each participant, each one week apart, so that test-rest reliability could be calculated and this was found to be good, r=.90, p<.001. Also, to check the internal reliability of the task, Cronbach's Alpha reliability coefficient was calculated and found to be acceptable, α=.79.

The phonological processing measures employed in this study were selected on the basis of their strong link with reading development in the literature. Although there has been much debate as to whether rhyme or phoneme awareness is more important for the development of reading (see Muter, Hulme, Snowling & Taylor 1998; Bryant, 1998) this study included them both. The rhyme detection task and the phoneme deletion task were selected because they are both very often used in the literature and this would enable a direct comparison between the findings of this study and other related studies. It is acknowledged that neither the rhyme nor the phoneme awareness tasks are flawless, particularly given their respective receptive and productive nature.

Children were assessed on two separate occasions. One batch of assessments included the non-word reading task, the phoneme deletion task, the rhyme detection task, and the normal condition of the stress manipulations task. The other batch included the experimental condition of the stress manipulations task, the British Picture Vocabulary Scales II, and the British Ability Scales word reading subtest. The batches were presented in a counterbalanced order and the tasks within each batch were presented in a randomised order.

Results

Table 1 shows the mean scores the children obtained on the measures of phonological awareness, reading, metrical stress sensitivity, and vocabulary. It can be seen from Table 1 that participants scored in the middle range on the two phonological awareness measures (the phoneme deletion task and the rhyme detection task). It can be seen that while participants obtained a high mean score on the baseline condition of the stress manipulation ('mispronunciations') task (15.36 from a possible 16) a relatively low mean score was obtained on the stress reversed condition of this task (6.30 from a possible 16) which was expected.

Table 2 shows the correlation matrix for all the variables included in this study. It can be seen from Table 2 that the stress manipulation was strongly correlated with the phonological awareness measures (rhyme r = 0.64 and phoneme deletion r = 0.74). Stress manipulation was also significantly correlated with the reading related measures, that is, the BAS word reading subtest and the non-word reading. This was expected given the growing amount of evidence linking speech rhythm to reading and phonological awareness. Furthermore, stress manipulation was correlated with age and vocabulary, although the relationship was not as strong as that observed between stress manipulation and the reading and phonological awareness measures. There was a strong positive relationship (>0.7) between the phonological awareness measures (rhyme detection and phoneme deletion) and the reading related measures (BAS word reading subtest and non-word reading) and this was not surprising given the documented relationship between the two.

The data were inspected to see whether they met the assumptions for a multiple regression analysis. A regression analysis was conducted to see whether metrical stress sensitivity could account for a significant amount of the variance in reading attainment after age, vocabulary, phoneme deletion and rhyme detection had all been accounted for (see Table 3).

Reading attainment was a composite measure which was constructed by obtaining a z-score for the two reading related measures (the British Ability Scales word reading subtest and the non-word reading task) and then adding them together. This was to produce a single reading measure that represented a range of reading strategies whilst ensuring that phonic decoding was necessarily assessed as part of this.

This analysis showed that after age and vocabulary had been accounted for, phoneme deletion was able to account for an additional 11.2 percent of the variance in reading attainment, R^2 change = 0.112, $F(1, 40) = 11.979$, $p = 0.001$. Following this, rhyme detection was able to account for an additional 5.7 percent of the variance in reading attainment, R^2 change = 0.057, $F(1, 39) = 6.967$, $p = 0.012$. However, metrical stress sensitivity accounted for an additional 3.8 percent of the variance in reading attainment, R^2 change = 0.038, $F(1, 38) = 5.127$, $p = 0.029$. Thus, performance on the metrical stress sensitivity task predicted a significant amount of the variance in reading attainment after age, vocabulary, phoneme deletion, and rhyme detection had been taken into account.

Another regression analysis was conducted to investigate the unique contribution of metrical stress sensitivity to reading attainment (see Table 4). This analysis also showed that metrical stress sensitivity relates quite strongly to reading attainment, Beta = 0.3, $t(38) = 2.264$, $p = 0.029$, although rhyme detection had the strongest unique contribution to reading attainment, Beta = 0.319, $t(39) = 2.281$, $p = 0.028$.

Discussion

It was found that performance on the stress manipulation task could predict a significant amount of variance in reading ability after age, vocabulary, phoneme deletion, and rhyme detection had been taken into account. This suggests that stress sensitivity has an association with reading ability which is independent of its link with segmental phonological awareness. This is a key finding which suggests that sensitivity to speech rhythm is an important reading-related skill, and one that we argue now needs to be incorporated into theoretical accounts of reading development.

The findings from this study were anticipated based on the relatively small amount of literature investigating the relationship between speech rhythm and reading. They were in line with Wood and Terrell (1998) who found that those with reading difficulties performed significantly worse than their age-matched controls on a rhythm matching task, even after accounting for vocabulary, and Wood (2006a) who found that metrical stress sensitivity was able to account for variance in phoneme deletion, rhyme detection, and reading ability in a broader sample of children. The results were also in line with those of Wood (2006b), who used a similar metrical stress sensitivity task to the one used here, and found that performance on the experimental condition of this task (manipulating the metrical stress) was significantly associated with reading attainment.

Due to the fact that the correlations between the stress manipulation task and the phoneme deletion and rhyme detection task were relatively high (.74 and .64 respectively) we do not dispute that sensitivity to aspects of speech rhythm as measured in this study are related to segmental phonological awareness, as there is clearly phonological processing involved in this task. Moreover, Wood (2006a) argues that metrical stress sensitivity contributes to the development of phonological awareness. However, the major finding from this study that the stress manipulation measure predicted significant, unique variance in reading attainment after controlling for phonological awareness raises the idea that sensitivity to speech rhythm may contribute to reading development not just through the anticipated mechanism of phonological awareness development but also via an additional route which needs additional empirical work to generate a comprehensive theoretical explanation of the associations observed in this study. It could be the case that we need to make a distinction between the contribution of segmental phonology and suprasegmental phonology in the phonological analysis pathway instead, with suprasegmental phonology being linked to both semantic access and phonological representation. Whether or not speech rhythm has the potential to contribute to reading independently of both these known pathways (implying a new route to reading) would need to be assessed empirically.

So, how do we explain the independent contribution of speech rhythm to reading observed in this study? It will be recalled that children who performed well on the speech rhythm task also had good phonological awareness scores. So, one possibility is that the young readers who have developed abstract segmental representations may also have a better developed orthographic lexicon. Children may therefore be relying on segmental phonological awareness and the activation of orthographic representations to identify the mispronounced words in the stress manipulation task. However, segmental phonological awareness was controlled for in the hierarchical regression, which would counter the first part of this argument. Also, according to Wood (2004), segmentation phonological awareness can be developed in the absence of orthographic or alphabetic knowledge. Therefore, even children with good segmental awareness may not have a sufficiently well developed orthographic representation of language for it to be activated during a language task. Given the age of the children in this study, we would argue that it is unlikely that they would have orthographic representations of the words used as items in the stress reversal task.

Another possibility is that sensitivity to aspects of speech rhythm is associated with reading attainment via its contribution to multisyllabic word reading. As Protopapas, Gerakaki, and Alexandri (2006, p. 428) note: “Reading models have all but ignored stress assignment…typically dealing with only monosyllabic words”. Sensitivity to stress assignment is essential to the realisation of multisyllabic word reading as well as semantic processing and it is bound up with morphological rules as, for example, the application of some English suffixes change the stressed syllable in a word, whereas others do not. Moreover, sensitivity to other aspects of speech rhythm, such as intonation and pitch, are clearly implicated in reading fluency as well as in reading comprehension processes (e.g. Kuhn & Stahl, 2003). It therefore seems reasonable to suggest that these processes may mediate the observed association between stress and word reading in this study, although further work to examine this claim is required.

We anticipated the results found here partly because we know that English is a stress-timed language. Therefore, we would expect that in other stress-timed languages, using a duplicate test with similar items in that language, that those with phonological awareness and reading difficulties would also perform more poorly on the metrical stress sensitivity task. Furthermore, we would anticipate that if a similar test was used in a syllable-timed language rather than a stress-timed language that no group differences may be found. Thus, it would be interesting to replicate the study with other languages both those that are stress-timed and those that are syllable-timed. We could then see whether metrical stress sensitivity is more related to phonological awareness and reading ability in those stress-timed languages.

Conclusion

Metrical stress sensitivity was found to predict a significant amount of variance in reading attainment after age, vocabulary, phoneme deletion, and rhyme detection had been accounted for. Although the results of this study must be treated with caution due to the relatively small sample size, the fact that a significant relationship between speech rhythm and reading was found shows the strength of the relationship. The metrical stress sensitivity task used here had good internal reliability and good test-retest reliability. The results are suggestive of a link between speech rhythm and reading ability, thus further research is certainly warranted investigating the role of metrical stress sensitivity in reading development in languages other than English, and to explore its association with other measures of cognitive processing, such as temporal processing ability.

References

Bryant, P. (1998). Sensitivity to onset and rhyme does predict young children's reading: a comment on Muter, Hulme, Snowling, and Taylor (1997). *Journal of Experimental Child Psychology*, *71*, 29-37.

Chiat, S. (1983). Why Mikey's right and my key's wrong: The significance of stress and word boundaries in a child's output system. *Cognition, 14*(3), 275-300.

Chiappe, P., Stringer, R., Siegel, L. S., & Stanovich, K. E. (2002). Why the timing deficit hypothesis does not explain reading disability in adults. *Reading and Writing, 15*(1), 73-107.

Cutler, A. (1994). The perception of rhythm in language. *Cognition, 50*(1-3), 79-81.

Cutler, A., & Carter, D. M. (1987). The predominance of strong initial syllables in the English vocabulary. *Computer Speech & Language*, *2*(3-4), 133-142.

Cutler, A., & Norris, D. (1988). The role of strong syllables in segmentation for lexical access. *Journal of Experimental Psychology: Human Perception and Performance, 14*(1), 113-121.

Dunn, L. M., Dunn, L. M., Whetton, C., & Burley, J. (1997). *British pictures vocabulary scales II.* Windsor, NFER-Nelson.

Ehri, L. C. (1999). Phases of development in learning to read words. In J. Oakhill, & R. Beard (Eds.), *Reading development and the teaching of reading* (pp. 79-108). Oxford, UK: Blackwell.

Elliot, C. D., Smith, P., & McUlloch, K. (1996). *British ability scales II.* Windsor: NFER-Nelson.

Frederickson, N., Frith, U., & Reason, R. (1997). *Phonological assessment battery.* Windsor: NFER.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, M. Coltheart, & J. Marshall (Eds.), *Surface dyslexia* (pp. 301-330). London: Lawrence Erlbaum Associates Ltd.

Goswani, U. (2002). Phonology, reading development, and dyslexia: A cross-linguistic perspective. *Annals of Dyslexia, 52*, 141-163.

Goswami, U. (2003). How to beat dyslexia. *The Psychologist, 16*, 462-465.

Goswami, U., & Bryant, P. E. (1990). *Phonological skills and learning to read.* Hove: Lawrence Erlbaum Associates.

Jusczyk, P. W., Cutler, A., & Redanz, N. J. (1993). Infants' preference for the predominant stress patterns of English words. *Child Development, 64*(3), 675-687.

Kuhn, M. R., & Stahl, S. A. (2003). Fluency: a review of developmental and remedial practices. *Journal of Educational Psychology, 95*, 3-21.

Manis, F. R., McBride-Chang, C., Seidenberg, M. S., Keating, P., Doi, L. M., Munson, B., & Peterson, A. (1997). Are speech perception deficits associated with developmental dyslexia? *Journal of Experimental Child Psychology, 66*(2), 211-235.

McBride-Chang, C. (1996). Models of speech perception and phonological processing in reading. *Child Development, 67*(4), 1836-1856.

Morais, J. (2003). Levels of phonological representation in skilled reading and in learning to read. *Reading and Writing*, *16*(1), 123-151.

Muter, V., Hulme, C., Snowling, M., & Taylor, S. (1998). Segmentation, not rhyming, predicts early progress in learning to read. *Journal of Experimental Child Psychology, 71*, 3-27.

Protopapas, A., Gerakaki, S., & Alexandri, S. (2006). Lexical and default stress assignment in reading Greek. *Journal of Research in Reading, 29*, 418-432.

Snowling, M. J. (2000). *Dyslexia* (2nd ed.). Massachusetts, USA: Blackwell publishers.

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly*, *21*, 360-364.

Wade-Woolley, L., & Wood, C. (Eds.). (2006). Prosody and reading development [Special issue]. *Journal of Research in Reading, 29* (3).

Walley, A. C. (1993). The role of vocabulary development in children's spoken word recognition and segmentation ability. *Developmental Review, 13*(3), 286-350.

Wood, C. (1996). *Natural speech segmentation and literacy*. Unpublished doctoral dissertation, University of Bristol, UK.

Wood, C., & Terrell, C. (1998) Poor reader’s ability to detect speech rhythm and perceive rapid speech. *British Journal of Developmental Psychology, 16*, 397-413.

Wood, C. (1999). The contribution of analogical problem solving and phonemic awareness to children's ability to make orthographic analogies when reading. *Educational Psychology, 19*(3), 277-286.

Wood, C. (2004). Do levels of pre-school alphabetic tuition affect the development of phonological awareness and early literacy? *Educational Psychology, 24*(1), 3-11.

Wood, C. (2006a). Sensitivity to speech rhythm and the development of reading. In F. Columbus (Eds.), *Trends in cognitive psychology research* (pp. 171-181). New York: Nova Science.

Wood, C. (2006b). Metrical stress sensitivity in young children and its relationship to phonological awareness and reading. *Journal of Research in Reading, 29*(1) 270-287.

Table 1.

Summary statistics for children on the measures of phonological awareness, reading, metrical stress sensitivity and vocabulary

Task	Mean	SD
Age (in months)	73.18	6.75
Phonological Awareness Measures		
Rhyme Test /21	9.73	6.86
Phoneme Deletion Test /24	11.14	7.50
Reading Ability Measures		
Non-Word Reading Test /20	6.93	5.74
Reading Ability (BAS Raw Scores)	21.64	18.56
Stress Manipulation Task and Vocabulary		
Baseline Condition /16	15.36	0.84
Stress Reversed /16	6.30	3.49
Vocabulary (BPVS Standard Scores)	103.34	11.92

Table 2.

Correlation matrix between age, phonological awareness, reading, metrical stress sensitivity, and vocabulary.

Variables	1	2	3	4	5	6
1. Age						
2. Rhyme	.44***					
3. Phoneme	.65***	.69***				
4. NW Read	.54***	.71***	.73***			
5. BAS Read	.53***	.73***	.75***	.88***		
6. MSS Exp	.5***	.64***	.74***	.72***	.73***	
7. Vocab	-.14	.53***	.34*	.39**	.34*	.34*

Notes: Age, Age; Rhyme, Rhyme detection task; Phoneme, Phoneme deletion task; NW Read, non-word reading task; BAS Read, BAS word reading subtest; MSS Exp, Stress manipulation task experimental condition; Vocab, Vocabulary.

*p<.05, **p<.01, ***p<.001

Table 3

The amount of variance in reading ability accountable to age, vocabulary, phonological awareness, and metrical stress sensitivity.

Stage	Predictor(s)	R Squared Change	F	Sig	Beta
1	Age	0.304	18.371	<0.001	0.107
2	Age, Vocabulary	0.21	17.679	<0.001	0.036
3	Age, Vocabulary, Phoneme	0.112	11.979	0.001	0.243
4	Age, Vocabulary, Phoneme, Rhyme	0.057	6.967	0.012	0.319
5	Age, Vocabulary, Phoneme, Rhyme, MSS	0.038	5.127	0.029	0.3

Table 4

Regression coefficients at Stage 5 for age, vocabulary, phonological awareness, and metrical stress sensitivity.

Predictor(s) at Stage 5	Beta	t	Sig
Age	0.107	0.789	0.435
Vocabulary	0.036	0.292	0.772
Phoneme	0.243	1.518	0.137
Rhyme	0.319	2.281	0.028
MSS	0.3	2.264	0.029