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**Andrew John Holliman**

**The Role of Speech Rhythm Sensitivity in Children's Reading  
Development**

**Doctor of Philosophy**

**Psychology**

**Submission Date: 22<sup>nd</sup> September 2008**

## Abstract

This thesis examines whether speech rhythm sensitivity is related to children's reading development, phonological awareness, and non-speech rhythm sensitivity, whether children at risk of reading difficulties have a specific speech rhythm sensitivity deficit, and whether speech rhythm sensitivity is predictive of children's reading development over time. Study One investigated the relatedness of speech rhythm, non-speech rhythm, reading ability and phonological awareness. A hierarchical regression analysis revealed that non-speech rhythm sensitivity was unable to predict unique variance in reading attainment after controlling for speech rhythm sensitivity and phonological awareness. In contrast, sensitivity to speech rhythm was able to predict a significant amount of unique variance in reading attainment after age, vocabulary, phonological awareness, short-term memory, and non-speech rhythm had been accounted for. These results suggest that speech rhythm sensitivity is not merely an aspect of general phonological awareness or rhythmic appreciation; it is a skill that is explaining new variance in reading ability. Study Two investigated whether a measure of speech rhythm sensitivity administered to 5 to 7-year-old children could predict the different components of reading ability one year later. A series of hierarchical regression analyses revealed that speech rhythm sensitivity was able to predict a significant amount of unique variance in word reading, reading comprehension, and the phrasing component of a reading fluency measure after controlling for receptive vocabulary, age and phonological awareness. Study Three investigated whether apparent speech rhythm sensitivity deficits in young poor readers represent a *specific deficit* in these children who were at risk of reading difficulties. It was found that after controlling for receptive vocabulary and phonological awareness, the 'at risk' children were outperformed by

their chronological-age matched controls, but not by their reading-age matched controls on measures of speech rhythm sensitivity. This is suggestive of a maturational lag as opposed to a specific deficit in speech rhythm sensitivity. The overall findings from these concurrent, longitudinal, and cross-sectional data suggest that speech rhythm 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.

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## **Chapter 1 - Theoretical Overview**

This thesis sets out to investigate:

- a. Whether speech rhythm sensitivity is related to young children's reading development, phonological awareness, and non-speech rhythm sensitivity, (that is, the extent to which they are assessing different components of the same skill);
- b. Whether speech rhythm sensitivity is predictive of children's reading development over time;
- c. Whether young English-speaking children at risk of reading difficulties display a specific speech rhythm sensitivity deficit.

To contextualise these research questions a review of current theoretical and empirical literature into the skills necessary for successful reading acquisition is presented. This will argue that although we know that phonological awareness and morphological awareness are necessary for good reading attainment, it is possible that other speech related skills which developmentally precede them are prerequisites for their successful development, and may even contribute to reading directly. In particular, it is suggested that sensitivity to rhythm, and speech rhythm specifically, may contribute to successful reading acquisition.

### **1.1. Typical Reading Development and Reading Difficulties**

This first section considers how reading difficulties might occur by discussing some of the proposed phases (or stages) of typical reading development. The aim of this section

is to review our understanding of the path that reading development typically takes, and where reading development seems to go wrong for children with reading difficulties.

Most theories of successful reading development acknowledge that it is marked by successful phonological awareness development (Snowling, 2000), which refers to the ability to perceive and manipulate the sounds of spoken language. While this standpoint is generally accepted, the learning processes that need to be developed, and the proposed phases and stages that need to be progressed through in order to acquire successful phonological awareness and reading skills, are heavily debated in the literature. The following three models of reading development (Frith, 1985; Ehri, 1997; Ziegler & Goswami, 2005) have been especially influential with respect to offering explanations of reading development and reading difficulties. However, each theory has a slightly different explanation concerning how phonological awareness and subsequent literacy develops. Table 1.1 summarises and compares the proposed stages/phases of reading development outlined by each of the three models reviewed here.



Table 1.1 An outline of the proposed phases/stages of reading development (adapted from Ehri, 2005)

	Frith (1985)	Ehri (1997)	Ziegler & Goswami (2005)
No. of stages/phases	3	4	5
	Logographic	Pre-alphabetic	Syllables
		Partial alphabetic	Onset-rime
	Alphabetic	Full alphabetic	Nucleus-Coda
			Phoneme
	Orthographic	Consolidated alphabetic	Phone

Some theorists argue that in the earliest stages of reading development children begin to read words as logograms; that is, as symbolic visual input. For example, Frith (1985) referred to this as the *logographic stage*, while Ehri (1997) re-labelled Frith's first stage to the *pre-alphabetic phase*. Ehri (1999) suggested that Frith's term *logographic* implied that children can read and remember the full visual forms of sight words and argued that this is not the case. It should be noted that in Ehri's model, it is suggested that in order to become a skilled reader, a child must progress through *phases* of alphabetic development, rather than *stages* of reading development. Ehri deliberately discusses *phases* of reading development rather than Frith's *stages* of reading development, because she believed that stages suggest a fixed sequence, and rejected the idea that completion of one stage must be a prerequisite for moving on to the next. This is one of the discrepancies between the two models, although there is a great deal of similarity between the two models as well.

According to these two theories, in the initial stage/phase of reading development, children remember words through making semantic connections with visual salient cues which help that word to be identified. Important to note is that no phonological processing strategies are utilised to decode words at this point because they are not yet developed; instead, words are recognised by attending to the salient visual features or contextual cues that are associated with particular words. There is some support for this initial stage/phase of reading development in the literature: for instance, Masonheimer, Drum, and Ehri (1984) found that preschoolers who could read relatively few words, could actually recognise several common signs or labels based on their visual features (e.g. McDonalds, Pepsi). It was also found that while these children knew approximately 60% of the letter names, they were unable to detect subtle changes to words when they were misspelled (e.g. Xepsi instead of Pepsi) and still read the word as *Pepsi*, which might suggest that they are relying on the visual features associated with words rather than their alphabetic letters. Additionally, Gough, Juel, and Griffith (1992) taught preschool children to read four words, one of which was associated with a thumbprint. It was found that children were able to master the thumbprint-associated word first, that the thumbprint alone resulted in pronunciation of the associated word, and that over half of the children could no longer identify the word when the thumbprint was removed. This supports the presence of a logographic stage or pre-alphabetic phase in children's reading development.

In further support of a pre-alphabetic phase, Bloodgood (1999) found that children could recognise their own names and the names of their friends in the absence of adequate letter-sound knowledge. It was argued on the basis of some qualitative

feedback, that children relied on the initial letter as the salient cue. Related to this, Treiman and Broderick (1998) showed that some children could correctly write and spell their own name yet could not name the letters they had included, which suggests that they are recognising the visual shapes rather than applying any knowledge of letter sounds. Moreover, Byrne (1992) showed that pre-alphabetic children were more able to make semantic connections than phonemic connections, which adds more weight to the argument that in the earliest stages of reading development, children rely on salient visual, contextual cues as a means of recognising words, because they lack knowledge of letter names, sounds, and general alphabetic awareness. Indeed, Berninger, Abbott, and Shurtleff (1990) found from a one-year longitudinal study with kindergarten children that visual language skills (consistent with the logographic stage) were able to predict reading and spelling at the start of the year, but not one year later, which perhaps suggests that logographic reading characterises 'early' reading and spelling.

In spite of the evidence in support of a logographic or pre-alphabetic phase, some theorists contend Frith's argument that children spell logographically before they can spell alphabetically and argue that there is no evidence for this claim (Goswami & Bryant, 1990). Other theorists (e.g. Stuart & Coltheart, 1988) argue that neither visual nor contextual cues facilitate reading development and reject the presence of a logographic or pre-alphabetic stage/phase. They argued that successful reading development is purely dependent on phonological processing skills and that salient visual cues and contextual associations are not necessary for reading development. It is likely that children do utilise the logographic stage or pre-alphabetic phase early on in reading development because that are not yet equipped with a more successful strategy

for recognising words. However, as Berninger et al. (1990) have shown, the use of this initial stage in later reading development is questionable.

A more widely accepted skill which is critical for reading development is knowledge of the alphabetic principle (Ehri, 2005). In Frith's (1985) second stage, the *alphabetic stage*, it is proposed that children learn to decode words into individual letter sounds, or phonemes. Here, words are read using the additional skill of applying grapheme-phoneme correspondence (GPC) rules, mapping graphemes (letters) to phonemes (sounds) to decode words; this requires an understanding of individual letter-sounds. Ehri agreed with this premise but subdivided this stage into two phases: the *partial alphabetic phase* and the *full alphabetic phase*.

In the *partial alphabetic phase* she argues that children begin to read sight words by forming connections between particular letters in the words, usually the first and last letters, and the sounds detected in their pronunciation. Thus, children at this point are beginning to exhibit early signs of phonemic awareness development. For instance, a child might be able to recognise their name (e.g. *John*) through an understanding of the beginning and last letter sounds 'J' and 'n'. However, the strategy used in this phase typically includes decoding errors (e.g. the word *Join* might also be decoded as *John*) and such errors have been demonstrated in Mason (1980). Thus, sight word reading in this phase is imperfect. While some theories of reading development overlook the presence of a partial-alphabetic phase (e.g. Gough & Hillinger, 1980), others contend that such 'phonetic cue' reading precedes decoding (Ehri & Wilce, 1985) and this idea has received some support (e.g. Roberts, 2003; Bowman & Treiman, 2002). While the

presence of this partial alphabetic phase is questionable. Ehri maintains that this phase does exist, but notes that the length of time spent in this phase is variable. Ehri (2005, p.145) commented that “there are no expectations about how long this phase will last”. Indeed, some children progress through this phase very quickly, while others take more time. It has been argued that the more transparent the writing system of a language, the faster children will move through this phase (Wimmer & Hummer, 1990).

In the *full alphabetic phase*, similar to Frith’s *alphabetic stage*, children begin to make alphabetic connections between other letters (not just at the beginning and end) using GPC rules to decode words. In this phase, children are able to form connections between graphemes in spellings and phonemes in pronunciations to recognise words. Phonemic awareness refers to the knowledge of individual letter sounds, for instance, the knowledge that the word ‘cat’ can be broken down into /k/ /a/ /t/ (Wood & Terrell, 1998a). This skill has been extensively linked to reading development and such systematic phonics instruction has resulted in better reading achievement (Chall, 1967). In a meta-analysis of the experimental studies on phonics and word reading, Ehri, Nunes, Stahl, and Willows (2001) found that systematic phonics instruction improved children’s decoding, word reading, and comprehension, more so than any other kind of instruction. While Frith’s model of reading emphasised development more generally and regarded sight word reading as non-phonological (Beech, 2005), central to Ehri’s (1997) model was the idea that it is essential to internalise the grapho-phonemic system in order to develop a sight vocabulary in memory. Such discrepancies between the two models continues into the final stage/phase.

Decoding words on a letter-by-letter basis is very time consuming and memory intensive. As reading develops, this strategy is substituted for a more efficient one, which involves recognising strings/sequences of letters and their sounds, rather than individual letters. This strategy characterises fast and fluent skilled reading. Frith calls this final stage the *orthographic stage*, while Ehri (1997) renamed this to the *consolidated alphabetic phase* because the former was deemed inadequate, too general, and ambiguous (Ehri, 1999).

In this final stage/phase, recurring letter patterns become consolidated so that children can identify words by chunking parts of them together. For instance, the word *string* might be processed in two parts as *str-ing* instead of *s-t-r-i-n-g*. Henry (2003) noted that it would be more difficult, memory intensive, and time consuming to learn the word *interesting* as 10 grapho-phonemic units and argued that a more effective strategy for making connections would be to divide the word into four syllabic units (e.g. *in-ter-est-ing*). Ehri (2005, p.150) argued that “the consolidated alphabetic phase replaces the full alphabetic phase when the predominant types of connections for retaining sight words in memory are morphographic”. Indeed, while few studies have investigated the effects of consolidation on sight word reading (Ehri, 2005) some research suggests in line with the theory, that common letter patterns and sequences facilitate learning and progression. For instance, Ehri and Robbins (1992) recruited first-grade children and asked them to learn one set of words followed by a second set of words. In one condition, the second set of words shared the letter strings (or rime endings) as the first set (e.g. feed and seed) and in the second condition they did not. It was found that

children learned words faster when they shared the letter strings and rime units with the first set, suggesting that recurring letter patterns/sequences helped to make connections.

Frith (1985) made attempts to integrate both reading and spelling development in her theory of reading development. She offered explanations as to how these skills develop in relation to each other. It was argued that cross-domain influences occur; that is, the development of reading and spelling proceed out of step, but the strategies acquired and utilised in one domain facilitates the development of that strategy in the other. Frith referred to 'pace makers' to explain how strategies from one domain are utilised and transferred to facilitate progression in the other domain. Thus, Frith (1985) argued that logographic reading (the whole-word approach) drives the development of logographic spelling, acting as a pacemaker. Then, to progress to the alphabetic stage, phonological awareness contributes more to spelling, which in turn acts as a pacemaker for alphabetic reading. It follows that orthographic representations gained from reading then act as a pacemaker and lead to orthographic spelling.

While there is a lack of empirical support for the shift from logographic reading to logographic spelling, there is evidence to support the idea that phonological awareness is related more to early spelling development. For instance, Wimmer, Landerl, Linortner, and Hummer (1991) found that phonological awareness was more strongly correlated with early spelling than reading. In addition to this, Lundberg, Frost, and Peterson (1988) recruited 200 Danish pre-school children that had received no formal reading instruction and found that phonological awareness training influenced spelling in Grade 1, but not reading, although phonological awareness training had a significant

effect on reading at Grade 2. Moreover, Uhry and Shepherd (1993) also found that beginning readers taught to practice phonetic spellings were more able to read sight words than beginning readers receiving other instruction. These findings perhaps suggests, in accordance with Frith's theory, that phonological awareness facilitates alphabetic awareness for spelling, which in turn facilitates alphabetic awareness for reading.

Frith emphasised that in the orthographic phase children develop a memory for spelling sequences. One of Frith's central claims was that orthographic knowledge of both form (spelling patterns within written words) and function (relationships between orthography, phonology, and morphology) only occur once GPC rules have been mastered. However, many contend this notion (e.g. Goswami & Bryant, 1990) and propose that children can recognise sequences much earlier in their reading development. Indeed, Lehtonen and Bryant (2005) found that 6 to 7-year-old children were able to identify incorrect forms, even when they did not know its function. They argued that this provides evidence that sophisticated GPC knowledge is not a prerequisite for orthographic knowledge. The sequential nature of Frith's theory is one of its major weaknesses.

So far, two theories of reading development (Frith, 1985; Ehri, 1997) have been considered and both emphasise the importance of developing knowledge of GPC rules and phoneme awareness. However, there is another phonological skill, which has received less attention from the theories reviewed so far, namely onset-rime knowledge. An *onset* refers to the consonants which precede the vowel in a spoken syllable and



*rime* refers to the vowel and following consonants. For example, in the spoken word 'cat' the onset would be the sound /k/ and the rime would be /at/. This should be distinguished from *rhyme*; for instance, the words *mountain* and *fountain* rhyme, but each word has two rime units 'ount' and 'ain' because they have two syllables. The words *mountain* and *counting* do not rhyme, but share one rime unit with 'ount' (Goswami, 2002, p.142). Ziegler and Goswami (2005) put forth a psycholinguistic grain size theory of reading development, which places more emphasis on onset-rime knowledge during reading development than the other two theories and also holds that phoneme awareness occurs as a result of literacy tuition.

Ziegler and Goswami (2005) argue that for successful, unambiguous mapping of visual symbols (orthography) to sounds (phonology) children need to find shared grain sizes between the two domains. It is thought that beginning readers are faced with three inevitable problems; availability, consistency, and granularity. For beginning readers, not all phonological units are explicitly, or consciously, accessible, which makes it more difficult to map phonology onto orthography (availability). In English, the same orthographic units can have multiple pronunciations, and the same pronunciations (phonological units) can be spelled in many different ways, which slows reading (consistency). Lastly, Ziegler and Goswami (2005) note that when access to the phonological system is based on larger grain sizes (e.g. when there are more words than syllables, more syllables than rimes, more rimes than graphemes, more graphemes than letters), there are more orthographic units to learn (granularity). These three problems need to be resolved in order to achieve proficient reading.

In terms of the developmental path reading seems to take, Ziegler and Goswami (2005, p.4) argue in line with Stanovich (1992) that “the emergence of phonological awareness can best be described along a continuum from shallow sensitivity of large phonological units to a deep awareness of small phonological units”. The idea that phonological awareness progresses from a shallow awareness to deep awareness has received some support (e.g. Stainthorp & Hughes, 2002; Stanovich 1986; Stanovich, 1992). As outlined earlier in Table 1.1, Ziegler and Goswami hold that syllable awareness develops first, when children are aged 3 or 4. Onset-rime follows when children are aged 4 to 5. It is then believed that phoneme awareness only develops once children are explicitly taught to read. This developmental progression has been supported by Goswami and Bryant’s (1990) theory of reading development, along with some other recent literature (e.g. Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003; Anthony & Lonigan, 2004) which found that mastery of word-level skills preceded syllable-level skills, mastery of syllable-level skills preceded onset-rime skills, mastery of onset-rime skills preceded phoneme-level skills.

The models proposed by Frith (1985) and Ehri (1997) differ from Ziegler and Goswami’s (2005) model because both ignore the salience of onset and rime in their discussions of phonological and alphabetic development. Important to Ziegler and Goswami’s theory is the notion that onset-rime knowledge facilitates phonemic awareness development and that phoneme awareness develops as a result of literacy tuition. In support of this, Goswami (2002, p.144) argued that “syllables, onsets, and rimes are represented prior to literacy. Phonemes are represented only as the alphabet is learned and literacy is taught”. Additionally, in Goswami and Bryant’s (1990) theory of

reading development it was proposed that children learn to associate onsets and rimes with strings of letters and as a result can make inferences about new words based on these spelling patterns through the process of analogy: for example, a child might be able to use knowledge of onset and rime in the word *dog* to decode the word *fog*.

Goswami and Bryant believed that as a result of this onset-rime knowledge, children become aware of phonemes and can use a phonemic code to assist with the decoding process. Goswami and Bryant speculated that reading ability and spelling ability are distinctly separate at this point, but that after two years of developing onset-rime awareness and phonemic awareness, children begin to integrate reading and spelling, enhancing their knowledge of the component sounds of words. The models proposed by Ehri and Frith do not suggest that onset and rime awareness is necessary for phonemic awareness development.

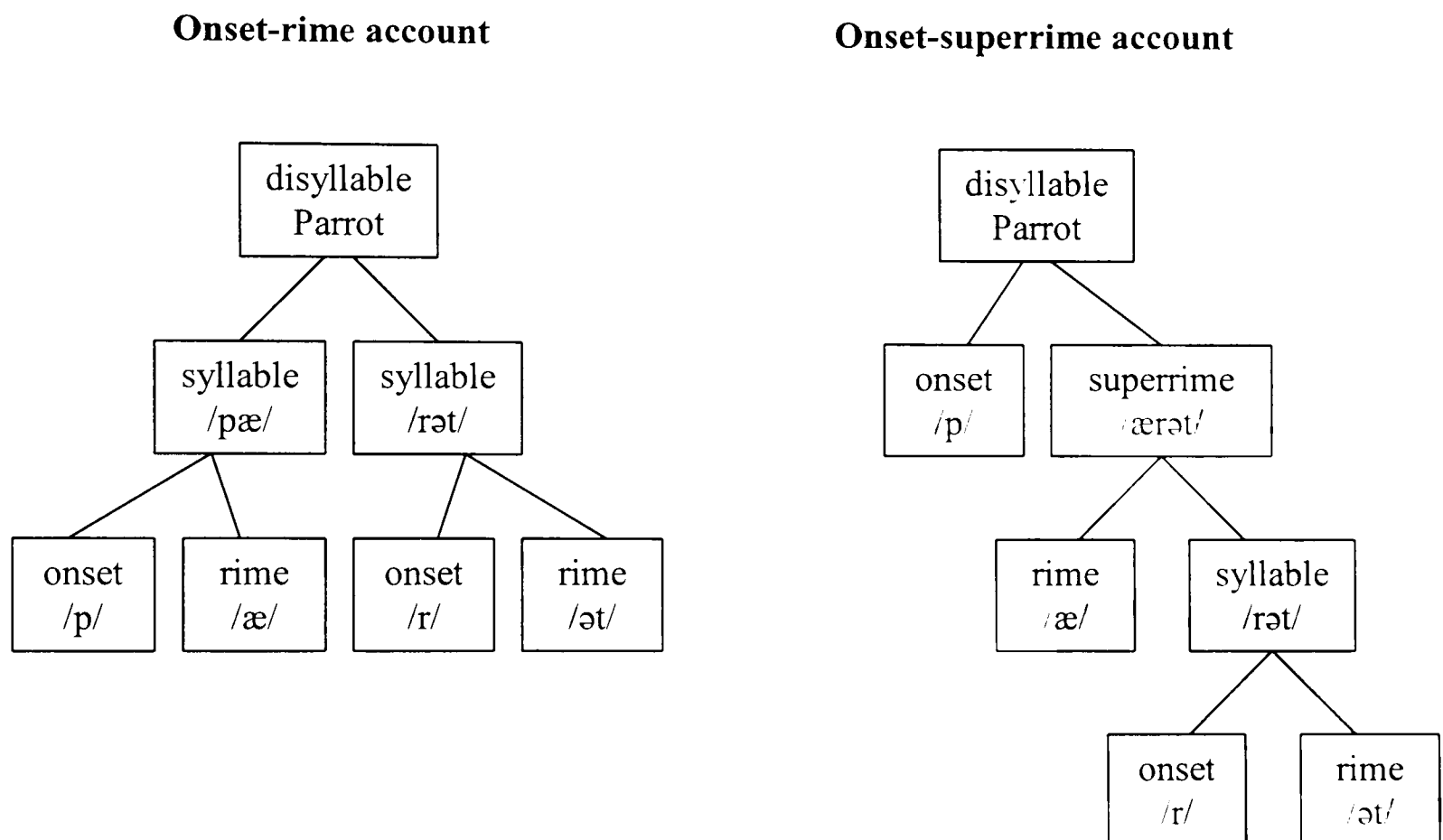
Whilst Ziegler and Goswami's (2005) theory of reading development has received some support, it is not without controversy. In Ziegler and Goswami's (2005) theory, it was argued, contrary to the models of Frith (1985) or Ehri (1997), that phonemic awareness skills are only acquired through formal tuition of the alphabetic principle, after literacy tuition. This standpoint has received some support (Goswami, 2002; Morais, 1991; Goswami & Bryant, 1990; Ziegler & Goswami, 2005). However, other researchers (e.g. Wood, 2004; Lundberg, 1991) contend this and argue that "phonemic awareness is a critical precursor of reading acquisition rather than a mere consequence of being literate" (Lundberg, 1991, p.50). There is other available evidence (e.g. Caravolas, 2006) which has demonstrated that children of a variety of European languages display good levels of phoneme awareness as early as two years prior to any literacy tuition.

Moreover, the claim that phonological awareness development progresses from large (onset-rime) units to small (phoneme) units has also been disputed and some evidence has been presented which suggests that the smaller units come first and that larger units are emphasised later on in development (e.g. Duncan, Seymour, & Hill, 1997).

Another problematic aspect of Ziegler and Goswami's (1995) model of reading development is its reliance on monosyllabic word reading. For instance, they explicitly used the term onset and rime to refer to the division of monosyllabic words (e.g. *d-og*, *c-at*, *h-it*, *c-ut*) and justify this by saying that almost all phonological processing tasks (rhyme and phoneme) use monosyllabic words with young children. This line of argument was also followed by Goswami and Bryant's (1990) earlier theory of reading development. However, what does this tell us about how children come to decode multisyllabic words? Indeed, Duncan, Seymour, and Bolik (2007, p.200) comment that "a striking feature of existing research on sensitivity to rime units is a reliance on the use of monosyllabic stimuli". To shed light on this matter, Duncan et al. (2007) investigated the relationship between rhyme and reading in multisyllabic words, which is less well-understood.

To contextualise this, while many monosyllabic words fit easily into an onset-rime structure, various disyllabic words do not fit so easily into this structure and are better classified into either an onset-remainder structure, rather than having an onset and a rime for each syllable (Duncan et al., 2007), or even an onset-superrime structure (Berg, 1989). Berg argued that disyllabic words (e.g. *rocket*) can be broken down into an onset (*r*) and a 'superrime' (*ɒkɪt*), and that the superrime itself can be broken down into a

rime and a syllable, which includes an onset-rime structure. See Figure 1.1 for an example of the distinction between onset-rime and onset-superrime using the word *parrot*, based on a diagram from Berg (1989).



**Figure 1.1** The hierarchical structure of the disyllabic word *parrot* based on Berg (1989)

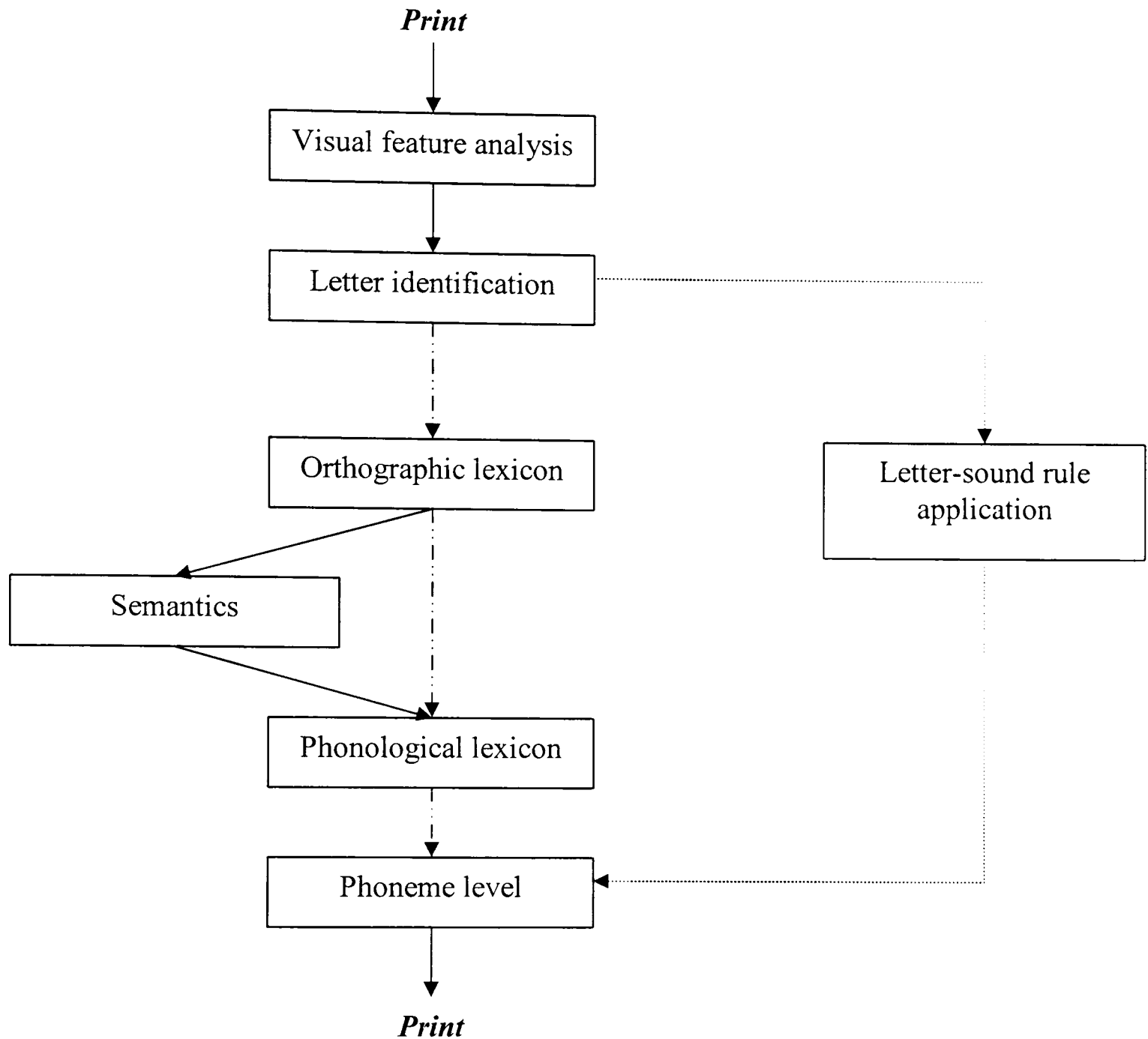
As can be seen from Figure 1.1, what constitutes an awareness of rhyme in multisyllabic words is less straightforward than with monosyllabic words, and it is possible that superrime units might be more salient than rime units in multisyllabic words (Duncan et al., 2007). To investigate this, Duncan et al. (2007) conducted a series of experiments with primary school children. In Experiment 1, children were asked to provide a rhyming word to a set of monosyllabic words, followed by a set of disyllabic words, and their response was scored for the placement of their rhyming unit, if they could rhyme at all. The disyllabic words either had first syllable stress or second

syllable stress and children participated in all conditions (repeated measures design). In Experiment 2 with a different set of primary school children, a similar procedure was followed only this time, the stimuli consisted of non-words and children only participated in one of the conditions (independent measures design). Both sets of results indicated that the location of stress has an impact on the nature of the rhyme in disyllabic words. For disyllabic words and non-words with initial stress (e.g. *muddle*, *satter*) a preference for superrimes emerged, however. for disyllabic words and non-words with final stress (e.g. *saloon*, *harpel*) the preferred rhyming unit was more variable. One of the conclusions from Duncan et al. (2007, p.214) was that “disyllabic rhyme is considerably more complex than monosyllabic rhyme”. The complexities related to non-monosyllabic word reading has not only been neglected in Ziegler and Goswami’s (2005) theory of reading development, but also, the models by Frith (1985) and Ehri (1997) have not explicitly dealt with how children come to read multisyllabic words.

In summary of these three theories, Ehri (1997) provides a model of typical, successful reading development that is generally in line with the other two theories. However, key discrepancies can be identified; Ziegler and Goswami’s (2005) model places more emphasis on the importance of onset and rime and suggests that awareness of phonemes is developed later in the reading development process. Also, Frith places greater emphasis on the importance of spelling in reading development. None of the theories sufficiently address how children come to read multisyllabic words, and focus predominantly on monosyllabic word reading.

While other theories of reading development have been proposed in the literature (see Ehri, 2005 for a summary), the three included in this review (Frith, 1985; Ehri, 1997; Ziegler & Goswami, 2005) have received a great deal of attention from researchers in the field. These models of typical reading development have not only provided us with a theoretical basis of how literacy develops, but have also enabled reading researchers to speculate about the precise developmental phase in which the reading development process seems to go wrong for those with reading difficulties. Indeed, people with reading difficulties seem to have trouble mapping graphemes to phonemes and tend to form *partial* rather than *complete* connections in the alphabetic phase when they store sight words in memory (Ehri, 1997), and thus have underspecified phonological representations of words. It should be noted here that there are some alternatives to stage theories (e.g. dual route theories), which inform us about the way in which skilled readers recognise words.

Phonological awareness is a skill which has been consistently related to literacy development (see Adams, 1990; Snowling, 2000 for reviews) and is implicated in models of reading development. It is most commonly measured through three different kinds of associated abilities: syllable awareness, onset-rime awareness, and phonemic awareness. These phonological processing skills play an important role in decoding and recognising words. However, some words (e.g. yacht) cannot be decoded using GPC rules. This distinction of how we recognise words, both phonologically and non-phonologically, is highlighted in the Dual-Route Model of Reading taken from Castles, Bates, Coltheart, Luciano, and Martin (2006) based on theories from Coltheart (1978) and Coltheart, Curtis, Atkins, and Haller (1993), see Figure 1.2.



**Figure 1.2** The dual-route model of reading adapted from Coltheart (1978) and Coltheart et al. (1993)

The word recognition model depicted in Figure 1.2 proposes two routes by which reading aloud is achieved, both of which begin with visual input from letters and result in a phonological output which generates a spoken response. The lexical pathway (connected with dashed lines) involves using knowledge of previously seen letter strings and matching the output with an item (or word) stored in memory, in the mental lexicon. In this pathway, word recognition is facilitated by the fact that we have seen



that particular word before or that the semantic context helps us to recognise it. The non-lexical pathway (purely on the right-hand side) does not tap into the lexicon, but utilises GPC rules to decode words. Unusual words such as ‘yacht’ can only be read via the lexical route; if GPC rules were utilised to decode this word it would be inaccurately read aloud. Conversely, non-words such as ‘ropsatch’ can only be accurately decoded and read aloud using grapho-phonemic correspondence rules because these letter strings (orthographic lexicon) do not match any stored in the mental lexicon. This model emphasises the importance of phonological awareness (phonemes, rhymes, and syllables), in early reading development at a time when a child’s orthographic lexicon and vocabulary may be limited. The phonological processing theory (and the phonological representations hypothesis) will now be considered in depth in Section 1.2.

## **1.2. Phonological Awareness and Literacy Development**

Phonological awareness has been described as a skill that directly influences reading development (Bradley and Bryant, 1983) with some arguing that it has a *causal* role in the acquisition of literacy (Goswami, 2002; Goswami, 1999). Children with reading difficulties almost always have accompanying phonological processing deficits (see Snowling, 2000 for review). For example, in a study by Ramus et al. (2003) it was found that 100% of their reading disabled sample displayed phonological processing deficits. Brady and Shankweiler (1991) also noted that phonological processing deficits are present in almost every poor reader. Other research from Juel (1998) showed that children who were in the bottom quarter in their class at reading displayed greater difficulties with phonological awareness four years earlier.

Most of the literature on children's reading development has focussed on those with reading 'difficulties' and therefore the study of typical and precocious readers has received less attention (Jackson & Coltheart, 2001). Despite this, there is a literature which demonstrates that performance on phonological awareness measures (or tasks which tap into phonological processing) is superior in precocious readers in comparison to non-precocious readers of the same chronological age (Singson & Mann, 1999; Stainthorp & Hughes, 1998). For instance, Stainthorp and Hughes (2004) followed fourteen 11-year-old children from the age of five who had been identified as precocious readers and compared their performance to fourteen non-early readers matched on age, gender, and receptive vocabulary on the phonological assessment battery (PhAB) along with a variety of reading assessments. It was found that the precocious readers maintained their reading advantage six years later and also demonstrated superior phonological awareness in comparison to the non-precocious controls. Therefore, there was stable, long-term phonological awareness superiority in precocious readers, which correlated with all measures of reading. Such findings indicate that poor readers typically have poor phonological awareness, but also that good readers have better phonological awareness.

Phonological awareness is an umbrella term which refers to knowledge of the sounds of spoken language. However, there are many different components of phonological awareness (e.g. syllable, phoneme, rhyme) which have been more or less related to reading development in the literature. Most of the literature investigating phonological awareness development has focussed on rime and phoneme awareness for which there is a great deal of literature. The research linking these two phonological processes to

reading development will now be considered separately because there is a great deal of conflicting evidence and debate surrounding which of these two phonological processes is the best predictor of literacy.

Onset-rime awareness is a measure of phonological awareness that has been linked to literacy acquisition for many years. According to Goswami (2002) and in line with Goswami and Bryant's (1990) and Ziegler and Goswami's (2005) theory of reading development, syllables, onsets, and rimes are represented prior to literacy attainment. Bryant (1998) has emphasised the importance of onset and rime in the development of phonological awareness and in determining how well children learn to read. In an early study, Bradley and Bryant (1978) assessed whether children could identify the odd one out from a list of rhyming words, and also whether they could produce a rhyming word that was similar to the target word. It was found that the children with reading difficulties were outperformed by their younger, reading-level matched counterparts. To explain such findings, Bryant (1998) has proposed that children become aware of the onsets shared by different words (such as boat, bike, bat, brunch etc) and the rimes shared by different words (such as goat, gloat, throat, bloat etc). It is proposed that once this knowledge has been developed, "this awareness eventually plays a part in their learning about spelling sequences" (Bryant, 1998, p.30). Bradley (1988, cited in Morais, 1991, p.10) further commented that it is "through their rhyming games children learn to analyse words within the syllabic unit at the level of the phoneme".

In support of this, Bryant, Maclean, Bradley, and Crossland (1990) conducted a two-year longitudinal study with 65 children from the age of 4 years 7 months and

monitored the progress in phonological awareness, reading, and spelling. It was found that rhyme awareness was able to predict significant, unique variance in reading after controlling for individual differences in phoneme awareness. They concluded that sensitivity to rhyme promotes phonemic awareness and in turn, literacy, and that sensitivity to rhyme can influence literacy development independently of its connection with phonemic awareness. Wood and Terrell (1998b) also found that poor readers have a specific deficit in rhyme awareness relative to both chronological-age and reading-age matched control groups. These studies emphasise the importance of rhyme awareness in both the development of phoneme, and more broadly, phonological awareness.

However, other studies contend that phoneme awareness is the best predictor and have found that only phoneme identification and phoneme deletion tasks correlated with reading attainment, whilst rhyme detection and rhyme production did not (Muter, Hulme, Snowling, and Taylor, 1998). Such findings have been replicated by Lundberg et al. (1988) who found that phonemic awareness tasks were powerful predictors of reading and spelling ability; more so than rhyming tasks. Macmillan (2002) critically reviewed the literature to investigate three claims from Goswami and Bryant (1990) concerning the onset-rime evidence; that sensitivity to rhyme is related to literacy, that there is a causal connection between rhyme and reading, and that rhyme awareness leads to phonemic awareness. She argued that none of these claims could be supported and that the majority of studies finding rhyme awareness to be a predictor of reading ability were methodologically weaker than those that found phonemic awareness to predict reading attainment. She concluded from this that it cannot be claimed, on the

basis of the available evidence, that rhyme awareness is related to literacy in a way that is distinctive of phonological awareness.

Phonemic awareness refers to the knowledge of letter sounds. In English, there are approximately 44 phonemes (although this varies depending on the source) but there are only 26 letters in the alphabet to represent them. Phonemic awareness can be measured using tests which assess the ability to think consciously about and perform mental operations on phonemes in words, such as segmenting, blending, deleting, and changing the order of individual phonemes. Yopp (1988, p.161) provided a summary of the different ways of assessing phoneme awareness, as displayed in Table 1.2.

**Table 1.2 Tasks used to assess phoneme awareness (adapted from Yopp, 1988)**

<b>Task</b>	<b>Example</b>
Sound-to-word matching	Is there a /f/ in calf?
Word-to word matching	Do pen and pipe begin the same?
Recognition/production of rhyme	Does sun rhyme with run?
Isolation of a sound	What is the first sound in rose?
Phoneme segmentation	What sounds do you hear in the word hot?
Phoneme counting	How many sounds do you hear in the word cake?
Phoneme blending	Combine these sounds: /c/-/a/-/t/.
Phoneme deletion	What word is left if /t/ were taken away from the middle of 'stand'?
Specifying deleted phoneme	What sound do you hear in meat that is missing in eat?
Phoneme reversal	Say 'os' with the first sound last and the last sound first
Invented spellings	Write the word monster

Yopp (1988) obtained 96 children aged 5 to 6-years-old and administered ten of the phoneme awareness tasks outline in Table 1.2 along with a test that assessed the rate to which children could read artificial printed words (and thus their early reading acquisition). It was found that almost all of the phoneme awareness tasks were

correlated suggesting that they are tapping into the same underlying ability (construct validity). The phoneme awareness tasks varied in level of difficulty with rhyme being the easiest and phoneme deletion being the hardest and almost all phoneme awareness tasks showed a strong correlation with the early reading ability task.

Phoneme awareness seems to facilitate the segmentation of words during decoding, which is a key skill related to successful reading development (Muter et al., 1998). Ehri, Nunes, Willows, Schuster, Yaghoub-Zadeh, and Shanahan (2001) conducted a quantitative meta-analysis to investigate the relationship between phonemic awareness instruction and reading ability. The analysis comprised 52 published studies, which included 96 cases. Phoneme awareness instruction was found to enhance phoneme awareness (as expected), word reading, spelling, and reading comprehension. It generally helped the later reading ability of typical developers and at-risk samples, children of different ages (preschoolers, kindergarten, first graders), and children of different socio economic status (SES). It was argued that “In Sum, PA instruction was found to make a statistically significant contribution to reading acquisition” (Ehri et al., 2001, p.250). Thus, phoneme awareness seems to play a pivotal role in literacy acquisition.

As noted earlier, some would argue that phonemic awareness skills are only acquired through formal tuition of the alphabetic principle (Goswami, 2002; Morais, 1991; Goswami & Bryant, 1990; Ziegler & Goswami, 2005). However others contend this standpoint and argue that phoneme awareness develops *prior* to literacy (Lundberg, 1991; Caravolas, 2006) and there is some evidence in support of this claim. Wood and

Terrell (1998a) recruited 30 preschool children who had received no formal teaching of the alphabetic principle at preschool. A variety of phonemic awareness assessments were used including a letter-sound knowledge task (e.g. what sound does the letter 'a' make), an alliteration detection task, which required children to identify which of three sounded words began with the same sound as the target word, and a phoneme deletion task, which required children to repeat words without the beginning or final phoneme. It was found that these preschool children displayed an awareness of phonemes despite any formal tuition of the alphabetic principle in preschool. Children scored just under 50% accuracy on the alliteration and letter-sound knowledge task, and even scored 25% accuracy on the phoneme deletion, which was previously identified as the most difficult phoneme awareness task (Yopp, 1988). While it cannot be ruled out that these children may have received some alphabetic tuition within the home, either by parents or by some other means, these results suggest that phoneme awareness can develop 'naturally' in the absence of explicit literacy tuition.

In perhaps the best summative statement about the debate as to whether phonological awareness is an artefact or precursor of reading tuition, Yopp (1992, p.697) argued that "the relationship between phonemic awareness and learning to read is most likely one of reciprocal causation...or mutual facilitation...in order to benefit from formal reading instruction, youngsters must have a certain level of phonemic awareness...reading instruction, in turn, heightens their awareness of language...thus, phonemic awareness is both a prerequisite for and a consequence of learning to read". Whether reading attainment or phonemic awareness comes first, the two skills are strongly related.

While distinctions have been made between rhyme and phoneme awareness in discussions of reading development, it should be noted that some research indicates that both abilities are aspects of the same fundamental ability (Anthony & Lonigan, 2004). Anthony and Lonigan argue that rather than excluding sensitivity to rhyme from the phonological awareness construct, we need to accommodate it because both are measures of phonological sensitivity, albeit at different levels of linguistic complexity. Anthony and Lonigan (2004, p.53) go on to argue that “debate over whether sensitivity to rhyme or sensitivity to phonemes is most important for reading and spelling has led research and theorists astray...we found that different phonological skills represent either the same ability or highly correlated abilities...children’s general sensitivity to the sound structure of language is important for learning to read and spell in an alphabetic system”.

Irrespective of whether literacy development is best predicted by measures of rhyme awareness or phonemic awareness (see Muter et al., 1998, Hulme, Muter, & Snowling, 1998; Bryant, 1998; Macmillan, 2002; Nation & Hulme, 1997 for the debate), the fact remains that some children, despite explicit alphabetic tuition, have difficulties acquiring phonological awareness. Indeed, Pratt and Brady (1988) demonstrated that phonological awareness skills are deficient in both children and adults in comparison to precocious readers of the same respective ages. The importance of phonological awareness has also been demonstrated in intervention studies. Using a meta analysis from 70 published studies, Bus and van IJzendoorn (1999) found that phonological awareness training improved children’s phonological processing skills and also their reading skills (to a lesser extent). The effect of phonological awareness on reading was



described as medium to strong, and while it was argued that phonological awareness is a substantial predictor, it was not considered to be the single, strongest predictor.

Nevertheless, Bus and van IJzendoorn argued that “phonological awareness should be considered a causal factor in learning to read” (Bus & van IJzendoorn, 1999, p.411).

While few researchers would dispute that phonological awareness is a strong predictor of reading ability, Castles and Coltheart (2004) point out that there is currently no convincing evidence of a *direct causal* association between phonological awareness and reading ability; they argue that a direct link has not yet been empirically demonstrated.

In summary, we know that phonological awareness is strongly associated with reading development and that it is underdeveloped in children with reading difficulties: the question is *why*. The most influential explanation comes from the “phonological representations hypothesis”, which was developed as a result of the phonological awareness deficits that were consistently observed in those with reading difficulties.

Fowler (1991) suggested that well-specified phonological representations are important for the development of typical reading ability. It follows that those with reading difficulties seem to have problems with other mental processes which require tapping into phonological representations. For example, Snowling (2000) commented that those with reading difficulties often have an inhibited phonological short-term memory (Hulme, 1981; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979; Snowling, Nation, Moxham, Gallagher, & Frith, 1997, cited in Snowling, 2000). In an attempt to explain these observed difficulties, Snowling (2000) hypothesised that verbal material is stored in memory in the form of a speech code, and that those with reading difficulties

seem to be less able to access these memory codes. This may be because they have faulty or underspecified phonological representations of words. This would restrict the number of items that could be retained in memory which would have a negative influence on working memory tasks. Similarly, children with reading difficulties have problems with naming tasks, in particular, rapid automatized naming, and word repetition (Katz, Curtiss, & Tallal, 2004). It was suggested that due to the fuzzy, underspecified phonological representations of the phonological forms of words, those with reading difficulties find it hard to recover from the “tip of the tongue state” and their receptive and expressive vocabularies seem dissociated (Snowling, 2000). Additionally, the phonological coding deficit theory (Vellutino & Fletcher, 2005) argues in line with the phonological representations hypothesis, that children with dyslexia are thought to have underspecified phonological representations of words, which compromise their ability to acquire phonological processing skills, alphabetic knowledge, decoding, and orthographic awareness.

The phonological representations hypothesis has been supported by the vast amount of research evidence demonstrating phonological processing deficits in dyslexic samples and in children with reading difficulties. 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” was developed, which proposed that irrespective of intelligence quotient (IQ), poor phonological representations underpin poor reading attainment. It 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 which occurs earlier on in child development; thus, we do not know exactly what causes poor phonological representations. While there is strong evidence that poor readers have underspecified phonological representations, which is manifested in phonological processing tasks (such as rhyme and phoneme awareness tasks), a more recent literature has shown that factors other than phonological awareness are also important for reading development. One such factor is morphological awareness, which will now be considered.

### **1.3. Morphology and Literacy Development**

The evidence of a link between phonological awareness and reading development has been demonstrated in Section 1.2. Phonological awareness enables the reader to map phonemes to graphemes, which helps to decode words. However, a more recent avenue of research has demonstrated that as children develop, morphological awareness becomes increasingly important in reading (Green, McCutchen, Schwiebert, Quinlan, Eva-Wood, and Juelis, 2003) and knowledge of morphology in terms of spelling, pronunciation, meaning, and inflectional and derivational word families also become increasingly important (Verhoeven & Carlisle, 2006).

Morphological awareness is a form of metalinguistic knowledge which is concerned with root words, affixes, and suffixes as opposed to phonemes (Jarmulowicz, Hay, Taran, & Ethington, 2008). Morphemes are the smallest units of meaning within a word

and Casalis, Cole, and Sopo (2004, p.115) give an example of how the word *unacceptable* is made up of three morphemes: *un* (the prefix), *accept* (the root, which may or may not be words themselves), and *able* (the suffix). Casalis et al. (2004) noted that knowledge of morphological rules can help uncover the meaning of a newly encountered, unknown word on the basis of its morphemic constituents. Jarmulowicz et al. (2008, p.277) describes morphemes as serving “both a syntactic function through inflection (e.g., plural *-s* or past tense *-ed*) and a lexical function through derivation (e.g., *-ic* changes nouns to adjective, as in *magnet* to *magnetic*) or compounding (e.g., *snow* + *flake*)”. Morphological awareness could include knowledge that the word *education* is derived from the word *educate*, and that *writing* stems from the word *write*. However, while the meaning of these words can be more easily derived based on its constituent parts, in other instances (e.g. *fine*, *final*) the meaning is less obvious and unrelated (Verhoeven & Carlisle, 2006, p.643) and words can be related in spelling structure but not in morphology (e.g. *car* and *carve*). Mahony, Singson, and Mann (2000, p.192) noted that strings that cannot be decoded on a phonemic basis, or that are less easily decoded on this basis, are decoded into morphemes: this is often because they are sight words of higher frequency (e.g. *of* and *the*), that occur more regularly, and have higher morphological productivity than others, or that have roots that occur in multiple derivations (e.g. *divide*, *undivided*, *divisive*, *division*), or common suffixes such as *-ly* or *-ed*. It has been argued that the development of inflectional morphology (e.g. *dog* and *dogs*, or *clap* and *clapped*) is acquired before derivational morphology (Jarmulowicz et al., 2008). This was supported by Deacon and Kirby (2004) who argued that children as young as 4 years of age and children in first-grade have demonstrated morphological awareness of inflections and simple derivations, but that

the understanding of more complicated derivations seems to develop at a later stage of development.

A number of studies in the literature have demonstrated that morphological awareness is related to decoding skill, and can predict reading development (Carlisle, 2000; Nagy, Berninger, & Abbott, 2006; Nagy, Berninger, Abbott, Vaughan, & Vermeulen, 2003; Ravid & Mashraki, 2007; Green et al., 2003). For instance, Carlisle (2000) investigated whether three morphological awareness tasks could predict reading comprehension in a group of 34 third-graders and 26 fifth-graders. It was found that the measures of morphology were significantly related to reading comprehension in both grade levels, with a more profound effect with the fifth-graders. However, Carlisle emphasised the fact that this effect was significant in the third-graders as well, who are still using fairly basic strategies to decode polysyllabic words. However, some might argue that the relationship between morphology and reading is accountable to its relationship with phonological awareness. Indeed, there is evidence to suggest that phonological awareness and morphological awareness are strongly correlated with each other (Casalis et al., 2004; Nagy et al., 2006). For instance, Nunes, Bryant, and Olsson (2003) found that training in phonology resulted in an improved use of morphology in reading. Casalis et al. (2004) also noted that the morphological process can be seen as somewhat dependent on phonological processing ability; Casalis (2001, cited in Casalis et al., 2004, p.118) found that suffix deletion was more difficult when the deleted suffix breaks up the final syllable (e.g. *rouge/rougeur* translated to *red/redness*) than when the deleted suffix corresponded to the whole of the final syllable (e.g. *noir/noirceur* translated to *black/blackness*).

Casalis et al. (2004) conducted a study with the central goal of establishing the relationship between morphology, phonology, and reading. 33 dyslexic children were gathered along with 33 younger, reading-age matched controls, and 33 chronological-age matched controls, and their performance on a series of morphological awareness tasks was compared. It was found that dyslexics were generally impaired and outperformed in terms of phonological and morphological segmentation in comparison to both control groups, especially the chronological-age matched controls, which might indicate more degree of overlap between phonological and morphological skills.

However, another key finding was that there were no significant differences between dyslexics and reading-age matched controls in terms of their performance on a sentence completion tasks which tapped into their productive knowledge of derived words.

Casalis et al. (2004) argued that this might suggest that productive knowledge may well be associated with reading, but that it is not necessarily dependent on phonological processing. As a result, Casalis et al. (2004, p.134) noted that “one cannot argue that morphological abilities strictly depend on phonological abilities”. While the relationship between morphology and phonology has been acknowledged, a great deal of literature has found that morphological awareness contributed to reading development above and beyond phonological awareness (Nagy et al., 2003; Nagy et al., 2006; Deacon & Kirby, 2004; Mahony et al., 2000; Siegel, 2008).

For instance, Nagy et al. (2003) investigated whether morphology was related to children’s reading and writing skills in a group of 98 second grade children at risk of reading difficulties and 97 fourth graders at risk of spelling difficulties. Morphology was assessed using three tasks; a suffix choice test, a compound structure test, and a

morphological relatedness test (which were all found to load onto the same factor in a confirmatory factor analysis). It was found that for the second graders, morphological awareness accounted for unique variance in reading comprehension independently of its relationship with phonological awareness, orthographic awareness, and vocabulary. Interestingly, morphological awareness was the strongest unique predictor of reading comprehension (above phonological awareness). However, it was unable to account for unique variance in word reading, spelling, or decoding. For the fourth graders, while there were significant correlations between morphology, word reading, decoding, and spelling, morphology was unable to account for unique variance in any of the reading measures.

In another study, Nagy et al. (2006) recruited 182 fourth and fifth graders, 218 sixth and seventh graders, and 207 eighth and ninth graders and investigated the role of morphological awareness in reading development. The same morphological assessments from Nagy et al. (2003) were taken (suffix choice test and the morphological relatedness test) apart from the compound structure test. It was found that for all three age groups, morphological awareness made a unique contribution to reading comprehension, vocabulary, and spelling after controlling for phonological decoding and phonological working memory, which adds weight to the developing argument that morphological awareness may be related to reading independently of phonological awareness.

In addition to these findings, Deacon and Kirby (2004) conducted a four-year longitudinal study which followed children from Grade 2 to Grade 5 to address three major research questions: whether morphological awareness can predict reading development after controlling for phonological awareness and intelligence, if this

contribution differs according to the type of reading being assessed, and if the relative involvement of morphology changes over time. The importance of establishing that morphological awareness is not simply an extension of phonological awareness was underlined; that is, that the observed relationship between morphology and reading cannot simply be explained via its link with phonological awareness. It was found that morphological awareness was indeed able to account for significant, unique variance in reading ability after controlling for verbal and nonverbal intelligence, phonological awareness, and reading ability at an earlier stage (as an autoregressor). Moreover, morphological awareness made a stronger contribution to reading comprehension and pseudoword reading than to single word reading, which is in line with Nagy et al. (2003), and that the impact of morphological awareness seemed to increase over time. It was argued that morphological awareness and phonological awareness make a comparable contribution to reading, and that morphological awareness plays a unique role in reading development that cannot be explained by its relationship with phonological awareness.

This independence of morphological awareness has been supported further by Siegel (2008) who used a cross-sectional design with three groups of children comprising children at risk of dyslexia, typical developers, and English language learners and found that morphological awareness was related to reading ability above and beyond phonological awareness, predicting unique variance in reading after phonological awareness and vocabulary had been controlled. These findings have also been replicated by Mahony et al. (2000) who found that morphological awareness predicted unique variance in reading after controlling for phonological awareness and vocabulary and



more recently by Saiegh-Haddad and Geva (2008) who found that both phonological awareness and morphological awareness were independent, unique predictors of word reading in English.

So *how* is morphology related to reading development? Deacon and Kirby (2004, p.224) argue that knowledge of morphology could facilitate a range of reading tasks. For instance, with single word reading, a child trying to pronounce the *ea* in *reading* and in *react* would be well informed by morphemic boundaries. Moreover, the base and affix morphemes within words such as *reading* and in *react* might help to convey the meaning of these words. Furthermore, it was argued that morphological awareness might play a role in decoding pseudowords; using the example from Deacon and Kirby, while the word *lagician* could be decoded based on analogy (magician) and phonemically, this word could also be interpreted as containing a root and suffix, thus *logic* and *ian* respectively. It was considered that morphological awareness plays different roles in word reading, pseudoword reading, and reading comprehension. Nagy et al. (2003, p.730) also argued that morphology might be related to reading and writing in at least five ways. Firstly, morphological awareness may provide insights into the writing system; for instance, the English writing system relies on morphological rules as well as phonemic rules, and the same morpheme often has the same spelling regardless of the pronunciation (e.g. *sign-signature*, *heal-health*, *nation-national*) and the same sound often has different spellings when there are different morphemes (e.g. *there-their-they're*, *to-two-too*). The latter only seems to make sense once we consider the morphological structure of the words and their relationship with other words. Secondly, morphological awareness enables readers and spellers to produce longer words and to

do so more fluently: for instance, the word *sleeplessness* would take a long while to decode and read based on GPC rules alone and by sounding out letters. However, if one observed and recognised the internal structure of the word and the frequency of its component parts (e.g. *sleep*, *less*, and *ness*) were more readily recognised, the whole word would be recognised more quickly and efficiently. This is similar with spelling sequences, which also relies on a combination of orthographic, phonological, and morphological coordinative resources. Thirdly, morphological awareness contributes to syntactic parsing (reading) or packaging (writing) and provides important cues which convey the syntactic structure of a sentence; this seems to develop and become more proficient as children get older. Fourthly, morphological awareness may facilitate vocabulary learning. It was noted that “a reader with a better grasp of word-formation processes will be better able to infer the meanings of these words and remember their meanings” (Nagy et al., 2003, p.731). Such knowledge, in turn, may facilitate reading and writing ability. Lastly, morphological awareness may enhance children’s ability to process language analytically since the language used helps to convey meaning.

Mahony et al. (2000, p.193) also demonstrate how derivational suffixes change the category to which they attach. For instance, the word *parent* is a noun, *parental* is an adjective, *familiar* is an adjective, and *familiarise* is a verb. Mahony et al. (2000) argue that awareness of these derivational suffixes and the categories to which they belong facilitates meaning and contributes to reading ability, particularly comprehension. Thus, there are several ways in which morphological awareness may facilitate the reading development of children.

In summary, it is clear that while phonological awareness is a strong predictor of children's reading development, morphological awareness is also an important predictor of reading development. Moreover, morphological awareness is related to phonological awareness, but it can also predict reading development independently of this association, so we now know that factors other than phonological awareness (e.g. morphological awareness) are important in reading development. However, what is underpinning this independent association? And what is underpinning the development of phonological and morphological awareness?

Recall an earlier point by Chiappe et al. (2002) who noted that there might be another underlying deficit to reading disorder which occurs prior to the development of phonological and morphological awareness. This was also argued by Wood and Terrell (1998a) who observed that the aetiology of successful phonological awareness is unknown. The answer might lie in skills which precede phonological and morphological awareness developmentally. This is a pivotal point because if phonological and morphological awareness are secondary to another underlying deficit, research and intervention may not be addressing the root cause of reading disorders. As a result of this, several lines of enquiry have tried to explain phonological awareness deficits in reading disabled populations by focussing upon the skills that precede its development. The next section of this thesis will focus on some of the skills which precede the development of phonological awareness and morphological awareness, namely, speech perception and spoken word recognition. It is important to identify whether children with reading difficulties have speech perception and spoken word recognition deficits.

#### 1.4. Speech Perception and Spoken Word Recognition

Some researchers have suggested that reading difficulties and phonological awareness difficulties are caused by deficits in basic speech processing abilities (McBride-Chang, 1995; McBride-Chang, 1996). Theoretically, problems with speech perception might compromise the encoding of phonological representations and related phonological processing, which could result in reading difficulties, given the documented relationship between phonological awareness and reading, discussed in Section 1.2. Indeed, Studdert-Kennedy (2002, p.5-6) suggested that “poor speech perception gives rise both to ‘fuzzy’ or ‘underspecified’ lexical representations and to weak verbal short term memory. These in turn give rise to deficits in syntactic awareness and in comprehension in listening and/or reading”.

Speech perception refers to how we identify or perceive the sounds of language (Harley, 1995). It is often assessed using tasks which require the participant to discriminate between two similarly sounding words. For instance, Manis et al. (1997) obtained 25 students from Grade 4 to Grade 10 classified with dyslexia, along with 25 chronological-age matched controls and 24 reading-level matched controls and compared them on their performance on a speech perception task, which involved discriminating between similar sounding words e.g. *bath* and *path*. It was found that the dyslexic children were outperformed by the chronological-age matched controls, but not the reading-level matched controls. It was also found that poor phonemic awareness was related to poor performance on the speech perception task.

Manis et al. (1997) notes that two major experimental paradigms have been used to assess the role of speech perception in dyslexia; categorical perception of stop consonants (e.g. /b/, /d/, /g/, and /p/) and the repetition of speech (including words and non-words) with and without background noise. Stop consonants in the English language are represented by the phonemes /k/, /g/, /b/, /d/, /t/, and /p/. These phonemes are more difficult to perceive because they occur more quickly in time in comparison to other phonemes (e.g. /t/ occurs more quickly than /l/) and unlike vowels and other speech sounds, their articulation involves the transition of different voice frequencies (McBride-Chang, 1995, p.110). Deficits in categorical perception of stop consonant have been observed in children with dyslexia (Reed, 1989), with these children having greater difficulty discriminating between similar sounding phonemes and words such as /ba/-/da/.

Repetition deficits have also been observed in children with reading difficulties (Brady, Shankweiler, and Mann, 1983). For instance, Brady et al. (1983) conducted a series of experiments investigating speech perception of 15 children with reading difficulties and 15 children without reading difficulties. In the first experiment, children heard sets of five monosyllabic words (in one condition they rhymed and in another they did not) and had to recall the word strings as best as they could. It was found that the children with reading difficulties were poorer at recalling the word strings in the non-rhyming condition, and made alterations to the phonemes in the words more regularly. In the second experiment, these children were compared for their ability to identify high and low frequency words while presented with background noise, or no background noise. Regardless of word frequency, children with reading difficulties were poorer at

identifying words in noise. Further exploration revealed that the children with reading difficulties had particular problems with stop consonants (e.g. /b/ and /d/). In a third experiment, to inform the debate as to whether speech perception deficits are speech-specific or auditory, children were played non-speech sounds (e.g. a piano or a baby crying) while presented with background noise, or without background noise. Contrary to the findings from the second experiment, no differences were observed between children with and without reading difficulties on this task, which perhaps suggests that the observed deficits in speech perception in poor readers is more accountable to a speech-specific, rather than a general auditory deficit.

The issue of whether speech perception deficits are part of a general auditory deficit has been heavily debated in the literature, and Studdert-Kennedy (2002) considered both hypotheses in turn. The *speech-specific hypothesis* proposes that speech perception deficits are speech-specific, purely linguistic, and are related closely to verbal working memory deficits (Mody, Studdert-Kennedy, & Brady, 1997). In line with this account, Mody et al. (1997, p.200) noted “accordingly, poor readers are said to have normal auditory capacities, but, for unknown reasons, to be less efficient in transforming linguistic input, whether spoken or written, into the phonological code necessary for working and long-term memory”. The *general auditory hypothesis* proposes that speech perception deficits are not speech-specific, but are due to an auditory deficit for processing temporal information, which refers to the perception of the temporal properties of the events, such as duration, sequencing, and rhythm. Indeed, Farmer and Klein (1995, p. 480) stated “if a temporal processing deficit contributes to a difficulty with perception and discrimination of phonemes, recognition of those phonemes will

not occur as easily and automatically as it would in a subject without a temporal processing deficit. Such an impaired recognition would undoubtedly lead to many of the problems described in children with a phonemic deficit who are at risk for reading problems”.

The auditory processing deficit hypothesis has been debated because of findings showing non-speech rhythm deficits in children with reading difficulties. For instance, David, Wade-Woolley, Kirby, and Smithrim (2007) investigated the role of rhythm in word reading in a five-year longitudinal study. A rhythm production task was administered to 53 children at Grade 1, which involved moving to a beat by tapping with both hands, tapping with alternate hands, moving their legs, walking on the spot, and walking forward. This measure of motor rhythm was found to predict reading in all five subsequent grades. It was also found to predict a significant amount of variance in word reading after phonological awareness had been controlled, but only in Grade 5, and predicted unique variance in Grades 2, 3, and 5 after naming speed had been accounted for. The authors concluded that rhythm seems to be more important as the reading demands increase and that rhythm seems distinct from naming speed, but is subsumed by phonological awareness. However, as the authors acknowledge, attrition reduced the sample size from 53 at Grade 1 to 38 at Grade 5; thus the results should be treated with caution with regard to the later grades.

In another study, Overy (2000) compared 6 children identified as being at ‘strong risk of reading difficulties’ with 16 children identified as ‘no risk of reading difficulties’ on a number of musical aptitude tests and found that the strong risk of reading difficulties

group scored significantly lower on all the tests involving timing, and particularly on the rhythm copying task, which required children to copy a short rhythm after hearing it. Following this, Overy, Nicolson, Fawcett, and Clarke (2003) administered musical aptitude tests to 15 dyslexic boys (mean age 9.0) and 11 control boys (mean age 8.9). Three rhythm skills were assessed; in the *rhythm copying* test a short rhythm played over headphones had to be copied by tapping a key on a computer keyboard, in the *rhythm discrimination* test children were played two short rhythms over headphones and had to decipher whether they were the same or different and in the *song rhythm* test children tapped the beat of happy birthday whilst singing the words. It was found that the dyslexic group scored lower on all of the non-speech rhythm tasks.

In an earlier study, Tallal (1980) investigated the relationship between auditory temporal processing and reading by comparing 20 children with reading difficulties (mean age = 9 years 7 months) with 12 typically developing children (mean age = 8 years 5 months) on a series of auditory perception tasks along with a non-word reading task. In the sequencing test children had to copy the sequence of two tones (e.g. 1-1, 2-2, 1-2, or 2-1), which were separated by 428ms inter-stimulus intervals (ISIs) by pushing panels in the correct order. In the rapid perception test children received the same stimuli from the sequencing test, only this time the ISIs varied from by either 8, 15, 30, 60, 150, or 305ms. In the same-different discrimination task, participants heard two tones and literally had to say whether they were the same or different. After an initial ISI of 428ms, the ISIs varied from 8 to 305ms. It was found that while there were no significant differences between the groups at slow rates (e.g. 428ms), the poor readers groups made significantly more errors when the length of ISIs became shorter



and thus, the stimuli were presented more rapidly. A strong, significant correlation was also found between the errors made on the auditory perception tasks and errors made on the non-word reading task. These findings were replicated by Tallal (1984, p.168) and it was argued that “as data accumulate in the field, they continue to support the hypothesis that phonetic processing deficits themselves may result from inefficiencies or deficiencies of the processing mechanisms essential for processing the rapidly changing acoustic spectra which characterize the ongoing speech stream”.

Other recent studies have found auditory rhythmic deficits in dyslexic children (Goswami et al., 2002; Thomson & Goswami, 2008) and dyslexic adults (Thomson, Fryer, Maltby, & Goswami, 2006). Goswami et al. (2002) obtained 24 dyslexic children, along with chronological-age matched controls, reading level-matched controls, young early readers, and non-early readers, and compared their performance on a beat detection task. Children heard sound sequences with either a rise time of 15ms (which sounded like a beat) to 300ms (which sounded continuous, with no beat) and children had to decide which of the two rhythms they had heard. Dyslexic children were significantly poorer on this task in comparison to their chronological-age matched counterparts. Performance on this task was also able to account for 25% of the variance in reading and spelling, after age, non-verbal IQ, and vocabulary had been controlled.

In a similar study, Thomson et al. (2006) recruited 19 dyslexic adults (mean age = 22;3) and 20 non-dyslexic adults (mean age 22;3) who did not differ significantly in terms of age, verbal IQ, or performance IQ. In addition to reading and phonological assessments, a battery of auditory processing tasks was administered including a rise time measure.

along with a receptive and expressive rhythm task, and a motor task. It was found that the dyslexic group were significantly poorer on the rise time measures, duration discrimination, and intensity discrimination task (auditory processing measures), along with the metronome measure (expressive rhythm). Sensitivity to auditory cues was also found to be significantly related to literacy and greater variability in finger tapping was related to reading development after controlling for IQ. Similar findings were demonstrated by Richardson, Thomson, Scott, and Goswami (2004) who compared the performance of dyslexic children with both chronological-age matched controls and younger reading-level matched controls on some auditory processing tasks, including a measure of rise time sensitivity. It was found that the dyslexic children displayed significant beat detection deficits when compared with chronological-age matched controls. More recently, Thomson and Goswami (2008) investigated the relationship between rhythmic processing and dyslexia by comparing the performance of 25 dyslexic children (mean age 10;8) to 23 typically developing readers on a battery of auditory processing and rhythm tasks, along with measures of motor rhythm, phonological awareness, and reading. Similar to Thomson et al. (2006), dyslexic children were found to be significantly poorer on rhythm and motor measures. These findings add weight to the argument that auditory processing skills are related to reading.

Although auditory deficits are commonly observed, “the developmental route to reading difficulty is unclear” (Thomson et al., 2006, p.334). Findings from Tallal (1980; 1984) among others, have commonly been considered in terms of a domain-general dysfunction in processing temporal information, which could be responsible for

phonological processing deficits (Chiappe et al., 2002). While some supportive literature for the temporal processing deficit hypothesis in poor readers has been presented, other research has provided contrary evidence and dispute the relationship between temporal processing and reading (Chiappe et al., 2002; Bretherton and Holmes, 2003). For instance, Bretherton and Holmes (2003) administered Tallal's tone-order judgement task to 42, 8 to 12-year-old children with reading difficulties and 36 typically developing control children, along with phonological awareness, reading, and other cognitive tasks. The 42 poor readers were then subdivided into two groups: poor tone-order subgroup and average tone-order subgroup. It was found that the two subgroups did not differ in their processing of speech sounds, phonological awareness, or reading, which are contrary findings to those of Tallal (1980).

Additionally, Mody et al. (1997) recruited 20 'good readers' and 20 'poor readers' from the second grade, matched for age and nonverbal IQ. The 20 'poor readers' were selected on the basis of them having poor performance on a /ba/-/da/ discrimination task, which was said to be attributable to deficiencies in processing rapidly changing information (Tallal, 1980, 1984). If this theory was true then similar deficits should be displayed when discriminating between other digraphs such as /ba/-/sa/. It was found that the groups did not significantly differ on any of the other more easily discriminated digraph pairings. The authors argue that these findings provide evidence that /ba/-/da/ deficits witnessed in poor readers in earlier studies, was more likely to represent difficulties discriminating between phonetically similar digraph pairs, rather than deficits in perceiving rapidly changing stimuli. Studdert-Kennedy (2002) also criticised the literature supporting the auditory temporal processing hypothesis and argued in line

with (Mody et al., 1997) that deficits in /ba/-/da/ discrimination, when observed, are phonetic rather than auditory in origin. As a result it was argued that deficits in speech perception are more likely to be speech-specific rather than auditory.

McBride-Chang (1996) has found phonological awareness to be substantially correlated with speech perception. In this study, 136 third and fourth graders (8 and 9 years olds) were assessed for their reading ability, IQ, phoneme awareness (deletion, positioning, and counting), verbal short-term memory, naming speed (RAN), and speech perception. For the speech perception task children heard a word (or a nonsense word) and had to point to the correct one on the computer. There were different kinds of manipulation. For instance /bath/-/path/ (b verses p), /slit/-/split/ (presence of p), and /ba/-/wa/ (nonsense words). It was found that phonological awareness was substantially correlated with speech perception (although speech perception and phoneme awareness were also shown to be distinct from each other to some degree), and that the best-fitting model was the indirect model, whereby the relationship between speech perception and reading is mediated by phonological processing.

In a review of the speech perception literature, McBride-Chang (1995) notes that speech perception deficits have been observed in children with reading disability (Brady et al., 1983; De Weirtdt, 1988; Freeman & Beasley, 1978; Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Hurford, 1991; Reed, 1989; Tallal, 1980; Werker & Tees, 1987), and in adults with reading disability (Lieberman, Meskill, Chatillon, & Schupack, 1985; Steffens, Eilers, Gross-Glenn, & Jallad, 1992; Watson & Miller, 1993). However, some studies have not found this relationship (Pennington, Van Orden, Smith, Green, &

Haith, 1990; Snowling, Goulandris, Bowlbey, & Howell, 1986). For instance, Pennington et al. (1990) obtained 15 adult familial dyslexics and 15 adult clinical dyslexics and obtained both a chronological-age matched control group along with a younger reading-age matched control group for each of the two dyslexic groups. Two perception tasks were used; a phoneme perception task measured whether participants could repeat words and non-words sounded through headphones either with, or without noise. A sounds detection task was used which measured whether participants could describe the source of the sound they had just heard through headphones either with, or without noise. Note that both of these tasks were based on Brady et al. (1983). It was found that both dyslexic groups performed similarly to their chronological-age matched controls and outperformed their younger reading-age matched controls on both the phoneme perception task and the sounds perception task.

The review by McBride-Chang (1995) concluded that the literature on speech perception deficits is mixed, although this is likely due to methodological issues. For instance, Wood, Wade-Woolley, and Holliman (in press) point out in accordance with McBride-Chang (1995) that one of the reasons why the evidence is mixed might be explained by the fact that many of the papers claiming to have measured speech perception along the /ba/-/da/ paradigm (De Weirtdt, 1988; Werker & Tees, 1987; Godfrey et al., 1981) were measuring phoneme discrimination; this argument was noted earlier by Studdert-Kennedy (2002) and Mody et al. (1997). Metsala (1997, p.160) also noted that many of the speech perception tasks may just be tapping into short-term memory.

As a result of this, some authors (e.g. Wood & Terrell, 1998b; Metsala, 1997) have focussed on a specific kind of speech perception ability, which is less concerned with phoneme discrimination. For instance, Wood and Terrell (1998b) obtained 30 poor readers, 30 gender and chronological-age matched controls, and 30 gender and reading-age matched controls and compared them for their performance on a rapid speech perception task, which required children to repeat a sentence that had been speeded up and played back 50 percent faster than the original sentence speed. Their responses were scored for the number of syllables inaccurately repeated. Like Manis et al. (1997), it was found that poor readers were outperformed by their chronological-age matched counterparts on this speech perception task.

According to Wood & Terrell (1998b, 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 (1998b) 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 (Harley, 1995). Spoken word recognition has been defined in a number of ways: such as “the processes involved in matching speech input to representations stored in lexical memory” (Metsala, 1997, p.160), “the process by which meaning is derived from the acoustic signal” (Cutler & Norris, 1988, p.113), or “the process by which a given word is perceived in the context of other words in memory” (Metsala & Walley, 1998, p.92). Spoken word recognition may play a causal role in children’s failure to acquire adequate alphabetic knowledge (Metsala, 1997).

Metsala obtained 39 reading disabled participants and compared them with 61 normally achieving participants on a task using a gating procedure: children listened to increasingly longer segments of a spoken word and at each 'gate' children were asked to attempt to identify the word. This continued until the word could be correctly identified. It was found that children with reading difficulties needed more speech input before they could recognise the spoken words and were subsequently slower to recognise spoken words than their age-matched controls. It was also found that performance on this task could predict a significant amount of variance in reading ability after controlling for phoneme awareness and receptive vocabulary. She explained these findings using the "lexical restructuring hypothesis". Walley (1993) argued that the growth in a child's vocabulary contributes to the segmental restructuring of lexical representations. She suggested that spoken word recognition is related to reading, but that this relationship may be mediated by vocabulary development; as vocabulary develops, children's ability on spoken word recognition measures will be enhanced. Furthermore, vocabulary and phonological awareness are believed to grow simultaneously; the more words you know the more you become aware of the different phonological patterns that occur, and the similarities between words at various levels, including rimes and ultimately phonemes. Thus, spoken word recognition may be related to phonological awareness, although it is assumed to be mediated by vocabulary development.

In summary, there is a great deal of evidence (albeit equivocal) linking speech perception to reading development. One key area of speech perception noted by Wood and Terrell (1998b) and Metsala (1997) concerns spoken word recognition and this may

be related to reading development. However, the question of *how* children identify words in fluent speech is less well-understood. What might explain individual differences in spoken word recognition? Sensitivity to speech rhythm (and stress in particular) seems to play an important role in the identification of word boundaries in the English language, and the evidence for this will be reviewed in the next section.

### **1.5. Speech Rhythm (Prosody) and Spoken Word Recognition**

Speech rhythm has been described as “the tempo, rhythm and stress of language” (Whalley & Hansen, 2006, p.288) comprising the pitch or intonation, stress or loudness, and duration or timing of an utterance (Kuhn & Stahl, 2003). An interrelated term that should be described here is *prosody* which is used interchangeably with speech rhythm. Each language is made up of particular rhythmic properties. Languages tend to fall in a particular rhythmic class; for instance, English, German, Dutch, and Russian (the Germanic languages) are stress-timed languages, while French, Italian, Spanish, and other Romance languages are syllable-timed (Ramus & Mehler, 1999). There are also tone-based languages such as Chinese. English is a stress-timed language where “speech rhythm is metrical: that is it is characterised by strong and weak syllables” (Wood and Terrell, 1998b, p.398). 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 (Graddol, Cheshire, and Swann, 1987). A weak syllable does not carry stress and often contains a reduced or abbreviated vowel, such as a *schwa* /ə/, e.g. the ‘weak-strong’ word *today* is often pronounced *t'day* (Wood and Terrell, 1998b). In stress timed languages such as English roughly the same amount of time elapses between the production of strong syllables in speech (Wood,



2006a, p.271) whereas in syllable-timed languages, there is roughly an equal amount of time elapses between syllables (Wood et al., in press). For instance, in the phrase “Mary had a little lamb” (SwSwSwS) we can see the pattern of strong (underlined) and weak syllables and observe that typically there is about the same amount of time elapses between the strong syllables when it is spoken. It has been argued that children are born with a periodicity bias (Cutler & Mehler, 1993) which allows them to ‘tune in’ to the particular rhythmic properties of speech in their first language. As adults, we can discriminate between languages based on our lexical knowledge, but infants do not have this capability due to a far less well-developed lexicon. Nevertheless, newborns have been found to be able to discriminate between languages on the basis of their different rhythmic classifications (Nazzi, Bertoncini, & Mehler, 1998) and this has even been demonstrated in monkeys (Ramus, Hauser, Miller, Morris, & Mehler, 2000). But how do children do this?

Ramus and Mehler (1999) argued that children must be tuning in to pre-lexical cues from the speech stream. Three properties were suggested; different languages use different phonemes (phonetic repertoire), the structural distribution of phonemes is restricted in some languages (phonotactic constraints), and children might be able to discriminate on the basis of their suprasegmental features, such as rhythm (prosody). As noted, stress is an important component of speech rhythm in the English language, and English-learning infants have been shown to be able to segment words on the basis of stress from the age of 7.5 months, to display sensitivity to additional auditory cues that facilitate the identification of word boundaries from 10.5 months, and recognise words from the speech stream at a rate similar to adults by 24 months (Jusczyk, 1999). So how

might being sensitive to speech rhythm give you a good basis for segmenting speech into words?

The speech stream is continuous with few audible pauses between words (Wood & Terrell, 1998b). As a result, the segmentation of *speech* is less clearly specified than written language where words are clearly separated by spaces. Before someone can access the meaning of a word in fluent speech, they must first identify where words begin (Cutler & Norris, 1988). Speech researchers are therefore interested to discover the cues which mark word boundaries in speech. Some researchers suggest that one of the skills that an infant needs in order to acquire spoken word recognition is rhythmic sensitivity. It has been suggested by Cutler (1994) 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 (an aspect of speech rhythm) seems to play a crucial role in this process. Moreover, Cutler (1994, p.81) noted that “the role of language rhythm is in understanding speech” and argued that “for English there is evidence...that listeners use stress in segmentation, by hypothesising boundaries when syllables are strong” (Cutler, 1994, p.80). Thus, aspects of speech rhythm, namely stress sensitivity, might facilitate the identification of word boundaries and subsequent literacy development, and this idea has been supported in the literature. For instance, Wade-Woolley, Goetry, and Lang (2004) suggest that sensitivity to stress may be used in both the segmentation of speech and in lexical access. Hardy, Stennett, and Smythe (1973, p.144) also argued that “success in auditory segmentation is heavily dependent upon knowledge of word meanings and awareness of the stress and intonation patterns inherent in the spoken language”. Sensitivity to the

rhythmic properties of native language seems to develop in the first year of life (Morais, 2003). Jusczyk et al. (1992, cited in Jusczyk, Cutler, and Redanz, 1993) found that English children are sensitive to boundaries of major phrases by 9 months of age, can segment words on the basis of stress from the age of 7.5 months, and to display sensitivity to other auditory cues that facilitate word identification from 10.5 (Jusczyk, 1999). Thus, stress sensitivity could be an important indicator of word boundaries in speech, and this has been demonstrated in a number of studies.

Recall that English is a stress-timed language characterised by strong syllables containing a full vowel sound, and weak syllables. In English, lexical words tend to begin with strong syllables rather than weak syllables (Cutler & Norris, 1988; Cutler & Carter, 1987). 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 good indicator of word boundaries.

This idea was empirically demonstrated by Cutler and Norris (1988) who investigated whether strong syllables help to trigger word boundaries and facilitate word identification. 30 typically developing adults heard a nonsense word, which always contained two syllables and was either made up of strong-strong syllables (e.g.

mintayve) or strong-weak (e.g. mintesh) and were required to press a response key when they heard a nonsense word that began with a real word, and they had to say what that real word was. It was found that participants identified the word *mint* in the strong-weak context significantly faster than in the strong-strong context. It was argued that when there is a strong vowel in the second syllables (in the case of strong-strong nonsense words such as mintayve), segmentation of the bisyllable is triggered, which means that the real word (e.g. mint) requires some additional speech assembly in order to be identified. More specifically, in the strong-strong condition (e.g. mintayve), the strong vowel in the second syllable might confuse the decoder into breaking the syllables down into *min* and *tayve*, thus making it harder to identify the word *mint*. This segmentation does not occur in strong-weak syllables. To explain these findings theoretically, Cutler and Norris (1988) proposed the Metrical Segmentation Strategy (MSS); this model 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. In English, strong syllables are marked as potential word boundaries and “a look-up process is started at each one, terminating when the longest word consistent with the input is identified” (Wood & Terrell, 1998b). As Wood and Terrell (1998b) note, this word searching identification process results in many word candidates, which will overlap on the same stretches of input. Once entered into a computational network, words will eventually inhibit each other and the word should be successfully identified and segmented from other words. Cutler and Butterfield (1992) found evidence for the described stress effects in predicting word boundaries; during faint speech it was assumed that strong syllables formed the beginnings of words. Lindfield, Wingfield, and Goodglass (1999) also argue that word stress facilitates the perceptual matching

process (spoken word recognition) and aids the retrieval of words from the mental lexicon and provides a means for accessing lexical representations. It seems plausible that a speech rhythm sensitivity deficit, might inhibit the perception of spoken language and spoken word recognition, and thus, impair reading development. If this was the case, we would expect to see a literature demonstrating a relationship between sensitivity to speech rhythm and phonological awareness, and sensitivity to speech rhythm and reading ability.

### **1.6. Speech Rhythm and Phonological Awareness**

Recall that phonological awareness has been consistently related to reading development (see Section 1.2). However, the fact remains that “the underlying neural factors leading to these characteristic difficulties in representing phonology are still under debate” although “one logical precursor of these difficulties with phonology is a deficit in basic auditory processing” (Thomson et al., 2006, p.334). One component of the auditory domain which has received a great deal of attention in the recent literature is speech rhythm sensitivity (see Wade-Woolley & Wood, 2006). Most theoretical accounts regarding how speech rhythm sensitivity contributes to reading development suggests that speech rhythm sensitivity might facilitate the development of phonological awareness and phonological representations. Therefore, a link between speech rhythm sensitivity and phonological awareness is implicated.

Wood (2006a p.271) noted that speech rhythm awareness may precede the development of phonological awareness and be an index of the phonological construction of language. Wood (2006a, p.271) argued further that sensitivity to speech rhythm may

direct our attention towards phonological features, which could subsequently enhance phonological awareness. Wood (2006a) investigated whether speech rhythm sensitivity was related to phonological awareness and reading. For study one, a sample of 23 pre-school children (mean age 4;3) and 16 reception children (mean age 5;2) were gathered and a stress mispronunciations task was developed, where children were required to listen to a household word that had been mispronounced in some way, which variously affected the stress of that word, and then locate the picture that corresponded to that word from a line drawing of a house. It was found that children's word recognition was mostly affected in the stress reversal condition of this task (where the stress was reversed, so that the word *sofa* for instance, was pronounced more like *s'fa*). In study two, Wood investigated whether performance on this stress reversal condition was related to phonological awareness and reading. Thirty-one children aged between 5, 6, and 7 years of age were recruited to the study. It was found that speech rhythm sensitivity was able to predict concurrent variance in rhyme detection and non-word reading, although not phoneme deletion skill. Furthermore, speech rhythm sensitivity was still able to account for significant variance in rhyme detection even after controlling for age. Related to this, Wood (2006b) revisited the earlier data from Wood and Terrell (1998b) which used a sample of 90 children consisting of 30 poor readers, 30 chronological-age matched controls, and 30 reading-age matched controls to investigate the relationship between speech rhythm and phonological awareness. In the original study, a sentence matching task was used to assess speech rhythm, whereby children had to match a low-pass filtered sentence with a spoken sentence based on its rhythmic features. It was found that performance on this task was able to predict unique variance in phoneme deletion after controlling for age and vocabulary, and was able to

predict variance in rhyme detection after controlling for age. It was also able to account for a significant amount of variance in syllable awareness after controlling for age. Furthermore, Holliman et al. (2008) administered the stress mispronunciations task from Wood (2006a) to 44 children (mean age = 6;1 years, SD = 6.75 months) and found that speech rhythm sensitivity was correlated with rhyme detection ( $r = 0.64, p < 0.001$ ) and phoneme deletion ( $r = 0.74, p < 0.001$ ), and while it was not reported in the publication, speech rhythm was able to account for unique variance in a composite phonological awareness measure including rhyme and phoneme scores, after controlling for age, vocabulary, and reading attainment. These findings provide strong evidence of an association between speech rhythm sensitivity and phonological awareness.

Wood and Terrell (1998b) argued in accordance with Chiat (1983) that sensitivity to speech rhythm may facilitate the development of phonological awareness in at least two ways. The first line of argument considers how sensitivity to speech rhythm might facilitate phoneme awareness. It was argued that in order to complete the stress mispronunciations task used in (Wood, 2006b) and Holliman et al. (2008) children need to be sensitive to the fact that the stress properties of each word have been manipulated, understand that the word had been incorrectly stressed, and then be able to reverse the stress, or apply stress to the unstressed syllable so that the word could be accurately represented and located in the mental lexicon. This is an argument supported by Kitzen (2001, p.33) who noted that a reader must be able to make stress placement shifts in mispronounced words and to be capable of pronouncing words with appropriate stress placement in order to match the stored lexical code and to recognise and access those words represented in the mental lexicon. For instance, a reader who successfully

decodes the phonemic information in the word *hotel* but who pronounces it with stress on the first syllable (HOT'l) must be capable of making a stress-shift to the second syllable in order to match the stored lexical code (hotel). Kitzen noted that for people with dyslexia, more practice is required to produce and shift stress from syllable to syllable when decoding words. Thus, the ability to manipulate stress and apply it to unstressed syllables may help to clarify ambiguous phonemes and enhance phoneme identification, which in turn, may facilitate phonological representations of words.

A second line of argument, related to the observed relationships between speech rhythm sensitivity and rhyme awareness, is that because the peak of loudness in a syllable corresponds to the location of vowels, sensitivity to speech rhythm may facilitate the identification of onset-rime boundaries and enhance rhyme awareness. This idea has been supported by Goswami and colleagues. As noted earlier, Goswami et al. (2002) investigated the relationship between speech rhythm, phonological awareness and reading difficulties. The speech rhythm task assessed children's sensitivity to, and perception of, beats (or rise time) and this was administered along with measures of phonological awareness and reading ability. Twenty-four children (mean age = 9.0 years) with dyslexia, were compared with twenty-four reading-age matched controls (mean age = 7.11 years) and twenty-five chronological-age matched controls for their speech rhythm sensitivity. It was found that the dyslexic group were significantly less sensitive to beat detection than their chronological-age matched counterparts. Speech rhythm sensitivity was also found to be significantly correlated with RAN, phonological memory, and phonological awareness after controlling for age and WISC, and that this was able to account of a significant amount of unique variance in phonological



processing after age, nonverbal IQ, and vocabulary had been accounted for. Speech rhythm has been able to predict unique variance in phonological processing more recently (Corriveau, Pasquini, & Goswami, 2007). To interpret these findings, Goswami et al. (2002) argued that sensitivity to the suprasegmental components of speech might facilitate the development of phonological awareness and reading. More specifically, as beats (peaks in amplitude of the speech signal) correspond to vowel location, sensitivity to these beats would facilitate the identification of vowels. This, in turn, would enable an individual to locate the onset (the part of the word before the vowel) and rime (the part of the word including the vowel and beyond) in words, and the boundaries between them. Goswami and Bryant (1990) argue that knowledge of these boundaries is an important factor in the development of reading. Wood et al. (in press) noted that we should expect research to find associations between speech rhythm sensitivity (suprasegmental phonology) and segmental awareness, and 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”. It should be noted that such *beat perception* deficits have also been observed in languages which are not stress-timed. For instance, Muneaux, Ziegler, Truc, Thomson, and Goswami (2004) found beat perception deficits in French dyslexics.

The strong relationships noted between speech rhythm and phonological awareness should not be overlooked. Indeed, an important point for further research was noted by Wood et al. (in press) who commented that given the well-documented link between speech rhythm and phonological awareness, to investigate any unique contribution of

speech rhythm to reading, phonological processing should be controlled. The next chapter will consider the relationship between speech rhythm sensitivity and reading more generally, for which we would expect to see a relationship if sensitivity to speech rhythm is underpinning poor reading development.

## **1.7. Speech Rhythm and Reading**

There is a growing literature demonstrating that speech rhythm sensitivity is related to reading development. As noted previously, Wood and Terrell (1998b) used a rhythm matching task, which measured how sensitive children were to metrical stress in speech. 30 poor readers (mean age = 9;1 years, SD = 21 months), 30 chronological-age matched controls, and 30 reading-age matched controls (mean age = 6;5 years, SD = 14.2 months) 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. Wood and Terrell found that those with reading difficulties performed significantly worse than their age-matched controls on a rhythm matching task, even after accounting for individual differences in vocabulary. No differences were found between the poor readers and the reading-age matched controls, which is suggestive of a maturational lag as opposed to a specific deficit. These findings were supported by Goswami et al. (2002) who also found that while dyslexic children were outperformed on a beat detection task by their chronological-age matched controls, no differences were found between the dyslexic children and their reading-level controls. These findings nevertheless suggested that sensitivity to speech rhythm is related to reading

development. However, there are three problematic issues concerning the methodology of Wood and Terrell's study. Firstly, as was acknowledged by the researchers themselves, there was a very broad age range in the poor readers group and this is problematic given the heterogeneous nature of reading difficulties. There is much variation in the nature of reading difficulties and the broad age range means that the poor readers group represents a highly diverse group of children which makes it difficult to generalise their data. It would be a better test of Wood and Terrell's claims if metrical stress sensitivity deficits could be found in a more restricted, homogeneous sample. Secondly, the rhythm matching task used was memory intensive, which could have confounded the subsequent findings; tasks of this nature sometimes become more of a 'test of memory', than anything else and may also result in fatigue on behalf of the participants, which would result in data that is not truly representative of their abilities. Thirdly, and most importantly, how rhythmic awareness related to phonemic awareness and phonological awareness was discussed as part of the rationale for the study, yet, the analysis did not directly consider whether performance on the rhythm matching task was related to performance on the phonemic awareness and phonological awareness tests. However, Wood (2006b) revisited the data from Wood and Terrell, and also found that speech rhythm sensitivity was able to predict unique variance in both word reading and spelling after age and vocabulary had been accounted for.

In support of the findings from Wood and Terrell (1998b), Whalley and Hansen (2006) used the 'DEEdee task', which was similar to the sentence matching task to assess prosody at the phrasal level in 81 children aged between 8 and 10-years-old (mean age = 9.3 years). In this task the prosodic structure of a phrase was retained but each

syllable was substituted by a meaningless syllable 'dee'. Children were played an original phrase, which was then followed by two Deedee phrases, one of which matched the prosodic pattern of the original phrase (stress, rhythm, intonation) and one of which did not. They had to decide which Deedee phrase matched the original phrase. This task eliminated the potential of phonemic information. They also assessed prosody at a word level where children had to discriminate between compound nouns 'ice-cream' and noun phrases 'ice', 'cream', which also differed only in terms of their prosodic features by selecting the appropriate graphic. It was found that phrase-level prosody predicted a significant amount of variance in reading comprehension after word reading accuracy, phonological awareness and general rhythmic sensitivity had been accounted for. Word-level prosody also predicted a significant amount of unique variance in word identification accuracy.

To overcome some of the methodological limitations of the Wood and Terrell (1998b) task, Wood (2006a) further investigated the association between metrical stress sensitivity and reading development in a group of pre-schoolers (mean age 4;3) and reception children (mean age 5;2). Rhythmic sensitivity was measured by a task in which children were required to find objects in a pretend house. It was firstly established that children could identify all of the objects that were to be used in the study. All of these words had two syllables and carried primary lexical stress on the first syllable with a weak syllable in the second syllable; an example of this is the word *sofa*. Following this, children were required to find the objects again, only this time the words were spoken incorrectly, including one condition in which the metrical stress pattern of the word was reversed. Here, the first vowel became reduced and the second vowel

became fully articulated; for instance the word *sofa* was pronounced *s'far*. Wood (2006a) found that performance on this reversed metrical stress condition was significantly associated with reading attainment. However, as Wood (2006a) acknowledged, the study did not include measures of phoneme deletion ability and this is a standard measure of phonological awareness. Also, there were only 39 participants in the study (23 pre-schoolers and 16 reception children) which is a relatively small sample. Furthermore, Wood (2006a) did not use vocabulary as a covariate, which is problematic given that vocabulary may mediate the relationship between spoken word recognition and reading development (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.

Holliman et al. (2008) also administered the mispronunciations task from Wood (2006a) to a group of beginning readers and young children (mean age = 6;1 years, SD = 6.75 months) and found that performance on the speech rhythm measure was able to predict unique variance in word reading ability after controlling for age, vocabulary and phonological processing. However, the metrical stress task used in Wood (2006a) and Holliman et al. (2008) can be criticised on three counts; firstly, with mispronounced words having to be found amongst many other items, the role of short-term memory may have been an influential factor and should have been controlled. Related to this, the task could have been simpler, such as finding the object from four different pictures rather than in a house with many items. Lastly, more words are required that begin with the same sound. For instance, in finding the word *sofa* no other objects began with the *s* sound and this is problematic as it could be tapping into 'process of elimination skills'

rather than children's sensitivity to stress. Despite the limitations of the studies discussed above, there seems to be a link emerging between metrical stress sensitivity and reading and phonological awareness.

In further support of these findings, De Bree, Wijnen, and Zonneveld (2006) compared 49 children at risk of dyslexia (mean age = 3;3) with 28 control children (mean age = 3;1) on a word stress task. Children were presented with non-words varying in length from 2 to 4 syllables, with the stress patterns in each non-word ranging from regular, irregular, highly irregular, to prohibited stress. It was found that the at-risk children made more errors than the controls with irregular and prohibited stress patterns and findings were considered in terms of metrical stress sensitivity, with the at-risk group finding it more difficult to repeat identical words with initial weak syllables than the control group. Due to the fact that the Dutch language shares a number of characteristics with the English language; it is a stressed-timed language and stressed syllables are characterised in a similar way with greater amplitude and longer duration (De Bree et al., 2006, p.305) it seems plausible that such findings might extend to the English language.

Kitzen (2001) investigated the relationship between prosody and reading by comparing 30 young adults with a history of reading difficulties with 30 young adult without a history of reading difficulties on two prosodic sensitivity tasks. Task 1 involved discriminating between two phrases (e.g. hotrod and hot-rod) which did not differ phonemically, but differed in terms of prosody and task 2 involved matching a Deedee phrase to a correctly spoken phrase based on prosody. Kitzen found that those with a

history of reading difficulties were significantly poorer on both of the prosodic sensitivity tasks. Prosodic sensitivity was also able to predict a significant amount of variance in oral text reading accuracy, oral text reading comprehension, and oral text non-word reading.

Gutierrez-Palma and Reyes (2007) also investigated the relationship between speech rhythm, reading and non-word reading in a group of 18 Spanish seven to eight-year-old children. To assess stress sensitivity, children were presented with non-words containing a stress contrast such as (/mi'pa/ - /mipa'/) and/or a phoneme contrast such as (/ku'pi/ - /ku'ti/). After a practice trial, children heard sequences of two, three, and four non-words and had to press particular keys on a computer keyboard that corresponded to the sequence of non-word they had just heard. For example, a correct response for /mi'pa/ - mi'pa/ would be /k/, /k/ and a correct response for /mi'pa/ - /mipa'/ would be /k/, /l/. To assess stress assignment, children were presented with disyllabic non-words on a computer screen and were required to read them out loud to the administration. The administrator then marked their responses for accuracy of stress placement. It was found that stress sensitivity in two non-word sequences predicted non-word reading, but not word reading. However, stress sensitivity did predict stress assignment, which was found to predict both word reading and non-word reading. The authors conclude that stress sensitivity may facilitate the acquisition of word-stress rules which may enhance reading fluency.

Furthermore, the 'rise time' literature has also demonstrated strong links between speech rhythm sensitivity and word reading. Recall the study by Goswami et al. (2002),

which was described in Sections 1.4 and 1.6. An additional key finding from this study was that after controlling for age, non-verbal IQ, and vocabulary, speech rhythm sensitivity was able to predict unique variance in word reading (25%), spelling (25%), and non-word reading (14%). Also, after controlling for phonological processing (rhyme oddity) at Step 4, speech rhythm sensitivity was further able to predict 9% of the variance in word reading. Thomson and Goswami (2008) and Thomson et al. (2006), both described in Section 1.4, also found significant relationships between speech rhythm sensitivity and word reading, thus, there appears to be strong evidence for a relationship between speech rhythm sensitivity and word reading.

From the review above, we can see that there is a great deal of evidence linking speech rhythm sensitivity to word reading in particular, but also to other aspects of reading such as comprehension. While the theoretical links between speech rhythm sensitivity and decoding have been discussed (enhancement of phonemes, identification of onset-rime boundaries, facilitation of speech perception and spoken word recognition), there are other proposed ways in which speech rhythm sensitivity (or prosody) might influence the other characteristics of skilled reading, namely, reading fluency and reading comprehension.

### **1.7.1. Speech Rhythm, Fluency, and Comprehension**

Before we investigate the relationship between speech rhythm and fluency, we must first discuss what reading fluency is and how it should be measured because this issue has been much debated in the literature. Typical measures of fluency include a word-per-minute measure (reading rate) and are simply concerned with how fast and accurate



a reader is. Dowhower (1991, p.165) commented that “reading researchers usually have investigated fluency by quantifying rate (words per minute) and accuracy (number of words correctly identified) and have left the third bedfellow of fluency called prosody unattended”. It was speculated that this could be because expression is difficult to measure and quantify. Dowhower (1991, p.166) considered what should be measured in fluency (prosodic reading) and suggested that prosodic features such as pausing (with varied duration), intonation and changes to pitch, emphasis of certain words, and lengthening of particular vowel sounds all help to segment the text into meaningful units and constitute fluent reading. Dowhower (1991) identified six prosodic fluency markers: i) presence or lack of pauses, ii) length of phrases between pauses, iii) number of appropriate and inappropriate phrases, iv) duration of final words of syntactic phrases, v) the change of pitch at final punctuation marks, and vi) stress or accent. Many researchers (e.g. Schwanenflugel, Hamilton, Kuhn, Wisenbaker, & Stahl, 2004; Miller & Schwanenflugel, 2006) agree that reading with expression is also a key component of reading fluency. Indeed, Kuhn and Stahl (2003, p.18) argue that “given that fluent oral reading is considered to be expressive as well as quick and accurate and that prosodic features are, to a large extent, responsible for such expression, it is important to consider a definition of fluency that encompasses more than rate and accuracy”. Kuhn and Stahl (2003, p.3) go on to argue that “effective fluency instruction moves beyond automatic word recognition to include rhythm and expression, or what linguists refer to as the prosodic features of language” and that “when an individual provides a fluent rendering of a text, there is a tacit understanding that he or she is doing more than simply reading the words quickly and accurately; he or she is also reading with expression” (Kuhn & Stahl, 2003, p.5). Moreover, Schwanenflugel et al. (2004, p.119) noted that “prosodic

reading, or reading with expression. is widely considered to be one of the hall marks of the achievements of reading fluency”. This distinction in the literature was acknowledged by Sargent (2004) who investigated the relationship between reading fluency and reading comprehension in fifty-two children in Grade 5. To assess reading fluency, an oral reading fluency measure was used, which essentially measured accuracy and rate, but also, the Multidimensional Fluency Scale (Zutell & Rasinski, 1991) was used, which assessed reading fluency by focusing on phrasing and smoothness, as well as rate. It was found that both fluency measures, that is, the typical measures of fluency (rate and accuracy) and the new fluency measure which incorporated prosodic components (phrasing, smoothness, and pace) were significantly related to reading comprehension, thus strengthening the association between prosodic reading fluency, typical measures of fluency, and comprehension. So, while the relationship between speech rhythm, reading fluency and reading comprehension will now be investigated, one should note this argument regarding the assessment of reading fluency.

So how does speech rhythm relate to reading fluency and comprehension? Kuhn and Stahl (2003) speculated that prosody might provide a link between reading fluency and reading comprehension. Reading with attention to stress and intonation on particular components of a sentence implies knowledge of the syntactic roles. This is a key component of microprocessing, which helps to arrange the text into hierarchically ordered elements. Readers more sensitive to prosodic features while reading make links between speech and reading which might help in the understanding of the text. Kuhn and Stahl (2003, p.6) developed this idea further and argued that “appropriate phrasing,

intonation, and stress are all considered to be indicators that a child has become a fluent reader...they act as indicators of the reader's comprehension...given that a fluent reader is one that groups text into syntactically appropriate phrases, this parsing of text signifies that the reader has an understanding of what has been read". So, reading fluency is related to reading comprehension, but sensitivity to prosodic features might mediate this relationship, facilitate the segmentation of text, and result in more proficient reading comprehension.

The relationship between prosody and reading comprehension has been demonstrated in other studies. For instance, Whalley and Hansen (2006) investigated the relationship between prosody and different components of reading in a group of 81, eight to ten-year-old children in Grade 4. It was found that prosody predicted unique variance in word reading accuracy and in reading comprehension after individual differences in phonological awareness had been controlled. Whalley and Hansen argued that sensitivity to prosodic features such as rhythm and stress facilitate reading comprehension because it enables the individual to segment the speech stream and chunk spoken language into syntactically comprehensible units, which in turn reduce memory load and enable the individual to focus (comprehend) the more relevant aspects. They also argue that it plays an important role in listening comprehension. It should be noted that the prosodic tasks used in this study were also found to discriminate between children with and without a history of reading difficulties, and to predict variance in reading accuracy, reading comprehension, and non-word reading in an adult sample (Kitzen, 2001).

Sensitivity to stress may also help comprehension by conveying the meaning of words. In English, lexical words tend to begin with strong syllables rather than weak syllables (Cutler & Norris, 1988; Cutler & Carter, 1987). When words have more than one syllable in the English language, one of them (usually the first) is stressed. Sometimes the stress changes depending on whether the word is a noun or a verb; for instance, Kitzen (2001) showed how disyllabic nouns were more likely to receive first syllable stress (PERmit, CONvict, IMport) whereas disyllable verbs are more likely to receive second syllables stress (perMIT, conVICT, imPORT). In words with more than two syllables there is often primary and secondary stress. For instance, in the word 'beautiful' and 'unicorn' primary lexical stress falls on the first syllable, and secondary stress falls on the third syllable. This pattern of strong and weak syllables can also discriminate between compound nouns and noun phrases. The first element of compound nouns (e.g. BLACKbird, LIGHThouse, HIGHchair) are more likely to received stress and the final element of phrases (e.g. black BIRD, light HOUSE, high CHAIR) are more likely to received stress (Whalley & Hansen, 2006). Furthermore, strong, stressed syllables can also help convey the meaning of a sentence. For instance: in the phrases 'JOHN kicked the ball', 'John KICKED the ball', and 'John kicked the BALL', the meaning and implications of each phrase changes depending on where the stress is located. So, sensitivity to stress, and strong and weak syllables (and generally, sensitivity to speech rhythm) seems to play an important role in conveying meaning, which would facilitate comprehension.

Schwanenflugel et al. (2004) proposed two models to account for the relationship between prosody and reading comprehension. In the 'reading prosody as partial

mediator model' it was argued that proficient, fast and accurate decoding skills should free up attention resources that can be made available to prosodic processing, which would then have some additional contribution to reading comprehension beyond decoding ability, thus, prosody might act as a mediator between decoding and reading comprehension. In the 'reading comprehension as predictor of reading prosody model' it was argued that children with proficient reading comprehension and decoding ability would be more likely to utilise prosodic reading. To inform the legitimacy of these two models, Schwanenflugel et al. (2004) conducted a study investigating how prosody is related to decoding and reading comprehension using 123 children in Grades 2 and 3, and in 24 adults. The prosodic measure involved using audio recordings and converting them to a .wav file in order to observe spectrographs which would highlight prosodic features of speech such as pausing and pitch. The findings showed that with regard to the reading prosody as partial mediator model, a strong relationship was found between decoding and prosody, with fluent decoding skills linked to proficient prosody. There was less support for the independent contribution of prosody to comprehension beyond decoding ability. With regard to the reading comprehension as predictor or reading prosody model, a relationship was once again found between decoding and prosody, but not between comprehension and prosody. The authors conclude that prosodic reading skills are likely to be evidence that children have proficient decoding ability, but also that prosody and reading comprehension are less related.

In summary, there is a growing literature which demonstrates empirical evidence of the links between speech rhythm sensitivity and various components of reading development: decoding, comprehension and fluency. However, there are some

methodological limitations with this literature as it currently stands, and there is a lack of research that has explicitly looked at the relationships between speech rhythm and word reading, reading comprehension and fluency within the same sample of children. In fact, reading fluency has yet to be considered empirically in relation to speech rhythm sensitivity. Moreover, there are currently no longitudinal studies assessing the contribution of speech rhythm sensitivity to reading development.

Earlier in the review, it was noted that morphological awareness is increasingly recognised as contributing to reading development. Could individual differences in morphological awareness be associated with sensitivity to speech rhythm? This question is considered in the following section.

## **1.8. Speech Rhythm and Morphology**

Recall that morphological awareness is concerned with root words, affixes, and suffixes (Jarmulowicz et al., 2008) and represent the smallest units of meaning within a word. There is a literature linking awareness of morphology to reading development (Carlisle, 2000; Nagy et al., 2006; Nagy et al., 2003; Ravid & Mashraki, 2007; Green et al., 2003). Some research (e.g. Deacon & Kirby, 2004) has found that morphological awareness is predictive of reading development after controlling for phonological awareness; thus, the links between morphology and reading are not simply mediated by phonological awareness. It was also found that morphology was a stronger predictor of reading comprehension than phonological awareness. Some researchers (e.g. Nagy et al., 2003) have noted that morphological awareness might play a unique role in reading development that cannot be explained through phonological awareness. Other research

has supported the uniqueness of morphology in reading development (Siegel, 2008; Mahony et al., 2000). It has been linked theoretically (in Section 1.3) to single word reading, decoding pseudowords, reading comprehension (Deacon & Kirby, 2004; Mahony et al., 2000), writing, vocabulary, and language (Nagy et al., 2003). It seems plausible that the unique relationship between speech rhythm sensitivity and reading after controlling for phonological awareness might be explained via links with morphology, which have been found to predict reading independently of phonological awareness. Thus, the observed relationship between speech rhythm and reading might be mediated by morphology.

When we are decoding multisyllabic words, stress rules become very important and the location of stress can change depending on the suffix of that word. For example, Wade-Woolley (2007) showed that in words ending in *ity* or *tion* there is a stress shift to the syllable immediately before that suffix. For instance, in the word *electric* the stress is on the *lec* syllable, but in the word *electricity* there is a stress shift and the stress moves immediately before the suffix on *tri*. The same principle applies to the suffix *tion* e.g. *operate* and *operation*. However, some suffixes e.g. *ness* do not result in a stress shift. For example, the location of stress in the words *happy* and *happiness* falls on the *ha* syllable in both cases. Kitzen (2001) also noted that disyllabic nouns are likely to receive first syllable stress (PERmit, CONvict) whereas disyllabic verbs are more likely to receive second syllables stress (perMIT, conVICT). Wade-Woolley argued that poor readers may be less sensitive to stress in oral language and be less aware of morphological rules when decoding multisyllabic words.

Current models of reading development typically deal with monosyllabic words (Protopapas, Gerakaki, & Alexandri, 2006) where the role of stress sensitivity has less importance; as noted it is in multisyllabic words where stress rules become more important. Wade-Woolley (2007) has argued that insensitivity to stress in oral language might be related to less awareness of morphological rules when decoding multisyllabic words, which might in turn, result in poorer reading ability. It has also been speculated that this might explain how sensitivity to stress can predict reading after controlling for phonological awareness. If this explanation for the link between speech rhythm and reading (mediated through morphology) was true, we would expect that if morphology was controlled for in studies investigating the relationship between speech rhythm and reading, that the amount of variance in reading accounted for by stress sensitivity would reduce, or disappear. At least one study has investigated this: Clin and Wade-Woolley (2007) found in a group of eight to thirteen-year-old children that speech rhythm sensitivity was unable to account for significant, unique variance in reading after controlling for morphology. This supports the suggested link between speech rhythm, morphology, and reading. However, it should be noted that many of the studies that found speech rhythm sensitivity to predict unique variance in reading (e.g. Wood, 2006a; Holliman et al., 2008) used younger children aged below 7 years old, where morphological awareness seems to be less important as it becomes more important as children get older (Green et al., 2003). Therefore, it remains unknown whether the results from Clin and Wade-Woolley (2007) would be replicated if a younger sample of children was used, whose morphological awareness was less well-developed.



In summary, sensitivity to speech rhythm might be related to morphological awareness, and facilitate the decoding of multisyllabic words. We have established from sections 1.6 and 1.7 that sensitivity to speech rhythm is related to phonological awareness and reading development. However, it is not yet known whether the relationship between speech rhythm sensitivity and reading skill is attributable to a general auditory rhythmic deficit that is not specific to speech, or whether the deficit is attributable to insensitivity to speech rhythm specifically. The following section therefore considers whether there is any evidence to suggest that sensitivity to speech rhythm is a skill that is distinct from sensitivity to other forms of rhythmic sensitivity.

### **1.9. Speech Rhythm and Non-Speech Rhythm**

While this thesis is primarily concerned with the role of *speech* rhythm sensitivity in children's reading development, the role of *non-speech* rhythm must also be acknowledged. Non-speech rhythm can be thought of as the same as speech rhythm (e.g. pitch, timing, stress, intonation) only without speech. Typical measurements involve using beats and musical stimuli. As noted in Section 1.4, there is a literature linking non-speech rhythm to reading development (e.g. Thomson & Goswami, 2008; Thomson et al., 2007; David et al., 2007; Overy, 2000; Overy et al., 2003; Tallal, 1980; Tallal, 1984; Farmer & Klein, 1995) and such findings have generally been considered in terms of a temporal processing deficit.

Similarly, there is a literature linking speech rhythm to reading development (e.g. Wood & Terrell, 1998b; Goswami et al., 2002; Wood, 2006a; Wood, 2006b; Whalley & Hansen, 2006; Holliman et al., 2008; De Bree et al., 2006; Kitzen, 2001; Gutierrez-

Palma & Reyes, 2007; Thomson & Goswami, 2008; Thomson et al., 2007). However, while the role of speech rhythm and non-speech rhythm in children's reading development has been considered in the literature, it remains unknown whether speech rhythm and non-speech rhythm are related components of the same skill. There is a lack of empirical research investigating the link between speech rhythm and non-speech rhythm.

Patel, Paretz, Tramo, and Labreque (1998) commented that both speech rhythm and musical rhythm share characteristics such as pitch, duration, and intensity, so such a link seems plausible, although only a handful of projects have investigated this. For example, Wolff (2002) compared 12 dyslexic students (mean age 13:7) with age and gender matched non-dyslexic students on their 'anticipation of motor sequences', their 'reproduction of manual motor rhythms' (both using tapping tasks), and their 'timing and assignment of phrasal stress during the repetition of nonsense syllables'. It was found that dyslexic students had significantly greater difficulty with their anticipation of motor sequences, with their timing of manual motor rhythms, and also with their reproduction of speech rhythm and order of syllables. While this study demonstrates both speech and non-speech rhythm deficits in those with dyslexia, it was not investigated whether the speech and non-speech rhythms were correlated with each other. Wolff (2002, p. 185) commented that "prosody is probably the closest linguistic analogue...to non-linguistic rhythms" and given the characteristics of both linguistic and non-linguistic rhythms "in this respect speech rhythms do not differ significantly from other rhythms...the two patterns when properly defined also share a number of fundamental properties". Wolff suggested further that the temporal processing deficits

witnessed in dyslexic students during non-linguistic rhythm tasks may well be related to deficits of linguistic rhythm in the speech stream.

In addition to this, Patel (1998) administered linguistic phrases using three different possible syntactic structures (words) in a sentence which varied in difficulty and musical phrases that were manipulated in a manner comparable to the above to fifteen musically trained participants and observed the event-related brain potential (ERP) from 13 sites around the head. Similar ERPs in terms of polarity, amplitude, and scalp distribution were found suggesting a common or largely overlapping set of neural generators in the syntactic processing of language and music. However, a limitation to this study was that the participants had an average of 11 years musical experience, they had studied music theory, and played a musical instrument an average of 6.2 hours per week, so it is unknown whether these findings would be replicated in a younger age group that were not musically gifted. This study also measured linguistic syntax and language rather than 'speech rhythm' per se. Although prosody is an aspect of spoken language the similarity found in this study between the ERP for the processing of linguistic and musical information may not have been found had the linguistic task focussed specifically and solely on the prosodic features of speech.

Furthermore, Patel et al. (1998) employed a test of prosody and a test of musical perception that were considered comparable to each other in terms of stimuli and task demands. Two participants with amusia (a specific music processing deficit) aged 40 years old and 38 years old respectively, were given 24 sentence pairs for prosody and 24 sentence pairs for music and had to indicate whether they were the same or whether

they were different. ‘Prosodic’ sentence pairs could differ either by pitch, for example, ‘take the *train* to Bruges, Anne’ versus ‘take the train to *Bruges*, Anne’ or by the placement of a pause or timing, for example, ‘Henry, the child eats a lot’ versus ‘Henry, the child, eats a lot’. These sentences were converted into tone sequences for the musical stimuli, which could also differ in length, rate, frequency, and timing. It was found in both participants that level of performance was statistically similar across domains, suggesting shared neural resources for the processing of prosody and music. However, this study had a small sample size ( $n = 2$ ) and it only used participants that were amusic. Therefore, generalisation beyond this population should be treated with caution. Moreover, the sentence pairs used in this study were conducted in the French language, which is a syllable-timed language (Patel & Daniele, 2003). Therefore, if we were to manipulate prosodic features such as stress in English, which is a stress-timed language, the same results may not be found.

It should be noted that this potential link between speech and musical rhythm is not supported by the neurological literature which suggests that the two are independent systems. For instance, Peretz (1993) found that perception of musical syntax can be selectively impaired after brain damage without impairing linguistic syntax. McMullen and Saffran (2004) also commented that while damage to the left temporal lobe commonly results in language problems, damage to the right temporal lobe commonly results in amusia. However, according to Patel (1998, p.39) this lack of relatedness could be explained by the “shared structural integration resource” (SSIR) hypothesis, which suggests that although the processing of linguistic and musical syntax may be cognitively distinct, both processes suffer a cost when elements of a sequence, albeit

linguistic or musically, are forged into working memory. When this occurs and there is conflicting information between what is expected and what is actually there, both processes depend on the same set of shared neural resources in order to cover this cost, which would help explain the link between the two domains. Thus, the SSIR hypothesis suggests that the two domains may indeed be distinct and that domain similarity, when found, could be due to the shared neural resources that cover costs in syntactical processing tasks.

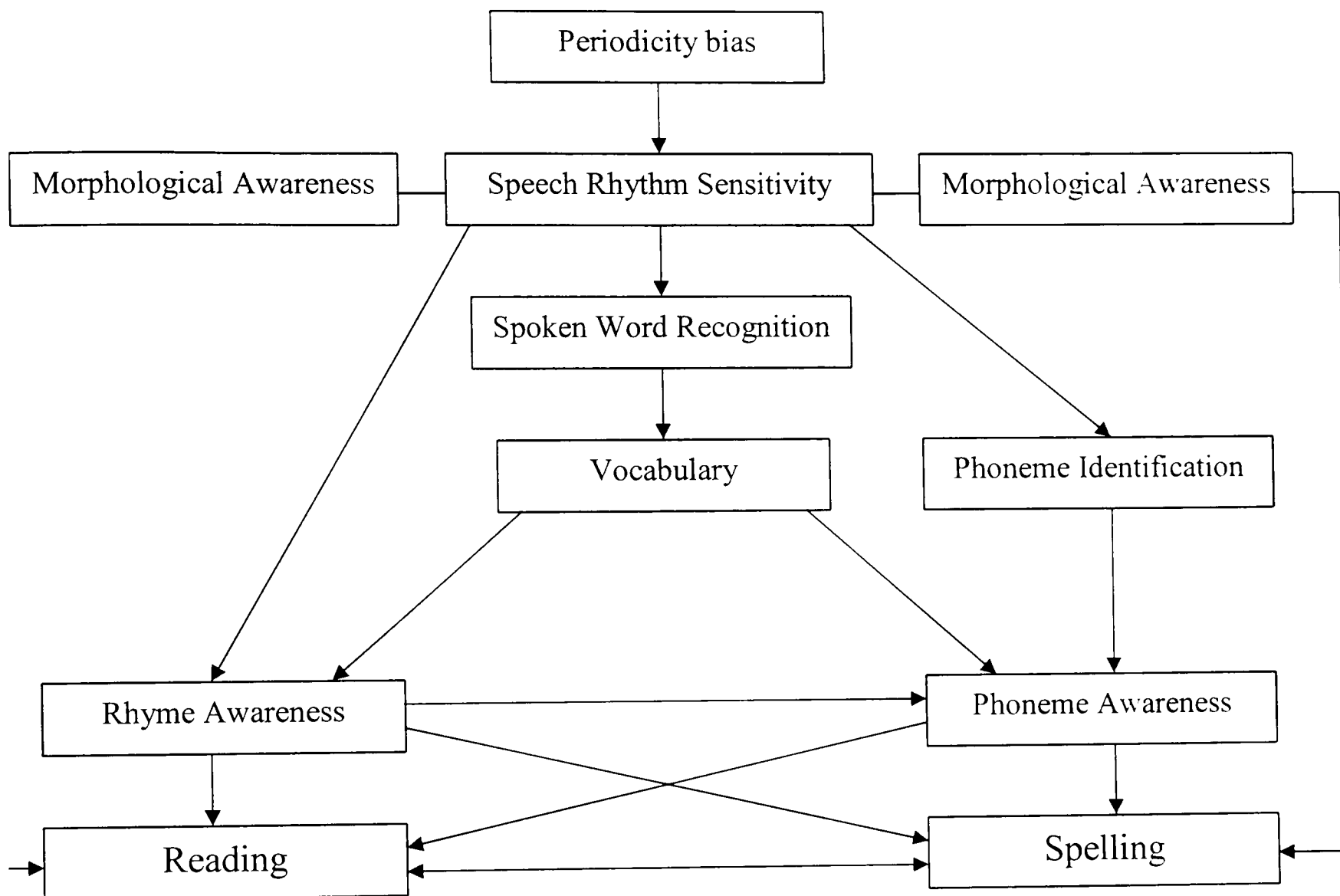
In summary, non-speech rhythm has been linked to reading development in many studies and this has often been explained via the temporal processing deficit hypothesis (although this is a contentious area). It seems plausible that speech rhythm and non-speech rhythm are related, although there is a lack of empirical research in this area.

## **1.10. Chapter Summary and Outstanding Questions**

This chapter has presented an overview of how reading seems to develop in typical and atypical developers, and where reading seems to go wrong in children with reading difficulties. Children with reading difficulties seem to have extreme difficulty mapping graphemes to phonemes; indeed, the most extensive links in the literature are between phonological skills, awareness, processing, and representation and reading. Links between morphological awareness and reading development were also presented. However, while the extensive link between phonological skills and reading development is noted, the fact remains that phonological awareness cannot explain all of the variance in children's reading ability and it is possible that phonological awareness is secondary to another underlying deficit which might occur earlier on in

child development. Subsequently, there is a literature, albeit an equivocal literature, which suggests that children with reading difficulties have deficits in speech perception and in identifying words in fluent speech, which seems to develop during infancy in the first year of life.

Speech rhythm sensitivity (or prosody) has received a great deal of attention over the last few years in particular. Theoretically, speech rhythm sensitivity has been linked to phonological awareness (including phoneme and rhyme awareness), morphology, speech perception, spoken word recognition, vocabulary, and other reading-related skills. Thus, it seems plausible that speech rhythm sensitivity plays an important role in children's reading development and this has been implicated in the recent literature. Perhaps the most up-to-date model (see Figure 1.3), which summarises the potential contribution(s) and relationships between speech rhythm sensitivity and reading development was devised by Wood et al. (in press). However, the nature of the relationship between speech rhythm sensitivity and reading development remains under-researched, there are many questions which remain unanswered, and there are many claims (e.g. those from Wood et al., in press) which require more empirically evidence.



**Figure 1.3 How speech rhythm sensitivity might be related to reading development from Wood et al. (in press)**

While there is a growing literature investigating the relationship between speech rhythm sensitivity and reading, and there is an established literature linking non-speech rhythm sensitivity to reading, only a handful of papers have investigated the relatedness of speech rhythm sensitivity and non-speech rhythm sensitivity, and we do not currently know whether speech rhythm sensitivity can predict unique variance in reading beyond that accounted for by non-speech rhythm. Moreover, while it is acknowledged that speech rhythm sensitivity is related to phonological awareness development, the fact remains that a handful of studies have found that speech rhythm sensitivity can account

for unique variance in reading development after controlling for phonological awareness, although more research is necessary to consolidate this finding. Thus, the first major aim of this thesis is to investigate the relationships between speech rhythm sensitivity, non-speech rhythm sensitivity, phonological awareness, and reading ability in children.

Additionally, whilst there is a growing literature linking speech rhythm sensitivity to reading development, both theoretically and empirically, few studies to date have explored how speech rhythm sensitivity is related to different components of reading such as decoding, comprehension and fluency, and how it relates to them over time. In order to make claims about causality (e.g. like in Figure 1.3), longitudinal evidence is required. Thus, the second major aim of this thesis is to investigate how speech rhythm sensitivity relates to measures of word reading, reading accuracy, reading fluency, reading comprehension, spelling, and non-word reading both concurrently and one-year later.

Furthermore, while speech rhythm sensitivity has been related to reading development in the literature, we do not yet know whether deficits in speech rhythm sensitivity represent a specific deficit in children at risk of reading difficulties or whether they indicate a maturational lag. Only two studies to date have used both chronological-age matched and reading-age matched control groups in their designs, and these studies compared them to either children with reading difficulties (Wood & Terrell, 1998b) or children with developmental dyslexia (Goswami et al., 2002); thus, the third and final aim of this thesis is to establish whether speech rhythm sensitivity deficits are



characteristic of a specific deficit or maturational lag in a group of young children at risk of reading difficulties. The general, overarching aim of this thesis is to make theoretical and empirical contributions to help establish the role of speech rhythm sensitivity (and stress in particular) in children's reading development.

To summarise, there were three major research questions addressed in this thesis:

1. Is speech rhythm sensitivity able to account for young children's reading development after individual differences in both phonological awareness and non-speech rhythm sensitivity have been taken into account?
2. Is speech rhythm sensitivity predictive of children's reading development over time?
3. Do English speaking children at risk of reading failure display a specific speech rhythm sensitivity deficit?

### **1.10.1. Statement of Originality**

- No study to date has looked at the relationship between sensitivity to speech rhythm and non-speech rhythm and their relative contributions to reading development.
- No study to date has looked at the relationship between speech rhythm sensitivity and measures of reading fluency.
- To date there have been no longitudinal studies of speech rhythm sensitivity and reading development.
- There have been no studies of speech rhythm sensitivity including an 'at risk' sample of young English-speaking children.

## Chapter 2 - Methodology

The previous chapter provided an overview of the evidence in support of the idea that speech rhythm sensitivity may be an important skill, which may be able to account for unique variance in reading attainment. This chapter will evaluate the possible methodologies that might be used to assess speech rhythm sensitivity in children. The aim is to identify the key components of speech rhythm that need to be assessed and to identify a task that will be capable of assessing sensitivity to these components in beginning readers and young children.

### 2.1. Review of Speech Rhythm Measures

As discussed in Chapter 1, speech rhythm sensitivity has been found to predict various components of reading ability (e.g. word reading, reading comprehension, and spelling), to differentiate between poor readers and chronological-age matched controls, and between individuals with dyslexia (or at risk of dyslexia) and chronological-age matched controls, and these findings have been demonstrated in both child and adult samples. The strong associations between speech rhythm sensitivity and reading have been demonstrated in different age-groups, in studies assessing different components of speech rhythm, and using different procedures and methodologies.

Speech rhythm has been described as “the tempo, rhythm and stress of language” (Whalley & Hansen, 2006, p. 288) and this is echoed by other researchers in the field such as Kuhn and Stahl (2003) who suggest that it comprises of pitch (or intonation), stress (or loudness), and duration (or timing). Assessments of speech rhythm typically measure one or more of these components. It is important to consider the different ways

in which speech rhythm sensitivity has been conceptualised and operationalised in the literature in order to develop a suitable task that would tap into speech rhythm sensitivity in beginning readers and young children. To do this, several key studies investigating the relationship between speech rhythm sensitivity and reading in children will now be reviewed paying special attention to the methodology that was used. The aim of this review is to be able to identify an appropriate methodology, which is clear about what aspect of speech rhythm sensitivity to measure, how to measure it, and how to administer the measure.

Table 2.1 outlines some of the key studies investigating the relationship between speech rhythm sensitivity and reading in children. The essential details of their respective methodologies (e.g. the stimuli used, details concerning the procedure, and details concerning the sample) are shown.

**Table 2.1 A summary of some key studies investigating the relationship between speech rhythm and reading including details of the method used, the procedure, and the sample.**

<b>Key speech rhythm studies (in order of publication)</b>	<b>Description of stimuli and component of speech rhythm measured</b>	<b>Details of procedure</b>	<b>Details of sample</b>
Wood & Terrell (1998b)	Match spoken phrases to low-pass filtered sentences based on metrical stress and intonation.	Voices and sounds presented on a computer using external speakers.	90 children. Mean age of 8:2, SD of 23.9. Poor readers, age-matched and reading-matched controls.
Kitzen (2001)	Match spoken phrases to Deedee phrases and discrimination task based on rhythm, stress, intonation, pause.	Heard phrases from the administrator. Deedee phrases were pre-recorded and played through a speaker.	60 adults. 30 with history of RD (mean age of 20.97, SD of 4.68) 30 without history of RD (Mean of 22.2, SD of 6.17).
Goswami et al. (2002)	Match a rhythm to either 'winnie the pooh' or 'tigger and eyeore' based on beat detection (rise time) and rhythm.	Heard the sound sequences through headphones.	101 children. 24 dyslexics (Mean age of 9), 24 age-matched and 25 reading-matched (Mean age of 7:11) controls.
Schwanenflugel et al. (2004)	Children read a passage which was audio recorded and scored for prosody inc. pitch and timing.	Children's voices were audio recorded while sitting next to the administrator. They were scored using the recordings.	123 children. Mean age of 8:6, ranging from 7:4 to 10:4. Also included 24 adults.
Wood (2006a)	Identify the items from a line drawing of a house when the stress of those items had been manipulated/reversed.	Heard the words through a minidisc player using external speakers while seated with the administrator.	39 Children. 23 pre-schoolers (Mean age of 4;3) and 16 reception children (Mean age of 5;2).
Whalley & Hansen (2006)	Match spoken phrases to Deedee phrases and discrimination task based on rhythm, stress, intonation, pause.	Heard phrases through a speaker and recorded their answer on an answer sheet while sat with the administrator.	81 children. Mean age of 9.3, SD of 4.58, ranging from 8.8 to 10.5.

**Table 2.1 A summary of some key studies investigating the relationship between speech rhythm and reading including details of the method used, the procedure, and the sample. Continued.**

<b>Key speech rhythm studies (in order of publication)</b>	<b>Description of stimuli and component of speech rhythm measured</b>	<b>Details of procedure</b>	<b>Details of sample</b>
De Bree et al. (2006)	Children had to repeat non-words that contained stress patterns which varied in terms of their regularity.	Heard stimuli through a speaker and the repetitions were recorded and later scored. Sat with the administrator.	49 children at risk of dyslexia (Mean age of 3.3) and 28 control children (Mean age of 3.1). In Dutch language.
Ravid et al. (2007)	Children's reading was recorded and scored for prosody inc. pauses, intonation, and emphasis.	Children's voices were audio recorded after receiving instructions from the administrator.	51 children. Aged between 9 and 10. Living in Israel, speaking Hebrew.
Gutierrez-Palma et al. (2007)	Children read aloud non-words and also had to taps keys corresponding to non-words based on stress location	Sounds and words were presented on a computer and their verbal and tapped response was scored by administrator.	18 children. Aged between 7 and 8. Spanish children in Spanish language.
Holliman et al. (2008)	Identify items from a line drawing of a house when the stress of those items had been manipulated/reversed.	Heard the words through a digital recorder while seated with the administrator.	44 children. Mean age of 6;1, aged between 5 and 6.

The first important methodological issue to consider is what aspect of speech rhythm to focus on for assessment. Recall from Chapter 1 the idea that children with reading difficulties may have difficulties perceiving and processing speech (McBride-Chang, 1996; McBride-Chang, 1995) and identifying units of meaning (words) from a fluent speech stream (Metsala, 1997). Cutler (1994) argued that children's sensitivity to the rhythmic properties of language, notably stress sensitivity, might facilitate this word identification process, given that strong (stressed) syllables are a good indicator of word boundaries in the English language (Cutler & Carter, 1987). Additionally, Goswami et al. (2002) argued that sensitivity to the suprasegmental features of speech such as beats (peaks in amplitude of the speech signal) correspond to vowel location, so sensitivity to these beats could facilitate the identification of vowels. This, in turn, might enable an individual to locate the onset (the part of the word before the vowel) and rime (the part of the word including the vowel and beyond) in words. Goswami and Bryant (1990) also argued that knowledge of these boundaries is an important factor in the development of reading. As a result of this theoretical evidence, most research on speech rhythm sensitivity in children seems to have focussed on children's sensitivity to *stress*.

The collection of studies from Table 2.1 will now be considered. They have been grouped below according to the age category of their sample; 3 to 6-years-old, 6 to 11-years-old, and 11+. This is important because the effectiveness of any speech rhythm measure may depend on the age of children to which it was administered.

*Studies using 3 to 6-year-old children*

De Bree et al. (2006) measured speech rhythm by focussing on children's pronunciation of non-words and then scoring them for stress accuracy. The children in De Bree et al. (2006) were presented with non-words through a speaker, which varied in length from 2 to 4 syllables, with the stress patterns in each non-word ranging from regular, irregular, highly irregular, to prohibited stress. The at-risk children were found to make significantly more repetition errors, especially with identical words with initial weak syllables. While relationships between speech rhythm and reading were found in this study, there are some issues for consideration. Firstly, this study was not conducted in the English language; however, as Dutch is a stress-timed language, like English, it seems plausible that such findings might extend to the English language. Secondly, the age of the sample in this study was very young (3 years of age) so the findings may be less applicable to beginning readers and young children who would be a little older. Lastly, this measure of speech rhythm was rather complex for such young children (e.g. it was a productive task and used non-words). So, repetition of non-words and scoring them for stress accuracy is one way in which speech rhythm sensitivity has been assessed in the literature.

A different method of assessing speech rhythm in pre-schoolers and beginning readers was developed by Wood (2006a) who developed the stress mispronunciations task; this measured children's sensitivity to, manipulation of, and recovery of word stress.

Children were seated at a desk with the administrator, and placed in front of them was a line drawing of a house, which contained many typical household items (see Figure 2.1).

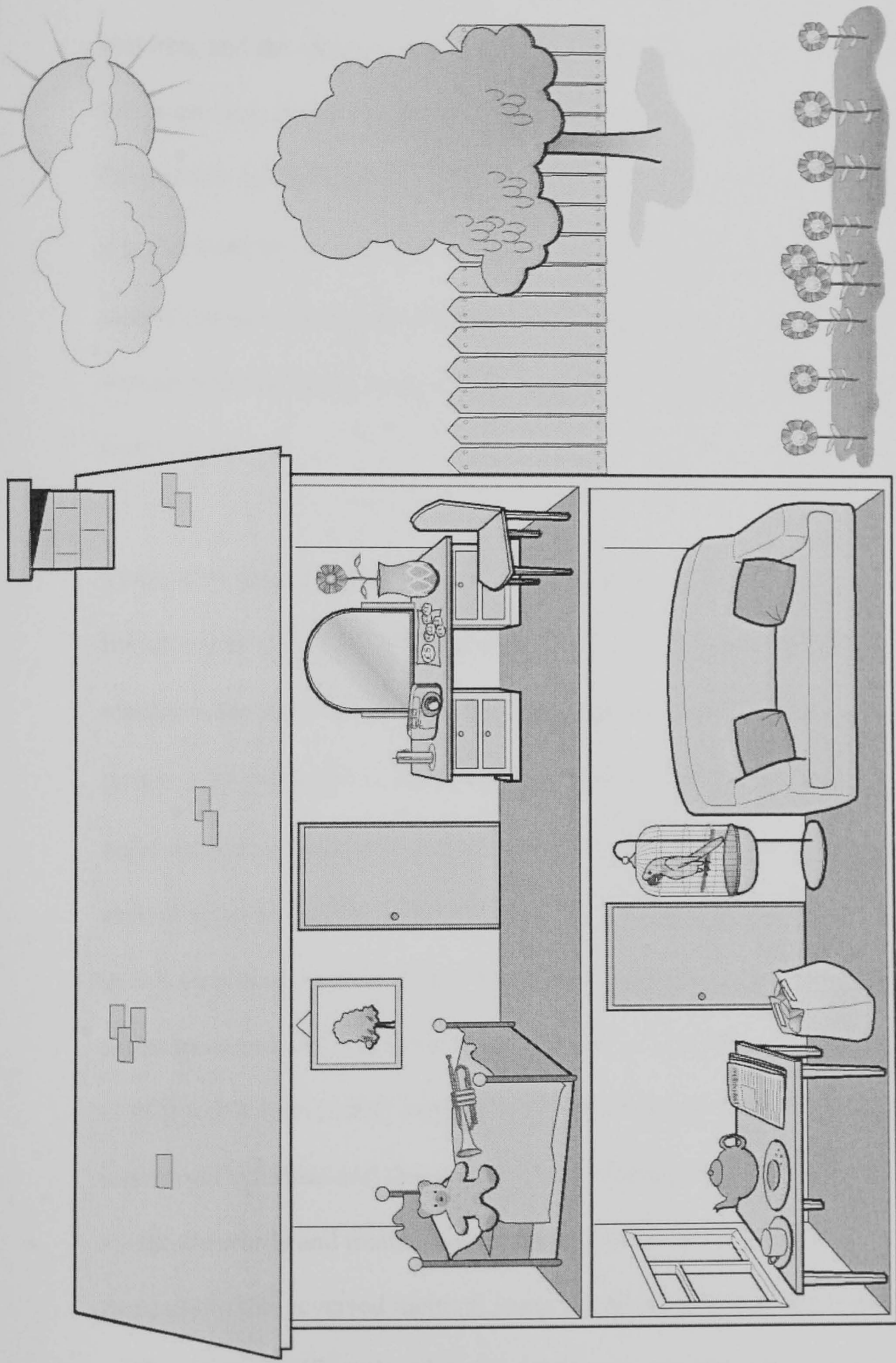


Figure 2.1 The house used in the original stress mispronunciations task from Wood (2006a)



The administrator used a digital recorder to play the pre-recorded household items to children, and the children then had to identify (by pointing to) the corresponding item in the house (e.g. if they heard the word *mirror* they would have to point to the picture of the mirror). In the baseline condition of this task the words were pronounced correctly e.g. the word *mirror* was pronounced [ˈmɪrə]. All items, when pronounced correctly, carried primary lexical stress of the first syllable and a reduced vowel (or schwa) in the second syllable. In the experimental condition of this task the words were mispronounced.

There were four different types of manipulation, which affected the location of primary lexical stress and changed the nature of the vowels in the words. For instance, in one condition the metrical stress of the word was reversed so that the word *mirror* was pronounced more like *m'ROR* [mə'ɔ:]. In this condition, the metrical stress had been reversed so that the vowel in the first syllable became reduced and the vowel in the second syllable became fully articulated. It was thought that to identify the target word in this condition, children would need to be sensitive to the fact that the words had been mispronounced and that the stress was inaccurately placed. Researchers such as Chiat (1983) and Kitzen (2001) suggest that children need to be able to apply stress to unstressed syllables and that this skill helps to identify phonemes, which in turn, helps to decode words and match them to words stored in the mental lexicon. Wood found that only in this reversed metrical stress condition of the mispronunciations task was performance significantly related to reading development in typically developing beginning readers. These findings have been replicated by Holliman et al. (2008) who also administered the mispronunciations task from Wood (2006a) to beginning readers

and young children and also found that performance on this task was significantly related to reading development. Both of these studies assessed speech rhythm sensitivity in beginning readers and of young children (4, 5, and 6 year olds).

The stress mispronunciations task had some advantages; for instance, whilst some productive measures of speech rhythm (e.g. De Bree et al., 2006) are more complex and used unfamiliar words, the stress mispronunciations task was particularly useful for assessing receptive stress in young children because it was fairly simple, interesting to children, and theoretically sound. It enabled the researchers to work with pre-school children, which means that it had the potential to be used, with some refinement, as an early identification tool. However, to date no-one has assessed its usefulness as a tool for discriminating between young children at risk of reading failure and typical readers. Nor has its ability to predict reading ability over time been assessed.

There were some limitations to this task; for instance, there were not many distracter items in the house that began with the same initial letter and phoneme. Therefore, to solve this task, children might hold the initial letter sound in working memory and then through process of elimination identify the target item based on the fact that it shares the same initial sound (without necessarily manipulating the stress). Thus, more distracter items should have been included which began with the same initial letter and phoneme. Additionally, despite its relative simplicity, the task could also have been made even simpler. Having to hold a mispronounced word in working memory while trying to decode it and locate it from the picture of a house containing many items might have demanded memory skills which could have confounded the findings. Perhaps a more

simple measure e.g. choosing the correct item from four pictures would have been a more useful method that would have been less memory intensive, yet maintain the same theoretical premise and experimental manipulation of the original task. Lastly, Wood did not control for vocabulary in her analyses. It should be noted that it is important to control for vocabulary in studies investigating the relationship between speech rhythm and reading because vocabulary might mediate the link between spoken word recognition skills and reading development (Walley, 1993).

#### *Studies using 6 to 11-year-old children*

In Wood and Terrell's (1998b) study, a sentence matching task was developed, which assessed children's sensitivity to rhythm, stress, intonation, and the metrical characteristics of speech. Children heard a phrase through speakers that had been low-pass filtered so that the precise words could not be identified (leaving only the prosodic contour of the utterance). This filtered phrase contained a particular combination of strong and weak syllables (e.g. SWWSSS). This was followed by two sentences that had not been low-pass filtered, one of which matched the prosodic patterns of the low-pass filtered sentence (e.g. SWWSSS) and one of which differed by one syllable (e.g. SWWSSW). Children had to say which spoken phrase matched the low-pass filtered sentence. It was found that poor readers were outperformed by chronological-age matched controls on this task even after controlling for vocabulary.

One of the limitations of the sentence matching task was that it was quite memory intensive and given that children with reading difficulties often display short-term memory problems, this is an important confounding factor. In a similar study, Whalley

and Hansen (2006) used the DEEdee task (which was similar to the sentence matching task), which assessed rhythm, stress, intonation, and pause at the phrasal level. In this task, an original phrase (children's film or book title) was played through speakers (e.g. Cinderella) and this was followed by two Deedee phrases, one of which matched the prosodic pattern of the original phrase (e.g. DEEdeeDEEdee) and one of which did not (e.g. DEEdeedeeDEE). Children had to decide which Deedee phrase matched the original. In addition to this, the compound noun task was also used which assessed rhythm, stress, intonation, and pause at the word level. Children heard a word played through speakers (e.g. chocolate, cake and honey) and then had to select the picture which best went with what they had heard. For instance, using the example above they would see a picture containing three items (chocolate, cake and honey) and a picture containing two items (chocolate-cake, and honey). They had to select which picture best went with what they had heard based on prosodic information. Although both tasks were found to be related to reading, the Deedee task placed high demands on memory and vocabulary was not controlled for. Both the Wood and Terrell study and the Whalley and Hansen study used children aged 8 to 10-years-old. Given the noted demands on memory, these tasks (or tasks of this nature) may be too memory intensive for beginning readers and young children.

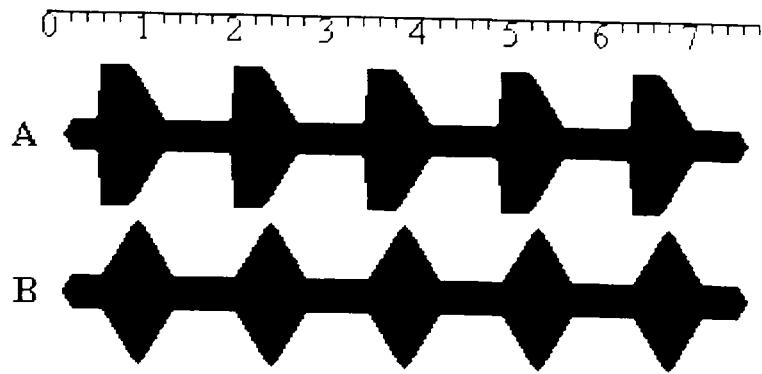
Using a similar paradigm to De Bree et al. (2006), Gutierrez-Palma & Reyes (2007) assessed speech rhythm by scoring children's pronunciation of non-words based on the accuracy of their stress placements. Gutierrez-Palma and Reyes investigated the relationship between stress sensitivity, stress assignment, reading and non-word reading in 7 to 8-year-old Spanish-speaking children. For the stress sensitivity task children

were presented with sequences of non-words containing stress contrasts (and phoneme contrasts) and had to press appropriate keys on the computer keyboard that corresponded to the sequence of non-word they had just heard. For the stress assignment task children had to read aloud a set of disyllabic non-words from a computer screen and the administrator scored the accuracy of their stress placement. It was found that speech rhythm sensitivity was related to reading. However, this study was not conducted in the English language, so we do not know whether such findings would extend to the English language. Additionally, due to the complexity of this measure (its productive nature and the fact that non-words were used), such a paradigm might be less appropriate for younger children.

Using a different technique, Schwanenflugel et al. (2004) and Ravid et al. (2007) both measured prosody by getting children aged 8, 9, and 10-years-old to read normal passages of text while seated with the administrator, audio recording them, and then later scoring their reading for prosodic accuracy (e.g. pitch, timing, pauses, intonation, and emphasis). Although links were found between speech rhythm and reading, this method of assessment might be less useful for beginning readers, young children, and children at risk of dyslexia, who are likely to have less well-developed reading skills, which, as a result, may inhibit the measurement of prosody.

In addition to these studies, Goswami et al. (2002) also assessed speech rhythm in a group of children (7 to 9-years-old) using an amplitude modulation/beat detection task. Children heard continuous sound sequences through headphones lasting 40 replications. Whilst the fall time of each beat was fixed at 350ms, the rise time could be manipulated

from 15ms to 300ms (see Figure 2.2).



**Figure 2.2 Example of the stimulus wave form for 15ms rise times (A) and 300ms rise times (B) adapted from Goswami et al. (2002)**

When the stimuli were presented with a rise time of 15ms, there was a clear beat, and this was presented as Tigger and Eeyore on a swing (with a beat when they get closer, which faded as they went away). When the stimuli were presented with a rise time of 300ms, there was no longer a clear beat and it sounded more like a continuous sound that varied in loudness. This was presented as Winnie the Pooh sliding down a spiral slide, getting either closer or further away; thus, the sound got continuously louder or quieter. Children heard sound sequences through headphones and had to match the rhythm to either ‘Winnie the Pooh’ or Tigger and Eeyore’. This task tapped into children’s sensitivity to beat detection (rise time). It was found that children with dyslexia were less consistent in their judgements on this task in comparison to their chronological-age matched counterparts, and performance on this task was able to account for 25% of the variance in reading and spelling, after controlling for age, non-verbal IQ, and vocabulary.

It should be noted that the ‘rise time’ paradigm has been adopted elsewhere. For instance, Thomson et al. (2006) and Richardson et al. (2004) used similar auditory

stimuli to Goswami et al. (2002). (e.g. participants heard a continuous sound sequence with 40 replications, where the fall time was 350ms and the rise time was either 15ms or 300ms). However, in these studies, each of the two rise times were assigned to a particular dinosaur and children (Richardson et al., 2004) or adults (Thomson et al., 2006) had to identify which of the two dinosaurs had the clearer, sharper beat. The answer of course should be the dinosaur (or sound sequence) with shorter rise times. In line with the findings from Goswami et al. (2002) dyslexics were significantly outperformed by their non-dyslexic counterparts on this task.

While this represents a very interesting paradigm, the rise time stimuli has not yet been used with beginning readers, so it remains unknown whether these findings would transfer, or whether this task is appropriate, for a sample of younger children. This task also assessed speech rhythm using non-speech stimuli (beats and tones) so it could be argued that this is more a measure of non-speech rhythm rather than speech rhythm, although there is likely to be a large degree of overlap between the two domains.

#### *Studies using 11+ children*

Kitzen (2001) investigated the relationship between speech rhythm and reading by comparing adults at risk of dyslexia, with adults not at risk of dyslexia. Speech rhythm was assessed at the phrasal and word level and focussed on rhythm, stress, intonation, and pause. Participants had to discriminate between two phrases: a noun phrase (e.g. hotrod) and a compound noun (e.g. hot-rod) which differed only in terms of their prosodic features. They also assessed speech rhythm using a task which involved matching a nonsense phrase to a correctly spoken phrase based on their prosodic features. The paradigm here, and the assessments used, inspired the aforementioned

Whalley and Hansen (2006) study. It was found that adults with a history of dyslexia were outperformed on these tasks by their counterparts without a history of dyslexia. This method of assessing speech rhythm has similar limitations to Whalley and Hansen's study in that it is quite a memory intensive task and vocabulary was not controlled in their analyses.

To summarise, there have been many different measures of speech rhythm, which have predominantly focussed on stress sensitivity, although other aspects have also been assessed such as pitch, timing, pause, and beat detection. Some of the noted measures are problematic for assessing speech rhythm sensitivity in beginning readers and young children based on their complexity and their use with older children. In fact, only Wood (2006a) and Holliman et al. (2008) have focussed on beginning readers and young children in the English language; this is the age-group of particular interest because this is the age at which children begin to read in the UK. Both of these studies used a stress mispronunciations task which was a useful tool, but had some notable disadvantages, which would need to be addressed if this kind of assessment was to be adopted. Based on the fact that the majority of studies in this review have focussed on stress sensitivity, the core speech rhythm component that will be focussed on in this thesis will be stress sensitivity, because this will enable a more direct comparison with the existing literature. Additionally, stress sensitivity seems to have many theoretical links with reading development, which provides a sound theoretical base for exploration, and these theoretical links can be empirically tested.



The second important methodological issue to consider concerns how to administer the measure. All of the speech rhythm tasks presented in Table 2.1 were administered by an administrator who sat with the child during assessment. This is typical for assessing children of this age because they require supervision for ethical reasons, but also to ensure that they complete the task successfully and are aware of what they need to do. It is also useful to assess children individually so that they do not get distracted or influenced by others. Lastly, the stimuli presented in the speech rhythm tasks noted in Table 2.1 were sounded through speakers using pre-recorded stimuli. This is important to ensure consistency in presentation.

As a result of this methodological review, a task was developed which measured children's sensitivity to, and manipulation of, stress in spoken words which had been mispronounced, based on the task from Wood (2006a) and Holliman et al. (2008). However, this revised task would have to overcome some of the notable limitations to the original task; it would need to be simpler so that it would be more appropriate for beginning readers and young children, and would also need to contain distracter items which began with the same initial letter sound and phoneme. To do this, the revised mispronunciations task was developed.

### **2.1.1. Development of The Revised 'Mispronunciations' Task**

This speech rhythm assessment was based upon the original mispronunciations task used by Wood (2006a) and Holliman et al. (2008) but was adapted to overcome some of the more problematic aspects of the task format. For instance, this task was simpler because children had to choose the correct item from a choice of four pictures, rather

than from a house containing many items. It also included more distracter items that began with the same letter and phoneme. To select the target items to be used in this task, nineteen words from the common lexicon of young children (one practice item and 18 test items) were selected from the children's printed words database (<http://www.essex.ac.uk/psychology/cpwd/>). In the baseline condition of this task, children were shown four pictures of two syllable words, each of which started with the same letter and sound, e.g. they would see pictures of a singer, skateboard, swordfish, and seagull (see Figure 2.3).

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After hearing the correctly pronounced word through a speaker, children had to identify which picture from the four provided went with the word they had heard. These correctly pronounced words were pre-recorded. The word frequency of the target and distracter items in the test were matched as closely as possible. All of the target words carried primary lexical stress on the first syllable, and the vowel in the second syllable was reduced (i.e. singer above).

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. This follows the same theoretical premise and experimental manipulation of the original task. For example, instead of the normal pronunciation of the word “singer” [ˈsɪŋə] it was pronounced “s`nger” [səŋˈɜː]. Children received one-point for each correct answer and an overall score out of 18 (as the first one was a practice trial) was obtained. To see the standardised instructions, stimuli, and scoring details for this task, see Appendix 1. To avoid order effects, the sequence of test conditions (baseline or experimental) was counterbalanced and were administered one week apart.

Using the sample of 102 children from Study One (discussed thoroughly in Chapter 3), the internal reliability of the experimental condition of this task was  $\alpha = 0.82$ .

Participants obtained a high mean score on the baseline condition of the revised mispronunciations task (17.57 from a possible 18) but a relatively low mean score was obtained on the stressed reversed condition of this task (12.55 from a possible 18) which

was expected. The difference between baseline and experimental conditions was significant,  $t(101) = 13.173, p < 0.001$ .

See Table 2.2 for a complete list of the target items and distracter items used in this task along with their word frequency per million and their phonetic transcription.

**Table 2.2 Phonetic transcription and word frequency per million for all target and distracter items**

Target Words and Freq	Phonetic Transcription	Stress Reversal Condition	Distracter Item 1 and Freq.	Distracter Item 2 and Freq.	Distracter Item 3 and Freq.
spider (93)	'spaɪdə	spə'dɜ:	swinging (83)	snowman (62)	sandwich (83)
baker (93)	'beɪkə	be'ɪkɜ:	beetles (83)	branches (93)	bottles (93)
barrel (10)	'bærəl	bə'rel	bracelet (10)	burglars (10)	ballet (10)
builder (21)	'bɪldə	bəl'dɜ:	blackbird (31)	biscuit (21)	bookcase (21)
butcher (41)	'bʊtʃə	bə'tʃɜ:	baseball (52)	badgers (31)	boiling (52)
butter (175)	'bʌtə	bə'tɜ:	breakfast (196)	bottle (186)	basket (186)
carrot (21)	'kærət	kə'rɒt	clipboard (10)	cutting (10)	camel (21)
cleaner (83)	'kli:nə	klə'nɜ:	crying (72)	counting (62)	cupboard (93)
cooker (31)	'kʊkə	kə'kɜ:	carrots (31)	cowboy (31)	crayons (31)
jumper (114)	'dʒʌmpə	dʒəm'pɜ:	jewels (114)	jolly (103)	jacket (93)
mirror (41)	'mɪrə	mə'rɜ:	married (41)	mushrooms (31)	marbles (52)
painter (21)	'peɪntə	pən'tɜ:	panda (31)	penguin (21)	peanuts (21)
parrot (83)	'pærət	pə'rɒt	pattern (72)	pumpkin (62)	pocket (62)
plaster (52)	'plɑ:stə	pləs'tɜ:	pencil (52)	penny (41)	pizza (41)
rubber (10)	'rʌbə	rə'bɜ:	rhino (31)	raining (10)	robot (21)
ruler (10)	'ru:lə	rə'lɜ:	rowing (10)	robin (31)	rainbow (21)
sailor (10)	'seɪlə	sə'lɜ:	swimmer (10)	smiling (10)	scarecrow (10)
singer (10)	'sɪŋə	sən'ɜ:	swordfish (10)	skateboard (10)	seagull (10)
tiger (52)	'taɪgə	tə'gɜ:	tissue (31)	tractor (31)	twenty (31)

*Notes:* The word frequencies in parentheses are per million.

There were however still at least two problems with this task which need to be addressed in any studies that employ it. The first, as noted, is that vocabulary might mediate the relationship between speech rhythm and spoken word recognition.

Vocabulary is particularly important in this study because children are shown pictures

in each trial and will have to identify words that go with each picture in order to solve this task. Although efforts were made to select items that were used with children of this age, all analyses using this task should include vocabulary as a control measure. This would eliminate any confounding effect accountable to vocabulary development and allow for a more conservative analysis. Secondly, there is still the possibility that children may use a phonological strategy to solve this task. It is not disputed 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, but efforts have been made to match the initial letter sound and phoneme to overcome this. However, to be conservative, all analyses including this task should also control for phonological awareness to eliminate this potential confound.

## **2.2. Recruitment and Ethical Considerations**

All of the studies included in this thesis were conducted in accordance with the British Psychological Society's Code of Conduct, Ethical Principles and Guidelines and all received ethical approval from the Open University Ethics Committee. Initial contact was established with the target school(s) through letter correspondence, which was followed by a telephone call and a meeting with the head teachers to provide a clear overview of the study whereby further queries could be answered. Parental consent letters were sent out after the head teacher had consented to take part and contact details were given to each parent to ensure that any issues could be discussed with the researcher. Children only took part in this study once informed consent had been obtained from the head teacher, the children's parents, and the children themselves.

Parents were given an information sheet outlining the reasoning behind the study and an overview of the assessment battery to be used. Every effort was made to guarantee that both the teachers and the parents had an understanding of the research study in question. Parental consent was obtained for each child from the parental consent form. Each child's behaviour during testing was monitored and any signs of discomfort or unwillingness to participate were acknowledged. It was made clear to the children and parents that participants had the right to discuss any feelings or personal matters that may have arisen during the course of study and that the children had the right to withdraw from the study at any point. If a child did not verbally express that they would like to withdraw from the session, but seemed to be expressing discomfort and unwillingness from their behaviour, the child was withdrawn from that session and returned to their class. Parents also had the right to withdraw their child or their child's data at any point.

Raw data were stored securely at all times, locked in a filing cabinet in a private room in the Open University to ensure security. Children's personal details were confidential and no data could be traced back to any individual child. This project was registered in accordance with the data protection act. The intentions underlying the study were clearly laid out. Contact details were given to the school and to parents to ensure that any unanswered questions could be addressed.

In these studies children were required to undergo a wide variety of cognitive assessments. The number of assessments was kept to a minimum within the study; children were often assessed on two or three separate occasions to overcome any

difficulties or lack of attention. Although each child was individually assessed in a quiet area within the school, it did not take place in a solitary area and was in view of their teacher. To avoid making the child feel like they had failed during the tasks they were given constant praise throughout and were handed reward stickers at the end of each assessment regardless of how well they actually performed. Once the data were obtained, the school received an account of the results of the study. Parents were also sent an overview of the results along with a debriefing that was sent via the schools. All individual scores, however, remained entirely confidential to the researcher. Contact details were left with the school to ensure that any concerned parent could still get in touch, even after the study had concluded.

### **2.3. Test Battery**

Many of the measures were used in multiple studies included in this thesis. Therefore to avoid repetition, all of the measures have been described in detail below and are only noted in passing later on in Chapters 3, 4, and 5. Note that all of the standardised baseline measures were administered in accordance with the instructions that accompanied each test. All of the assessments included in this thesis (apart from the speech rhythm assessments for which there is less literature) were selected because they are commonly used in the field and would allow for a more direct comparison with the literature.

#### *Vocabulary*

To provide a measure of receptive vocabulary, children were assessed using the British Picture Vocabulary Scales II (Dunn, Dunn, Whetton & Burley, 1997). Children heard a



word from the administrator and then had to select the picture which best illustrates that word from a choice of four possible pictures. As children progress through the test, the series of words become increasingly unfamiliar and the test is terminated when a child makes eight or more failures in a set of twelve. A total score for the number of correct answers is then obtained.

#### *Digit Span Test – Forward*

The digit span subtest from the British Ability Scales II (Elliot, Smith, & McUllock, 1996) was used to provide a measure of the children's short term memory ability. The administrator read some digits out loud (at a steady pace, dropping the voice on the final digit) and the child had to repeat the same digits in the correct order back to the administrator. Children received one point for every item correctly repeated and the test was discontinued if children made four or more errors in any block of five digit sequences. A total score from thirty-six test items was obtained.

#### *Rhyme Detection*

The rhyme detection subtest of the Phonological Assessment Battery (PhAB: Frederickson, Frith, & Reason, 1997) was used to provide a measure of the children's sensitivity to rhyme. Children heard three words from the administrator and then had to verbally identify the two rhyming words from the three provided e.g. of the words "made", "hide", and "fade" a correct response would be "made" and "fade". The task began with three practice items followed by up to twenty-one test items of increasing difficulty depending on their score in the first batch of rhyming words. Children received corrective feedback during the practice items, but no feedback was provided

during the test items. Children received one point for each pair of words named correctly and children only progressed onto the second batch of rhyming words if they correctly identified nine or more rhyming words from the first batch of twelve.

### *Phoneme Deletion*

This phoneme deletion assessment was taken from Wood (1999). Children heard a word spoken by the administrator and then had to repeat the word back to the administrator, but without either the first or last phoneme. In one subtest the first phoneme was deleted e.g. ‘try to say “car” without the /k/ sound’ and the answer would be “are”. In the other subtest the last phoneme was deleted e.g. the word “went” would become “when”. Prior to testing it was ensured that all children understood the concepts of ‘first’ and ‘last’. To check this they were shown the following diagram and were asked to point at the person in ‘first place’ and the person in ‘last place’ (see Figure 2.4). For each subtest, four practice items were followed by the twelve test items and the subtests were always presented in a counterbalanced order. Children received corrective feedback during the practice items, but no feedback was provided during the test items. Children received one point for each correct deletion made and a total score out of twenty-four was obtained. To see the instructions and the items for this task, see Appendix 2.

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task. There were six categories of error: mispronunciations (words that are only partially decoded), substitutions (other words used instead of the true word), refusals (unable to attempt a word), additions (other words inserted), omissions (words omitted from the text), and reversals ('no' for 'on' for example). 'Refusals' and 'omission' were recorded at the time of reading, but the other categories of error were identified afterwards using the audio recording. Children received one point for every error made and the time it took to read the passage was also recorded. The z-scores for errors and time taken to read the passage were calculated and added together to obtain a composite fluency score.

### *Reading Fluency # 2*

Due to the criticisms surrounding the rate-per-minute measure of reading fluency, another measurement of fluency was taken which incorporated aspects of expression and prosody. The Multidimensional Fluency Scale, based on Zutell and Rasinski (1991) and used by Sargent (2004) was employed to obtain a fluency score based on phrasing (stress, intonation, expression), smoothness (pauses, hesitations, structure), and pace (slow, fast, conversation speed). In line with the guidance provided with this task, a reading passage was chosen that was well within the range of reading ability in the sample, thus helping to isolate the fluency component of this task. The audio recordings from the first passage of the NEALE were chosen for analysis because children would be more likely to be able to read this passage, thus isolating the fluency component of this task. The scorer listened to each passage a number of times and then assigned a score of 1-4 for each category of fluency (phrasing, smoothness, and pace). These scores were used individually, but could also be combined to obtain a total fluency

score out of twelve, where a higher score would indicate more proficient reading fluency. To see the standardised instructions and scoring details for this task, see Appendix 3.

### *Reading Accuracy*

Reading accuracy was measured using the Revised Neale Analysis of Reading Ability (Neale, 1997) and was used to see how well children identify words within a passage of text. Following a practice passage, children were required to read up to six passages depending on the number of errors made (e.g. mispronunciations, substitutions, refusals, additions, omissions, or reversals) as quickly and as accurately as possible. The passages became increasingly difficult to read as children progressed through the test. If a child made sixteen or more errors in the first five passages or twenty errors in the sixth passage, the test was terminated and the scores for that particular passage were not included in the calculations. Children received one-point for every word read out loud correctly.

### *Reading Comprehension*

Reading comprehension was also measured using the Revised Neale Analysis of Reading Ability (Neale, 1997) and as before, the administration details of this task followed those described above for reading accuracy. However, at the end of each passage, where the child had not exceeded the number of errors, they were asked some open-ended questions about what they had just read. There were four comprehension questions for the first passage and eight comprehension questions for the remaining passages, which made the total possible reading comprehension score out of forty-four.

### *Non-word Reading*

Non-word reading was assessed using the non-word reading test from the Phonological Assessment Battery (Frederickson et al., 1997). Children had to decode and then accurately read out loud as many non-words, e.g. “fot” as they could to the administrator. Following three practice items there were up to twenty test items (two blocks of ten) and the test was terminated if there were six or more failures in any one block and a score out of twenty was obtained.

### *Spelling*

Spelling ability was measured using the British Ability Scales II spelling subtest (Elliot et al., 1996). Children had to write down and try to spell each of the words read out loud by the administrator. The words became increasingly difficult as children progressed through the test. The test was terminated if children made eight or more errors in any one block of ten words and a total score was obtained by adding up the number of correctly spelled words.

### *Non-speech Rhythm Tasks (overview)*

The following two non-speech rhythm tasks (Rhythm Copying Task and Rhythm Matching Task) were based broadly on the research by Overy et al. (2003). A program called ‘rhythms’ was developed to assess how well children could copy rhythms and how well they could discriminate between rhythms. See Appendix 4 for the programming manual and a detailed description for each of these tasks.

*Non-speech Rhythm Tasks: Rhythm Copying*

This productive assessment provided a measure of children's non-speech rhythm skills using one form of musical aptitude test based on that used by Overy et al. (2003).

Children were seated at a laptop computer and were played a short rhythm twice over headphones, with particular time intervals between beeps. They were then required to copy this sequence as accurately as possible using the spacebar on the keyboard to represent beeps. The computer measured the time interval between each of their copied beeps and if this interval was within 20% of the true time interval they scored that time interval correctly and received one point. Following a fairly simple practice trial, the test trials were repeated at an increasing level of difficulty, with rhythms ranging from two to seven beeps in duration. There were a total of twenty-one time intervals so children obtained a score out of the twenty-one on this task.

*Non-speech Rhythm Tasks: Rhythm Matching*

This receptive assessment, also based on Overy et al. (2003), provided a measure of children's non-speech rhythm skills using another form of musical aptitude test.

Children were seated at a computer and were played two sets of rhythms over headphones. They had to decide whether the second rhythm matched the first, by saying either "same" or "different" so that the administrator could select the appropriate option on the computer screen. Children received one point for each rhythm correctly identified as "same" or "different". Following a fairly simple practice trial, the trials were repeated at an increasing level of difficulty, with rhythms ranging from two to seven beeps. There were a total of twelve test trials so children obtained a score out of twelve on this task.

*The Original 'Mispronunciations' Task*

This speech rhythm sensitivity assessment was slightly adapted from Wood (2006a) to include one additional target household item (jumper). It was first checked that children could accurately identify seventeen common words from a line drawing of a cartoon house by pointing to the correct picture: this was the baseline score. All of the objects had two syllables and carried primary lexical stress on the first syllable, and a reduced vowel in the second syllable (i.e. sofa). In the experimental condition of this task, 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 “parrot” (‘pærət) it was pronounced /pə’rɒt/. Following one practice item, an overall score out of sixteen was obtained. In terms of presentation, the correctly pronounced words and the mispronounced words were recorded beforehand and were then played through a speaker to children during this task. To see the stimuli for this task, see Appendix 5. This reason for including the original mispronunciations task, in addition to revised version of this task for Study One is as follows: we felt that it was important to include both tasks (the original and the revised task) to see whether the revised version of this task followed the trend of the original with respect to the other measures used in this study. We also wanted to ensure that there was a strong, significant relationship between the two measures to enable us to treat the data from studies using the original mispronunciations task and the revised mispronunciations task as comparable.



*The DEEdee Task*

To assess speech rhythm sensitivity at the phrasal level, the DEEdee task from Whalley and Hansen (2006) was used (see Whalley & Hansen for a detailed description of this task). Children heard a pre-recorded phrase through a speaker, which took the form of a cartoon title (e.g. “The Simpsons”). This was followed by two Deedee phrases, one of which retained the prosodic structure of the original phrase and one of which did not and children had to indicate which of the two phrases matched the original phrase (e.g. for “The Simpsons” example above, “deeDEEdee” would be a correct answer and “DEEdeeDEE” would be an incorrect answer). To solve this task, children had to be sensitive to the prosodic features of speech and non-speech sounds and the nature of this task eliminated the potential of phonemic information. Following two practice items, there were eighteen test items, so children obtained a score out of eighteen. To see the stimuli for this task, see Appendix 6.

*The Compound Noun Task*

To assess speech rhythm sensitivity at the word level, the compound noun task from Whalley and Hansen (2006) was used (see Whalley & Hansen for a detailed description of this task). Children heard either a compound noun (e.g. bow-tie and shoes) or a noun phrases (e.g. bow, tie and shoes) sounded through a speaker and then had to select the appropriate graphic which corresponded with the words from a choice of two pictures available. For example, for the test item “bow-tie and shoes”, the graphic with two items (e.g. a bow-tie and shoes) would be the correct answer and the graphic with three items (e.g. a bow, tie, and shoes) would be the incorrect response. To solve this task, children had to be sensitive to the prosodic features of the words and use this sensitivity

to discriminate between compound nouns and noun phrases. Both the compound noun and noun phrase scenarios were used throughout the task and there were twenty test items altogether; thus, children obtained a score out of twenty. To see the stimuli for this task, see Appendix 7.

### *The Aural Suffix Judgment Task*

Another measure of speech rhythm was obtained from the aural suffix judgment task (Wade-Woolley, 2007). In this task, children heard a non-word through a computer speaker in isolation, and then heard this word in a sentence (e.g. Prethur, the Prethur book was in the library). Children then heard this non-word (e.g. Prethur) in a larger word (e.g. prethurity) in a different sentence (e.g. I read up on Prethurity). The word “prethurity” was spoken in two different ways in this sentence, one of which placed the stress on the first syllable (e.g. I read up on PREthurity) and one of which placed the stress on the syllable before the suffix (e.g. I read up on preTHURity). Children had to indicate which way sounded better in the sentence provided from the two sounds available. To solve this task, children had to be sensitive to stress and morphological rules because in decoding multisyllabic words stress rules become very important because depending on the suffix of that word, the location of stress can change. For example, in English, for words ending in “ity” there is a stress shift to the syllable immediately before the suffix (e.g. ACTIVE would become acTIVity, SENSitive would become sensiTIVity, and with relation to the test item above, prethur would become preTHURity and not PREthurity). Following two practice items, there were fifteen test items. Although there were originally thirty test items, only the first fifteen items were

chosen to indicate ability on this task in order to minimise the length of testing period with these children. To see the stimuli for this task, see Appendix 8.

### *The Stress Assignment Task*

A further measure of speech rhythm was obtained from the stress assignment task (Wade-Woolley, 2007). In this task, children heard a single word through a speaker (e.g. direct). They then had to repeat this word out loud and then clap on the part of the word with the strongest beat (the stressed syllable). For example, in the word “direct”, which can be split into two syllables, a clap on the “rect” part of this word would be a correct response because this is where the stress falls in the normal pronunciation of this word. Similar to the aural suffix judgement task, there were originally thirty test items in the stress assignment task, but to minimise the length of testing period, only the first fifteen items were chosen to indicate ability on this task following the two practice items. To see the stimuli for this task, see Appendix 9.

All of the assessments included in this thesis have now been presented. To see which assessments were used in each of the three studies included in this thesis, see Table 2.3.

**Table 2.3 A summary of the test battery used in the three studies included in this thesis**

Tasks	Study One	Study Two	Study Three
Original mispronunciations task	✓		
Revised Mispronunciations Task	✓		✓
Deedee task			✓
Compound Nouns Task			✓
Aural Suffix Judgement Task			✓
Stress Assignment Task			✓
Rhythm Copying (NSR)	✓		
Rhythm Matching (NSR)	✓		
Digit Span Test	✓		✓
Vocabulary (BPVS)	✓		✓
Phoneme Deletion Task	✓	✓	✓
Rhyme Detection Task	✓	✓	✓
BAS Word Reading	✓	✓	✓
Non-word Reading		✓	
BAS Spelling		✓	
Reading Accuracy		✓	
Reading Comprehension		✓	
Fluency: Phrasing		✓	
Fluency: Smoothness		✓	
Fluency: Pace		✓	
Fluency (NEALE) shortened version	✓		

## 2.4. Computer Equipment

For all of the tasks involving a computer a ‘Dell Inspiron 6400’ laptop was used, which had a 1.73 GHz processor. It had 1014MB RAM and used Windows Vista Home Premium (6.0, Build 6000) as the operating system. The screen size was 21cm in height and 33cm in width. This laptop was also used to record children’s voices for later scoring, although an additional microphone was required for clarity.

## 2.5. Summary

The aim of this chapter was to provide an overview of the possible methodologies that might be used to assess speech rhythm sensitivity in children. Using theoretical and

empirical evidence from the literature, a rationale was developed for the design of the core speech rhythm measure (the revised mispronunciations task) to be used in this thesis. This was followed by a description of this speech rhythm measure and the other measures that were employed in the three experimental studies in this thesis, along with a brief description of ethical considerations. The thesis will now report the three empirical studies that were carried out to investigate the role of speech rhythm sensitivity in children's reading development.

## **Chapter 3 - Study One: The Contribution of Sensitivity to Speech Rhythm and Non-Speech Rhythm to Early Reading Development**

### **3.1. Introduction**

The theoretical overview (Chapter 1) outlined that one of the aims of this thesis was to investigate how speech rhythm sensitivity is related to non-speech rhythm, phonological awareness and reading, and this was explored in this study.

Despite the well-documented link between phonological awareness and reading ability, the fact remains that phonological awareness does not account for all the variation in children's reading ability. It is also possible that phonological awareness deficits may be secondary to another underlying deficit which occurs earlier on in child development (Chiappe et al., 2002). Several lines of enquiry have investigated which other factors can account for the remaining variance in reading that is not accounted for by phonological awareness. Other research has also explored phonological awareness deficits in reading disabled populations by focussing upon the skills that precede its development.

#### *Speech Perception, Spoken Word Recognition and Speech Rhythm*

Earlier on in child development, before the emergence of any kind of reading ability, an infant must first learn to perceive speech and elements within the speech stream (Harley, 1995). According to Wood and Terrell (1998) an infant faces the inevitable problem of distinguishing units of meaning within speech because it is continuous with

few audible pauses between words. In order to access the meaning of a word in fluent speech an infant must first identify where each word begins. Cutler (1994) proposed that in order to achieve this, infants become attuned to the prosodic features of speech and language. Evidence suggests that strong syllables are a good indicator of word and segmental boundaries in spoken language in English (e.g. Cutler & Carter, 1987), and Cutler and Norris (1988) therefore suggest that a 'look-up' process is started at each strong syllable, which stops when the longest word consistent with the speech input is identified.

#### *Speech Rhythm, Reading and Phonological Awareness*

There is evidence of a spoken word recognition deficit in children with reading difficulties (e.g. Metsala, 1997), and Wood and Terrell (1998b) explored whether this deficit is linked to speech rhythm insensitivity. They found that children with reading difficulties performed significantly worse on a measure of speech rhythm than their age-matched controls even after accounting for differences in vocabulary. In a follow-up to this, Wood (2006b) found that speech rhythm sensitivity accounted for a significant amount of variance in phoneme deletion, rhyme detection, and reading ability; therefore it was not only predictive of reading, but it was also predictive of phonological awareness.

In addition to this, Wood (2006a) used a 'mispronunciations task' to investigate whether beginning readers could recover the correct stress allocation from a mispronounced word and accurately identify the corresponding object from a line drawing of a house. Wood found that performance on the 'reversed metrical stress' condition of this task (in

which the stress pattern and reduced vowel location in the two syllable words was swapped, such that a word like 'SOfa' was pronounced as 's`FAR') was the only word manipulation that was significantly associated with reading attainment in typically developing beginning readers. It was also found that this measure of speech rhythm sensitivity could account for a significant amount of variance in early spelling ability after phonological awareness has been accounted for. To explain such findings, Wood argued, in accordance with Chiat (1983), that perhaps the identification of phonemes could be enhanced by the manipulation and application of stress to unstressed syllables in speech. This was supported by Kitzen (2001) who argued that readers need to be capable of making stress placement shifts in mispronounced words, and that children with dyslexia have more difficulty with this. It was further suggested that as the peak of loudness in a syllable corresponds to vowel location, sensitivity to the stress in spoken language may facilitate the identification of onset-rime boundaries. Indeed, many studies have demonstrated that poor readers are less sensitive to beats (rise time) in comparison to those without reading difficulties (Goswami et al., 2002; Corriveau et al., 2007; Muneaux et al., 2004; Thomson et al., 2006). However, this study only included 31 beginning readers, which is a fairly small sample size and thus, results should perhaps be treated with caution, although a more recent study by Holliman et al. (2008) including a larger sample size replicated these findings. This finding is consistent with other studies that have demonstrated an association between speech rhythm and reading development (e.g. Wood 2006b; Kitzen, 2001; Whalley & Hansen, 2006; De Bree et al., 2006; Goswami et al., 2002; Gutierrez-Palma & Reyes, 2007).



*Speech Rhythm and Non-Speech Rhythm*

There seems to be a link emerging from the literature between prosody (in particular stress sensitivity) and reading even after accounting for individual differences in phonological awareness. However, it should be noted that there is already a literature linking non-speech rhythm to reading proficiency. For instance, Overy (2000) found that children with a strong risk of reading difficulties were outperformed on a variety of musical aptitude tests (especially on the rhythm copying task) by children that were not at risk of reading difficulties. Moreover, Overy et al. (2003) administered a rhythm copying task, a rhythm discriminations task, and a song rhythm task to 15 dyslexic boys and 11 control boys and found that the dyslexic group scored lower on all measures of non-speech rhythm. Such non-speech rhythm deficits in dyslexics have been found in other studies (Thomson & Goswami, 2008; Thomson et al., 2006; David et al., 2007; Wolff, 2002).

Non-speech rhythm deficits have most commonly been attributed to deficits in processing temporal information such as duration, sequencing, and rhythm perception among other temporal aspects, although it should be noted that the relationship between the temporal processing deficit hypothesis and reading is controversial and has been disputed in the literature (Chiappe et al., 2002; Bretherton & Holmes, 2003). While research has linked non-speech rhythm to reading it remains unknown as to whether speech rhythm and non-speech rhythm are related components of the same underlying skill. It is conceivable that speech rhythm, in addition to non-speech rhythm could be explained by a deficit in processing temporal information.

Only a handful of studies have investigated whether speech and non-speech rhythm may be related components of the same skill. Patel et al. (1998) and Wolff (2002) have noted that speech rhythm and non-speech (or musical) rhythm share a number of characteristics (e.g. pitch, duration, and intensity), so links between them seem plausible. Indeed, performance similarity across domains has been demonstrated (Wolff, 2002; Patel et al., 1998), although in Patel et al. (1998) there were many confounding factors, such that the findings should be treated with caution: for instance, the study only included two participants and both participants had a clinically diagnosed musical deficit (amusia) so it is not known whether these findings would generalise beyond this population. An additional problem with this study was that it was conducted in the French language, which is syllable-timed and thus, we do not know whether these findings would be replicated in the English language, which is stress-timed. Moreover, Patel (1998) found similar ERP for the syntactic processing of language and music suggesting a common set of overlapping neurons. However, the sample consisted of musically gifted individuals with years of experience, so it remains unknown whether the findings will translate to non-expert musicians. Also, linguistic syntax was measured rather than speech rhythm explicitly, so we do not know whether the findings would be replicated if a purely prosodic (speech rhythm) task was used. Incidentally, the neurological literature does not support the idea that speech rhythm and non-speech rhythm are related components (Peretz, 1993; McMullen & Saffran, 2004).

### *Rationale*

Despite the growing amount of literature linking sensitivity to the prosodic features of speech (such as stress) to the development of reading, further research is warranted as

we currently do not know whether speech rhythm sensitivity is related to non-speech rhythm sensitivity and whether speech rhythm can predict unique variance in reading beyond its relationship with non-speech rhythm. Many of the studies reviewed in Chapter 1 found that prosodic sensitivity is predictive of reading even after phonological awareness has been accounted for and this suggests that prosody is not merely related to reading via the anticipated mechanisms of phonological awareness. There has been speculation that prosody may be related to reading in a similar way to musical, or non-speech rhythm. This has been suggested by Wolff (2002) and has been partially demonstrated in the studies by Patel (1998) and Patel et al. (1998). However, these studies were subject to methodological flaws and the findings were also not in line with the neurological literature (Peretz, 1993; McMullen & Saffran, 2004). A study investigating the relationship between speech rhythm, non-speech rhythm, phonological awareness and reading in typically developing children is necessary to inform the debate because no study to date has sufficiently investigated this.

In the current study, in addition to the various reading and phonological awareness assessments, two measures of speech rhythm were used: the mispronunciations task used in Holliman et al. (2008) and the revised version of the mispronunciations task described in Chapter 2. This study therefore aims to overcome some of the limitations in the Wood (2006a) and Holliman et al. (2008) study, as the revised mispronunciations task was simpler, included more distracter items with the same initial letter and phoneme, and a digit span test was administered to control for short-term memory. This study also employed a test of non-speech rhythm using the rhythm copying task, which

required children to reproduce a rhythm previously sounded, which should tap into temporal processing ability.

This study will help to answer the following three major research questions:

1. Is there a significant relationship between sensitivity to speech rhythm and sensitivity to non-speech rhythm?
2. Can sensitivity to speech rhythm predict a significant amount of variance in reading attainment after non-speech rhythm and phonological awareness have been taken into account?
3. Can non-speech rhythm predict a significant amount of variance in reading attainment after speech rhythm sensitivity and phonological awareness have been taken into account?

It was predicted, based on Patel et al. (1998), Patel (1998), and Wolff (2002) that there would be a significant, positive correlation between performance on the speech rhythm tasks and performance on the non-speech rhythm task. While the processing of speech rhythm has been linked with non-speech rhythm and phonological processing in the literature, based on Wood (2006a), Whalley and Hansen (2006), and Holliman et al. (2008) which emphasised the uniqueness of speech rhythm sensitivity in children's reading development, it was predicted that performance on the speech rhythm task would be able to account for a significant amount of unique variance in reading after controlling for non-speech rhythm and phonological awareness. Lastly, given the noted links between temporal processing and phonological processing (e.g. Farmer & Klein, 1995) along with the links between the processing of speech rhythm and non-speech

rhythm. and due to the fact that there is a lack of empirical research investigating whether non-speech rhythm can predict reading after controlling for both phonological awareness and speech rhythm, a conservative prediction was that non-speech rhythm would be unable to predict unique variance in reading after controlling for speech rhythm and phonological awareness.

## **3.2. Method**

### **3.2.1. Participants**

All participants in this study ( $n = 102$ ) were recruited from two combined schools in Buckinghamshire, UK, in the year 2006. The two schools were comparable in terms of their locality, number of students, age range, academic achievement as judged by their average point score on English, Mathematics, and Science, and on the number of pupils with SEN. Children were aged between 5 and 7-years-old (mean age = 6;7) and were in either Reception ( $n = 4$ ), Year-One ( $n = 57$ ), or Year-Two ( $n = 41$ ) classes. Forty-six children were female and fifty-six were male. The mean standardised vocabulary score of the sample was 101.48 ( $SD = 10.33$ ), and the mean word reading score was 29.82 ( $SD = 20.81$ ), which equates to a reading age equivalent of 7;1. All participants were approached to participate only once both their parents and head-teachers had given their consent.

### **3.2.2. Materials**

The following assessments were used in this study:

- The original mispronunciations task

- The revised mispronunciations task
- Vocabulary (BPVS)
- Phoneme deletion
- Rhyme detection
- Fluency (a shortened version from NARA)
- Rhythm copying
- Rhythm matching
- Word reading

Details of these measures can be found in the Methodology Chapter. These assessments were administered over three sessions to minimise the length of testing period in a quasi-randomised order, that is, the three batches always included either; rhythm copying and rhythm matching, or the original mispronunciations task, vocabulary and rhyme detection, or the revised mispronunciations task, phoneme deletion and fluency. However, the order of batches was randomised, and the order of tasks within each batch was randomised. Participants performed individually and were sat on a chair next to the researcher at a table.

### **3.3. Results**

This section begins with a description of the internal reliability for each of the speech and non-speech rhythm measures used in this study and a comment regarding the inter-rater reliability of the fluency measure. It then presents summary statistics (mean and standard deviation) for each measure, along with a correlation matrix including each of the assessments in this study. This is followed by a series of hierarchical regressions to assess whether speech and non-speech rhythm sensitivity can predict unique variance in

reading after controlling for other variables. A factor analysis is then presented to assess the extent to which the various measures used in this study are tapping into the same skill.

Based on this sample of children, the internal reliability of items used in the rhythm copying task was  $\alpha = 0.602$ , which was acceptable. The internal reliability of items used in the rhythm matching task was  $\alpha = 0.193$ , which was so low that this task was not included in the final analysis (for additional analyses and considerations as to why this test had such poor internal reliability, see Appendix 10). The internal reliability of items used in the original MSS task was good,  $\alpha = 0.87$ , and the internal reliability of items used in the revised MSS task was also good,  $\alpha = 0.82$ . The audio recordings were also scored for reading errors by an independent researcher so that inter-rater reliability could be calculated. A significant positive relationship was found between the researcher's error scores and the independent researcher's scores ( $r = 0.999$ ,  $n = 102$ ,  $p < 0.001$ ). It should be noted that three participants did not attempt the fluency task because it seemed too daunting, so their fluency scores were not included in the final analysis.

Table 3.1 shows the mean scores that the children obtained for each of the assessments in this study.

**Table 3.1 Summary statistics for children on all measures used in this study**

Task	Mean	Std. Deviation
Original Mispronunciations task baseline / 16	15.58	0.67
Original Mispronunciations task experimental / 16	9.69	4.06
Revised Mispronunciations task baseline / 18	17.57	0.68
Revised Mispronunciations task experimental / 18	12.55	3.92
Rhythm Copying / 21	9.24	3.86
Rhythm matching / 12	7.49	1.82
Word Reading / 90	29.82	20.81
Rhyme Detection / 21	10.91	6.79
Phoneme Deletion / 24	11.75	8.2
Digit Span / 36	18.16	3.87

It can be seen from Table 3.1 that participants scored in the middle range on both of the phonological awareness measures (the phoneme deletion task and the rhyme detection task) and the rhythm copying task. It can also be seen that while participants obtained a high mean score on the baseline condition of the original mispronunciations task (15.58 from a possible 16) a relatively low mean score was obtained on the stressed reversed condition of this task (9.69 from a possible 16). This difference between baseline and experimental conditions was significant,  $t(101) = 15.484, p < 0.001$ . Similarly, while participants obtained a high mean score on the baseline condition of the revised mispronunciations task (17.57 from a possible 18) a relatively low mean score was obtained on the stressed reversed condition of this task (12.55 from a possible 18) which was also expected. The difference between baseline and experimental conditions was significant,  $t(101) = 13.173, p < 0.001$ .

Table 3.2 shows the correlation matrix for all the variables included in this study.



**Table 3.2 Correlation matrix between age, reading, phonological awareness, speech rhythm, and non-speech rhythm**

Variables	1	2	3	4	5	6	7	8	9	10
1. Age										
2. BAS Read	.59***									
3. Fluency	.39***	.73***								
4. Digit Span	.26**	.41***	.35***							
5. Vocab	.51***	.51***	.25*	.37***						
6. Rhyme	.40***	.69***	.53***	.54***	.59***					
7. Phoneme	.54***	.76***	.67***	.37***	.45***	.69***				
8. Rev Misp	.43***	.63***	.48***	.36***	.40***	.56***	.54***			
9. Orig Misp	.45***	.62***	.59***	.39***	.30**	.57***	.55***	.58***		
10. RhythmC	.23*	.31**	.33**	.34**	.34**	.34**	.32**	.17	.16	
11. RhythmM	.22*	.46***	-.37***	.39***	.32**	.35***	.44***	.36***	.3**	.19

Notes: Age, Age; BAS Read, BAS word reading subtest; Fluency, Reading fluency from the NARA; Digit Span, BAS digit span subtest; Vocab, Vocabulary; Rhyme, Rhyme detection task; Phoneme, Phoneme deletion task; Rev Misp, Revised mispronunciations task; Orig Misp, Original mispronunciations task; RhythmC, Rhythm copying task (N-SR); RhythmM, Rhythm matching task (N-SR)

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

It can be seen from Table 3.2 that the revised stress mispronunciations task was strongly correlated with word reading ( $r = 0.63$ ,  $p < 0.001$ ) and was found to be significantly correlated with reading fluency ( $r = 0.48$ ,  $p < 0.001$ ) and the phonological awareness measures (rhyme  $r = 0.56$ ,  $p < 0.001$  and phoneme deletion  $r = 0.54$ ,  $p < 0.001$ ). This was not surprising given the growing amount of evidence linking speech rhythm to phonological awareness and reading ability. The revised stress mispronunciations task was found to be correlated with the original stress mispronunciations task ( $r = 0.58$ ,  $p < 0.001$ ) as expected. Furthermore, the revised mispronunciations task was not significantly correlated with the non-speech rhythm measure ( $r = 0.17$ ,  $p = 0.095$ ), which is suggestive of a lack of similarity between speech rhythm and non-speech rhythm using the tasks in this study. There was a strong positive relationship between the phonological awareness measures and the reading-related measures used in this study, which was also anticipated given the well-documented link between these skills.

Note that in the following three regression analyses speech rhythm sensitivity was measured using the revised mispronunciations task. Also, a composite measure of phonological awareness was constructed by obtaining z-scores for each of the two phonological awareness measures (the phoneme deletion task and the rhyme detection task) and then adding these scores together. Preliminary analyses were conducted to ensure that the data met the assumptions for a hierarchical regression analysis. The sample size was adequate, there was no evidence of multicollinearity, there were no outliers, and there were no violations to the assumptions of normality, linearity, homoscedasticity, and independence of residuals.

In the first exploratory analysis, a hierarchical regression was conducted to see whether speech rhythm sensitivity could account for a significant amount of the variance in reading attainment (using the BAS word reading subtest) after controlling for phonological awareness and non-speech rhythm. The results are depicted in Figure 3.1.

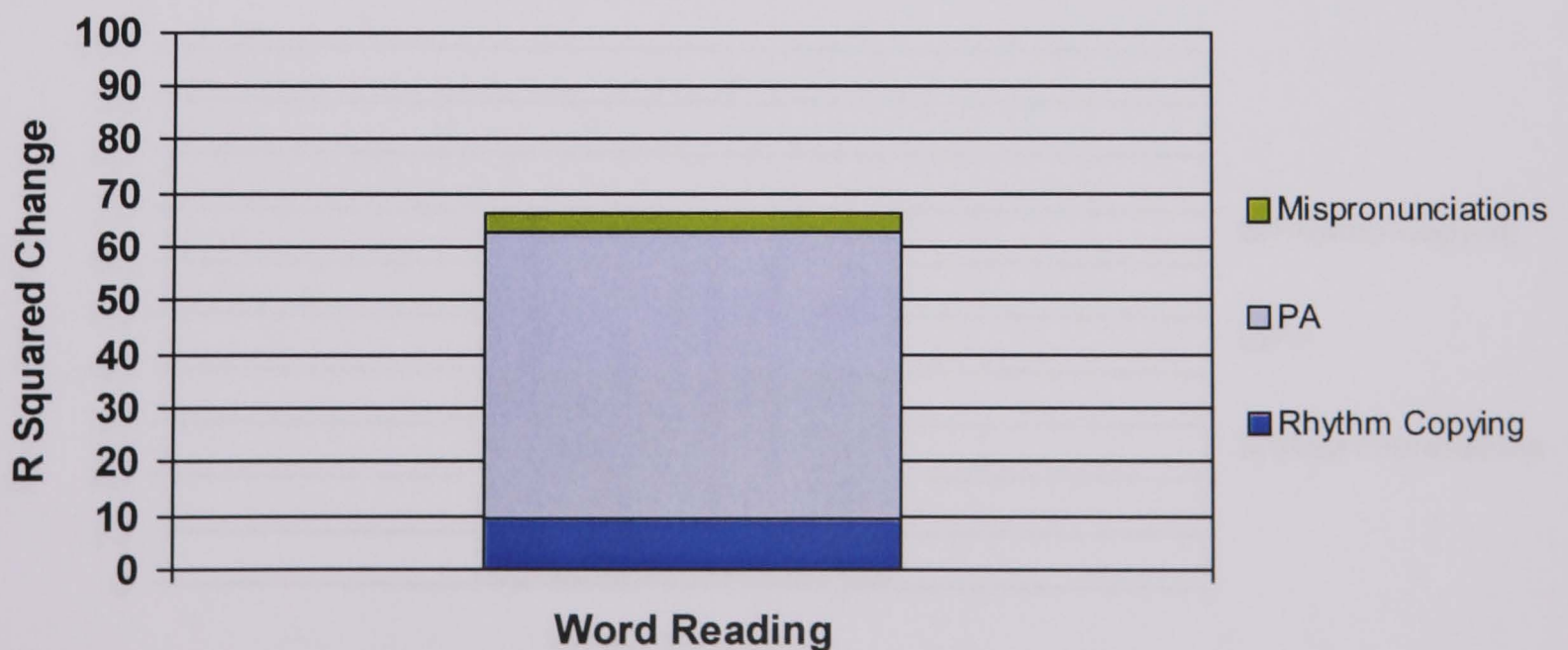


Figure 3.1 The amount of variance in word reading accounted for by rhythm copying (NSR), PA, and the mispronunciations task (SR)

The results from the regression analysis showed that non-speech rhythm was able to account for 9.5 percent of the variance in reading attainment when entered at the first step,  $R^2$  change = 0.095,  $F(1, 100) = 10.496$ ,  $p = 0.002$ . Phonological awareness was able to account for an additional 53.1 percent of the variance in reading attainment,  $R^2$  change = 0.531,  $F(1, 99) = 140.438$ ,  $p < 0.001$ . However, speech rhythm sensitivity accounted for a further 3.9 percent of the variance in reading attainment,  $R^2$  change = 0.039,  $F(1, 98) = 11.335$ ,  $p = 0.001$ . Thus, performance on the revised mispronunciations task was able to predict a significant amount of unique variance in reading attainment after both non-speech rhythm and phonological awareness had been taken into account.

In the second exploratory analysis, a hierarchical regression was conducted to see whether non-speech rhythm could account for a significant amount of the variance in reading attainment after phonological awareness and speech rhythm sensitivity had been accounted for. The results of this are graphically depicted in Figure 3.2.

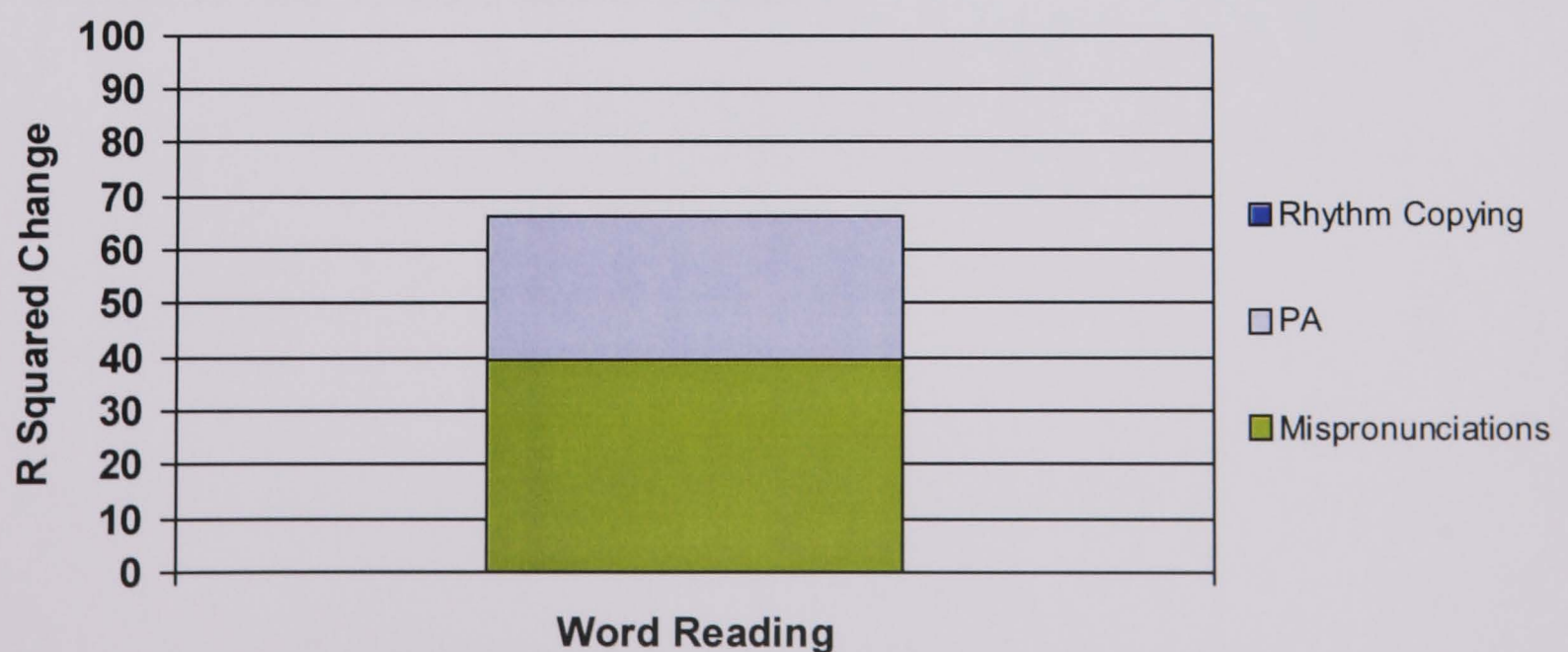


Figure 3.2 The amount of variance in reading accounted for by the mispronunciations task (SR), PA, and rhythm copying (NSR)

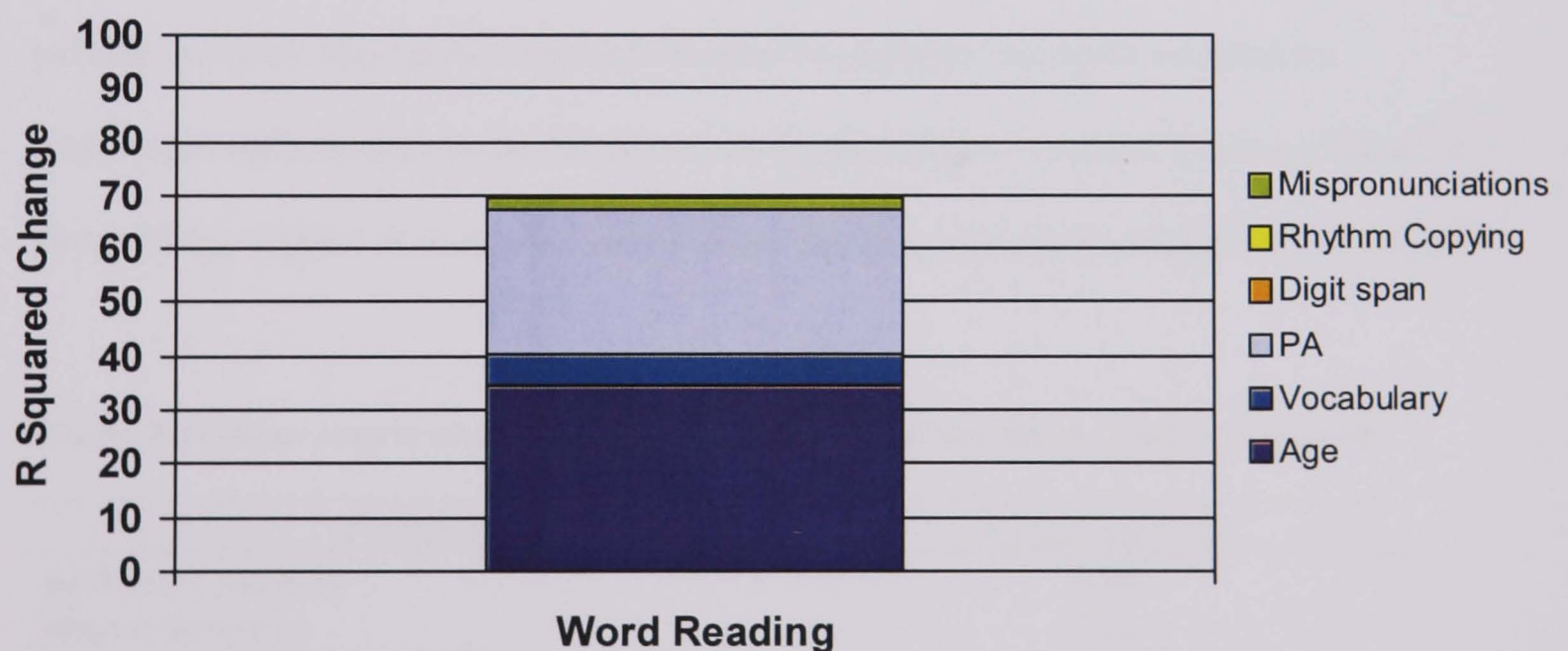
Speech rhythm sensitivity, when entered at the first step, was able to account for 39.5 percent of the variance in reading attainment.  $R^2$  change = 0.395.  $F(1, 100) = 65.267$ ,  $p < 0.001$ . Phonological awareness was able to account for an additional 26.8 percent of the variance in reading attainment,  $R^2$  change = 0.268.  $F(1, 99) = 78.731$ ,  $p < 0.001$ . However, non-speech rhythm only accounted for an additional 0.2 percent of the variance in reading attainment,  $R^2$  change = 0.002,  $F(1, 98) = 0.480$ ,  $p = 0.490$ . Thus, performance on the non-speech rhythm task could not predict a significant amount of unique variance in reading attainment after both speech rhythm sensitivity and phonological awareness had been taken into account.

Based on the strength of the associations in the two exploratory analyses, a more robust analysis was undertaken to see just how strongly speech rhythm was related to reading. Therefore, another regression analysis was conducted to see whether speech rhythm sensitivity could predict variance in reading after age, vocabulary, phonological awareness, short-term memory, and non-speech rhythm had all been accounted for; this is shown in Table 3.3 and is depicted in Figure 3.3.

**Table 3.3** The amount of variance in reading accountable to age, vocabulary, phonological awareness, short-term memory, non-speech rhythm, and speech rhythm sensitivity

Variable	B	SE B	$\beta$	$\Delta R^2$
Step 1				
Age	0.581	0.166	0.249**	
Vocabulary	0.005	0.119	0.003	
Phonological Awareness	7.377	0.903	0.651***	
Digit Span	0.117	0.364	0.022	0.672***
Step 2				
Age	0.580	0.167	0.249**	
Vocabulary	0.002	0.120	0.001	
Phonological Awareness	7.355	0.915	0.649***	
Digit Span	0.105	0.371	0.020	
Non-Speech Rhythm	0.066	0.356	0.012	0.000
Step 3				
Age	0.505	0.163	0.216**	
Vocabulary	-0.010	0.116	-0.007	
Phonological Awareness	6.244	0.966	0.551***	
Digit Span	0.001	0.360	0.000	
Rhythm Coping (NSR)	0.162	0.345	0.029	
Mispronunciations (SR)	1.087	0.383	0.205**	0.026**

Notes: \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$



**Figure 3.3** The amount of variance in reading accounted for by the variables in this study

It can be seen from Table 3.3 that while performance on the non-speech rhythm sensitivity task failed to predict a significant amount of variance in reading attainment

after age, vocabulary, phonological awareness, and short-term memory had been accounted for,  $R^2$  change = 0.000,  $F(1, 96) = 0.034$ ,  $p = 0.854$ . speech rhythm sensitivity task was still able to predict a significant amount of variance in reading attainment after age, vocabulary, phonological awareness, short-term memory, and non-speech rhythm had been accounted for.  $R^2$  change = 0.026,  $F(1, 95) = 8.053$ ,  $p = 0.006$ . It can also be seen that speech rhythm sensitivity relates quite strongly to reading attainment, Beta = 0.205,  $t(95) = 2.838$ ,  $p = 0.006$ , although age and phonological awareness also made a unique contribution.

A factor analysis was also conducted to see how the measures of speech rhythm sensitivity, non-speech rhythm sensitivity, phonological, and reading loaded together. The data was initially checked to ensure that it met the assumptions for a factor analysis. The technique that was chosen to identify the number of factors to retain was parallel analysis; this method is considered to be superior and more accurate to traditional methods such as the 'Eigenvalues greater than 1' criterion (Velicer, Eaton, & Fava, 2000). Table 3.4 shows the results from the factor analysis using parallel analysis.

**Table 3.4 Factor matrix showing factor loadings for all the tasks used in this study**

Variables	Factor Loadings
BAS Word Reading	0.89
Rhyme Detection	0.83
Phoneme Deletion	0.82
Fluency (time & error comp)	-0.73
Original Mispronunciations Task	0.70
Revised Mispronunciations Task	0.69
Vocabulary BPVS	0.56
Digit Span	0.54
Rhythm Copying (non-speech rhythm)	0.39

Notes: Rhythm matching was not included due to such poor internal reliability

Using parallel analysis, only a single factor was identified and the loadings for this factor are displayed in Table 3.4. This factor comprised of all nine variables. As expected the reading measures (word reading and fluency) loaded heavily together (0.89 and -0.73 respectively), along with the key phonological measures including rhyme detection (0.83) and phoneme deletion (0.82). This was unsurprising given their documented link in the literature. Interestingly, the original and revised versions of the mispronunciations task were also loaded heavily on this reading-related factor (0.7 and 0.69 respectively) which emphasises the relationship between speech rhythm sensitivity and reading skill. Vocabulary (0.56), digit span (0.54), and rhythm copying (0.39) were also loaded on this factor. It is noteworthy that non-speech rhythm was not heavily loaded on this factor, which included speech rhythm sensitivity and reading skills, which might suggest that non-speech rhythm is less related to reading than speech rhythm sensitivity. Thus, although the regressions revealed that speech rhythm sensitivity could predict reading independently of its relationship with phonological awareness, the factor analysis perhaps indicates that speech rhythm sensitivity must share characteristics and to some extent be related to phonological awareness: this was not unexpected.

### **3.4. Discussion**

In this study, a weak, non-significant relationship was found between speech rhythm (using the revised mispronunciations task) and the non-speech rhythm measure, which suggests that speech rhythm and non-speech rhythm do not seem to be as related as some would have argued (Wolff, 2002; Patel, 1998; Patel et al., 1998). This lack of

relatedness was further supported by the results from the factor analysis, where non-speech rhythm had a weak factor loading in comparison to the speech rhythm measure.

From the regressions, it was found that speech rhythm sensitivity could predict a significant amount of the variance in reading attainment after age, vocabulary, phonological awareness, short-term memory, and non-speech rhythm had been accounted for. While the factor analysis suggests that speech rhythm sensitivity is related to reading and phonological awareness, the fact that speech rhythm sensitivity could predict unique variance in reading after non-speech rhythm was accounted for suggests that it is accounting for variance that cannot be entirely subsumed by awareness of non-speech rhythm. Furthermore, it was found that although non-speech rhythm was correlated with reading, it could not predict a significant amount of the variance in reading attainment after speech rhythm sensitivity and phonological awareness had been accounted for. This shows that speech rhythm is contributing additional variance in children's reading, which still requires further exploration.

The results from this study have contributed to the growing literature showing that prosodic sensitivity can account for variance in reading attainment after controlling for individual differences in phonological awareness (Whalley & Hansen, 2006; Wood, 2006a; Holliman et al., 2008), which is a key finding. Some might have argued that speech rhythm sensitivity is predicting reading attainment because the mispronunciations task(s) can be seen as a form of phonological awareness measure. However, as the results show, speech rhythm sensitivity predicted a significant amount of variance in reading attainment after phonological awareness had been accounted for.



This raises the idea that sensitivity to speech rhythm may contribute to reading development not just through the anticipated mechanisms of phonological awareness development but also in a way that was previously unanticipated and which needs additional empirical work to generate a more comprehensive theoretical explanation of the associations observed in this study.

Holliman et al. (2008) argued in accordance with Kuhn and Stahl (2003) that sensitivity to the rhythmic/prosodic features of speech, such as stress, are implicated in both the reading comprehension and reading fluency process. It seems plausible that these processes could mediate the observed relationship between stress sensitivity and word reading, in a manner that does not necessarily depend purely on phonological skills, which could explain the findings here. Another explanation for the relationship between speech rhythm and reading independent of phonological awareness is that speech rhythm could be related to reading via its link with morphology, although morphology was not assessed in the present study. Current reading models typically deal with monosyllabic words (Protopapas et al., 2006) where stress sensitivity has little importance. However, when we are decoding multisyllabic words, stress rules become very important and the location of stress can change depending on the suffix of that word (Wade-Woolley, 2007). Wade-Woolley argued that poor readers may be less sensitive to stress in oral language and be less aware of morphological rules when decoding multisyllabic words. This speculation might explain how sensitivity to stress (speech rhythm) can predict word reading after phonological awareness has been controlled. If this explanation was the case, we might expect that if morphology was entered into a hierarchical regression model before stress sensitivity that the amount of

variance accounted for by stress sensitivity would reduce, or disappear. In support of this explanation, Clin and Wade-Woolley (2007) found in a group of eight to thirteen-year-old children that prosodic sensitivity could no longer predict a significant amount of variance in reading once morphological awareness was accounted for. However, it remains unknown whether these results would be replicated in a sample of younger children whose morphological awareness is less developed.

In spite of the fact that the revised speech rhythm sensitivity task had undergone lots of changes to overcome previous criticisms surrounding the original, there is at least one methodological limitation which may help to explain the strong relationship found between speech rhythm and reading. In this study there was no measure of problem solving ability or intelligence. The metrical stress sensitivity task can be seen as a 'problem solving' task and it could be that the task demanded a specific problem solving skill that may be absent or less developed in those with poorer reading ability. It could therefore be problem solving which is mediating the link between metrical stress and reading. However, vocabulary was accounted for, and this measure is very highly correlated with general IQ and has been used in other studies as a proxy for it (e.g. Wood & Terrell, 1998b).

Some might argue that the revised stress mispronunciations task is more a measure of speech rhythm *insensitivity* rather than speech rhythm sensitivity given that the words in this task are mispronounced with irregular stress. However, it can be argued that in order to do well at this task, children need to be sensitive to the fact that the stress has been manipulated in the target words (stress sensitivity) and must be able to manipulate

this irregular stress in order to arrive at the correct pronunciation of the word, which can then be found in the mental lexicon. Furthermore, the fact that a positive relationship was found between the revised mispronunciations task and the reading measure (as indicated by the beta values), rather than a negative relationship, lends further support to the idea that this task is more a measure of stress sensitivity, rather than insensitivity.

Another limitation of this task concerns the discrepancies between the foil items in relation to the target items. For instance, there was not an equal ratio of target items in comparison to foil items that ended in a schwa vowel or in an open syllable, and the type of affixes and compound words used was not controlled for in any way. It could therefore be argued that correct answers could have arisen from some implicit awareness of the target item similarities. However, while it is acknowledged that other factors could have been controlled for in this task, it was essential to control for the most important problematic aspects of this task, which might underlie the observed relationship between speech rhythm and reading. For instance, one of the major criticisms of the original task was that few items began with the same phoneme as the target item and therefore phonemic sensitivity, rather than stress sensitivity could help children to solve this task (Holliman et al., 2008). It therefore had to be ensured that all distracter items began with the same phoneme and initial letter. In doing so, we then had to decide how to select distracter items. Knowing that vocabulary has been argued to mediate the link between spoken word recognition skills and reading development (Walley, 1993) it was also essential to match them on frequency of occurrence in children of this age. It was extremely difficult to find words with a similar initial letter and phoneme that are matched on word frequency. However, had the distracters been

matched on all other factors noted above, it would have meant the matching of items in terms of their familiarity and initial phoneme relative to the target items was even more difficult, if not impossible, to achieve and it was felt that these were the most important factors to control theoretically.

There are some limitations regarding the assessment of non-speech rhythm which may help to explain why this was not found to be predictive of reading after stress sensitivity and phonological awareness had been accounted for. The only thing which was manipulated in these tasks was the duration of gaps between beeps in an attempt to isolate and assess the temporal processing deficit hypothesis. However, in other studies, different aspects of non-speech rhythm are manipulated and investigated. For instance, Patel et al. (1998) considered musical, non-speech rhythm to consist of pitch, duration, and intensity and in their assessment of music, length, rate, frequency, and timing were manipulated. Perhaps this study did not find a strong relationship between non-speech rhythm and reading and between non-speech rhythm and speech rhythm because only a single aspect of musical, non-speech rhythm (duration between beeps) was investigated. If the assessment of non-speech rhythm had manipulated length of beeps, tones, and intensity which may well have made it more comparable with the speech rhythms tasks, a link may have been found. Another possible explanation for this lack of relatedness could be due to the fact that the assessment of non-speech rhythm in this study, unlike the assessment of speech rhythm, was a productive measure. Perhaps the inclusion of a receptive non-speech rhythm measure would yield different findings. Indeed, this was the purpose of the rhythm matching task, however, the internal reliability was so low that we could not use this task.

It is becoming clear that prosodic sensitivity in the form of stress sensitivity is related to concurrent reading attainment independent of phonological awareness and non-speech rhythm, but how it is doing this is less clear. One line of enquiry might investigate whether stress sensitivity can predict other aspects of reading over time (other than just word reading in this study) such as reading comprehension, reading fluency and spelling. This has not been done and such a study would tell us a lot about the predictive power of metrical stress sensitivity in the development of all areas of literacy. It could be for instance, that metrical stress is related to word reading via its relationship with reading comprehension. A longitudinal design is also necessary if we wish to make causal explanations concerning the relationship between speech rhythm and reading development.

### **3.5. Conclusion**

The regression analyses showed that metrical stress sensitivity could predict a significant amount of variance in reading attainment after age, vocabulary, phonological awareness, short-term memory, and non-speech rhythm. This suggests that although metrical stress appears to be related to phonological awareness, it can also predict reading independently of this association. In summary, the results suggest that prosodic sensitivity (particularly stress sensitivity) is an important reading-related skill which needs to be incorporated into current discussions concerning the development of English-speaking children's phonological representations.

## Chapter 4 - Study Two: Does Speech Rhythm Sensitivity Predict Children's Reading Ability One Year Later?

### 4.1. Introduction

In Study One, it was found that speech rhythm sensitivity is a skill related to children's reading development when assessed concurrently. However, less is known about how it is related to reading development, how it relates to the different components of reading that have not been assessed in Study One, and how it relates to reading over time. This was addressed in Study Two, which revisited the same children from Study One.

It is now widely accepted that successful reading development is characterised by more complete phonological representations of words in the mental lexicon, and phonological processing deficits are consistently witnessed in children with reading difficulties (Vellutino & Fletcher, 2005). Phonological deficits are often accompanied by speech perception deficits (see McBride-Chang, 1995 for review) which may compromise the acquisition of phonological codes, interfere with the processing of oral language, and make it more difficult to segment the speech stream into interpretable units such as phonemes and syllables. This is problematic given that segmental awareness is important for decoding and has been linked to successful reading development (Muter et al., 1998).

There are two types of phonology; *segmental* phonology is primarily concerned with separable sound segments in speech such as phonemes, whereas *suprasegmental* phonology (prosodic features such as stress, tone and pitch) relates to overarching patterns or elements of the speech stream. According to Kitzen (2001, p.42) deficits in

speech perception might lead to underspecified representations of both phonemic (segmental) and prosodic (suprasegmental) phonological information, which might result in an under-developed system for mapping orthographic information with phonological representations. However, as Kitzen noted, while a great deal of research has investigated the role of segmental phonology in children's reading development, the role of suprasegmental phonology is less well understood and it is speculated that sensitivity to both phonemic and prosodic word structure are necessary for reading proficiency. A literature is now emerging to investigate the role of speech rhythm in reading, and this has led to the development of theoretical models which aim to explain the nature of this relationship based on the available evidence (e.g. Wood, Wade-Woolley, & Holliman, in press).

### *Speech Rhythm and Word Reading*

A number of studies have demonstrated a link between sensitivity to speech rhythm and word reading (e.g. Wood, 2006a; Holliman et al., 2008; Gutierrez-Palma & Reyes, 2007; Wood & Terrell, 1998b; Goswami et al., 2002). Indeed, Goswami et al. (2002) found that performance on their speech rhythm sensitivity measure could predict an additional 9% of the variance in word reading after controlling for age, non-verbal IQ, and vocabulary. A link between speech rhythm and word reading was also demonstrated in Study One.

So how can we explain the observed relationship between speech rhythm and word reading specifically? A variety of possible contributory pathways have been hypothesised in the model outlined by Wood et al. (in press), which was presented in

Chapter 1. In one pathway in this model, it was argued that children are born with a periodicity bias (Cutler & Mehler, 1993) which allows them to 'tune in' to the rhythmic properties of speech in their native language. English, which is a stress-timed language, is characterised by patterns of strong (stressed) and weak syllables, and Cutler and Norris (1988) suggest that sensitivity to such rhythmic properties might facilitate spoken word recognition. Indeed, English-learning infants have been found to segment words on the basis of stress from 7.5 months of age, to display sensitivity to other auditory cues that support the identification of word boundaries from 10.5 months of age, and to display recognition of words from the stream of speech at a rate similar to adults by 24 months of age (Jusczyk, 1999). Wood et al. (in press) anticipate that these word recognition skills facilitate the development of vocabulary (Walley, 1993), phonological awareness and reading. Such a route to reading ability has been partially supported by Lindfield et al. (1999) who argued that word-level stress facilitates word recognition processes providing a means for accessing lexical representations, and aids the retrieval of words from the lexicon. So in summary, sensitivity to stress (an aspect of speech rhythm), may help infants to segment fluent speech into interpretable units, thus facilitating spoken word recognition, which has been linked to proficient reading (see Metsala, 1997; Wood & Terrell 1998). This link may also be mediated by vocabulary and phonological awareness.

In a second pathway, Wood et al. (in press) considered that speech rhythm sensitivity may be related to reading via its links with phoneme awareness, for which there is a great deal of supporting literature (Hulme et al., 1998; Macmillan, 2002; Yopp, 1988; Muter et al., 1998; Ehri et al., 2001). Wood (2006a) and Chiat (1983) have argued that it



is more difficult to decode phonemes in unstressed syllables. Therefore, an infant who is more sensitive to stress, or who could apply stress to an unstressed syllable should find it easier to recognise the phonemes within words, which would in turn help them to decode words and be able to read them. Such a theory is consistent with Kitzen (2001) who argued that prosodic sensitivity may help to bring some syllables into prominence e.g. at the word level prosody can provide reliable cues regarding the grammatical identity of words (e.g. CONvict and conVICT) and at the sentence level prosody may provide cues to help identify word boundaries. Kitzen (2001) also argued that the capability to make stress placement shifts and to apply stress to unstressed phonemes should facilitate the matching process between speech input and the stored lexical code.

In a third pathway, Wood et al. (in press) argued that speech rhythm may be related to reading via its links with rhyme awareness. Indeed, there is a literature demonstrating a strong association between rhyme awareness and reading (Goswami 2002; Goswami & Bryant, 1990; Ziegler & Goswami, 2005; Bradley & Bryant, 1978; Bryant, 1998; Bryant et al., 1990; Wood & Terrell, 1998b). It was argued that sensitivity to stress may facilitate the categorisation of words by rime unit and the identification of onset rhyme boundaries (Goswami, 2003; Goswami et al., 2002). This could enable a child to make analogies between words to decode new ones: a skill that has been linked to reading proficiency (Goswami & Bryant, 1990).

Some of the research noted above also found that speech rhythm could account for unique variance in reading after accounting for individual differences in vocabulary and phonological awareness (e.g. Holliman et al., 2008) so it is possible that speech rhythm

has some direct effect on reading beyond its association with spoken word recognition, vocabulary, and phonological awareness. It is possible that the unique contribution of speech rhythm to reading could be explained via its links with fluency and comprehension (Kuhn & Stahl, 2003).

### *Speech Rhythm, Reading Fluency, and Reading Comprehension*

So how does speech rhythm sensitivity relate to reading fluency and comprehension specifically? Some researchers (e.g. Kuhn & Stahl, 2003) have argued that speech rhythm might provide a link between reading fluency and reading comprehension. For instance, it was argued that an individual who reads with appropriate attention to phrasing, stress, and intonation has some knowledge of syntactic roles. This prosodic knowledge might help to highlight the relative importance of aspects of the text and facilitate understanding. In line with this argument, Kuhn and Stahl (2003, p.6) suggest that “appropriate phrasing, intonation, and stress are all considered to be indicators that a child has become a fluent reader...they act as indicators of the reader’s comprehension...given that a fluent reader is one that groups text into syntactically appropriate phrases, this parsing of text signifies that the reader has an understanding of what has been read”. Therefore, it is likely that prosody, fluency, and comprehension are related skills in reading.

Speech rhythm has been related to reading comprehension in the literature. Whalley and Hansen (2006) found that speech rhythm sensitivity was able to account for unique variance in children’s word reading accuracy and reading comprehension after controlling for phonological awareness. Whalley and Hansen speculate that speech

rhythm sensitivity might facilitate reading comprehension by enabling the individual to segment (chunk) the stream of speech into syntactically comprehensible units, which would help to reduce memory load. This would also allow the individual to focus on the more relevant aspects of the text, thus enhancing comprehension of it. Kitzen (2001) has also found that prosodic sensitivity could discriminate between children with and without a history of reading problems, and could also predict unique variance in reading accuracy, reading comprehension, and non-word reading in an older, adult sample.

Schwanenflugel et al. (2004) proposed two models concerning the relationship between speech rhythm and reading. The 'reading prosody as partial mediator model' holds that proficient decoding skills should free up attention resources that can be utilised by prosodic processing. This would likely have some additional contribution to reading comprehension, beyond decoding ability. The 'reading comprehension as predictor of reading prosody model' holds that proficient reading comprehension skills and decoding ability allow the individual to utilise prosodic reading. Schwanenflugel *et al* found strong relationships between speech rhythm and decoding, however, speech rhythm was unable to predict comprehension beyond decoding ability. The authors conclude that prosody and decoded are related, but that the relationship between prosody and comprehension is less well-supported.

Another explanation for the relationship between prosody and reading from Study One is that children with reading difficulties may be less sensitive to prosodic features of speech, such as stress, and be less able to utilise morphological rules when decoding words with more than one syllable (Wade-Woolley, 2007; Holliman et al., 2008; Wood

et al., in press). While decoding multisyllabic words, stress rules are extremely important due to the variable location of stress depending on the word's suffix (Wade-Woolley, 2007). For instance, Kitzen (2001) argued that disyllabic *nouns* are more likely to receive stress on the first syllable (PERmit, CONvict) whereas disyllable *verbs* are more likely to receive stress on the second syllable (perMIT, conVICT). In support of this, strong correlations have been recently found between prosody, reading comprehension, and morphological skills (Ravid & Mashraki, 2007) albeit in a group of fifty-one Hebrew-speaking children in Grade 4, although Ravid and Mashraki (2007, p.142) note that there is still a lack of empirical investigation into the relationship between prosody and reading comprehension. This theoretical link was also argued by Wood et al. (in press).

### *Summary and Rationale*

While there is a growing literature investigating the relationship between prosody and reading, longitudinal research is now needed in order to assess the causal direction of the positive association between prosodic sensitivity and reading. Such research also needs to include a *variety* of reading measures, along with phonological processing measures to help assess the legitimacy of the model proposed by Wood et al. (in press) and to understand precisely how speech rhythm sensitivity is related to reading by examining its relationship with the *different components* of reading over time. The purpose of this study therefore is to use a longitudinal design to investigate whether speech rhythm, as measured using the revised mispronunciations task at Time 1, can predict children's word reading, reading accuracy, reading comprehension, spelling, non-word reading, and components of reading fluency after controlling for individual

differences in vocabulary, age, and phonological awareness. A path analysis will also examine how speech rhythm relates to reading via the components noted in the model by Wood et al. (in press) such as vocabulary, phoneme, and rhyme awareness. This study is unique because no study to date has carried out a longitudinal study of speech rhythm and reading and this is necessary if we are to make causal explanations about the relationship between speech rhythm and reading.

It was predicted, based on Holliman et al. (2008), Wood and Terrell (1998b), Gutierrez-Palma and Reyes (2007), Goswami et al. (2002) that speech rhythm sensitivity would be able to predict a significant amount of unique variance in reading after controlling for vocabulary, age, and phonological awareness. Based on the research by Whalley and Hansen (2006) it was also predicted that speech rhythm would be able to predict unique variance in components of reading fluency and reading comprehension after controlling for vocabulary, age, and phonological awareness. While there is a lack of research investigating the role of speech rhythm sensitivity in spelling and non-word reading, based on Wood (2006a) and Kitzen (2001) it was also anticipated that speech rhythm would be unable to predict unique variance in spelling, non-word reading.

## **4.2. Method**

### **4.2.1. Participants**

A total of 69 children from the original 102 that took part at Time 1 participated in this study at Time 2 (one year later) and were recruited from two combined schools in Buckinghamshire, UK, in the year 2007. At Time 2, the age of children ranged between 5:11 and 8:8 years (mean age = 7:7) and were in either Year-One, Year-Two, or Year-

Three classes. All of the males ( $n = 41$ ) and females ( $n = 28$ ) that took part had English as their first language and 11 children had been exposed to a second language within the home. The mean standardised vocabulary score of the sample was 101.70 ( $SD = 10.24$ ) which falls in the ‘average score’ range, and the mean word reading raw score was 47.70 ( $SD = 18.09$ ), which equates to a reading age equivalent of 7:10. All participants were approached to participate only once both their parents and head-teachers had provided informed consent.

#### **4.2.2. Materials**

Children’s scores were taken from the following measures as Time 1 in the first phase of data collection:

- The revised mispronunciations task
- Vocabulary (BPVS)
- Phoneme deletion
- Rhyme detection
- Word reading

In the second phase of data collection (Time 2) the children were assessed on the following measures:

- Phoneme deletion
- Rhyme detection
- Word reading
- Non-word reading
- Spelling
- Reading accuracy

- Reading comprehension
- Multidimensional fluency scale (phrasing, smoothness, pace)

Details of these measures can be found in the Methodology Chapter. These assessments were presented in a randomised order over two sessions in order to minimise the length of testing period, although the reading accuracy measure was always followed by the reading comprehension measure. Participants performed on an individual basis and were seated next to the researcher at a table.

### **4.3. Results**

This section begins with a comment regarding the inter-rater reliability of the fluency measure. It then provides some descriptive statistics (mean and standard deviation) along with a correlation matrix, which includes all of the measures used in this study. A series of hierarchical regressions are then presented to assess whether speech rhythm sensitivity can predict unique variance in the various reading-related measures after controlling for vocabulary, age, and phonological awareness. This is followed by a series of path analyses to assess the direct and indirect relationships between speech rhythm sensitivity and the various reading-related measures.

For the fluency measure, a subsection of passages were also scored by an independent researcher: a significant positive relationship was found between the researcher's scores and the independent researcher's scores ( $r = 0.888$ ,  $n = 25$ ,  $p < 0.001$ ).

Table 4.1 shows the mean and standard deviation scores on the speech rhythm, reading, and phonological measures taken at Time 1 and 2.

**Table 4.1 Summary statistics for children on the speech rhythm, reading, and phonological measures at Time 1 and Time 2**

Task	Mean	Std. Deviation
T1: Age (in months)	79.74	8.57
T1: Vocabulary (standard scores)	101.7	10.24
T1: Phoneme Deletion Task / 24	12.62	8.01
T1: Rhyme Detection Task / 21	11.7	6.33
T1: BAS Word Reading / 90	31.01	20.03
T1: Revised Mispronunciations Task / 18	12.8	3.85
T2: Rhyme Detection Task / 21	17.13	5.65
T2: Phoneme Deletion Task / 24	16.86	6.58
T2: BAS Word Reading / 90	47.7	18.09
T2: Non-word Reading / 20	10.88	5.87
T2: BAS Spelling / 76	28.88	11.2
T2: Reading Accuracy / 499	38.16	18.79
T2: Reading Comprehension / 44	10.45	5.59
T2: Phrasing (fluency) / 4	3.25	0.91
T2: Smoothness (fluency) / 4	3.12	0.85
T2: Pace (fluency) / 4	3.36	0.86
T2: Fluency (phrasing, smoothness, pace) / 12	9.72	2.36

It can be seen from Table 4.1 that participants scored in the upper-middle range on the revised mispronunciations task (12.8 from a possible 18) at Time 1. Participants scored in the middle range on the measures of phonological awareness (the phoneme deletion task and the rhyme detection task) at Time 1 and scored in the upper-middle range at Time 2. On the word reading task, participants obtained a higher mean score at Time 2 (47.7) in comparison to the mean score obtained at Time 1 (31.01). These improvements on the phoneme deletion task, rhyme detection task, and word reading task at Time 2 were expected. Furthermore, relatively high mean scores were obtained on the fluency measures of phrasing, smoothness, and pace (3.25, 3.12, and 3.36 respectively from a possible 4).

Table 4.2 shows the correlation matrix for all the variables included in this study.



Table 4.2 Correlation matrix between speech rhythm, reading and phonological awareness at Time 1 and Time 2

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1: Age (in months)															
2: Vocabulary	-.21														
3: Phoneme Deletion	.47***	.1													
4: Rhyme Detection	.23	.42***	.67***												
5: BAS Word Reading	.58***	.1	.77***	.67***											
6: Mispronunciations	.46***	.12	.55***	.59***	.68***										
7: Rhyme Detection	.18	.26*	.58***	.67***	.58***	.49***									
8: Phoneme Deletion	.34**	.03	.72***	.57***	.62***	.48***	.82***								
9: BAS Word Reading	.42***	.09	.77***	.69***	.9***	.63***	.66***	.67***							
10: Non-word Reading	.34**	.12	.71***	.66***	.79***	.56***	.65***	.65***	.85***						
11: BAS Spelling	.44***	.07	.73***	.69***	.87***	.62***	.65***	.65***	.9***	.87***					
12: Reading Accuracy	.45***	.16	.73***	.67***	.9***	.6***	.59***	.6***	.94***	.85***	.91***				
13: Comprehension	.38**	.3*	.68***	.69***	.69***	.61***	.58***	.6***	.75***	.68***	.67***	.75***			
14: Phrasing (fluency)	.19	.11	.4**	.38**	.47***	.45***	.6***	.41***	.65***	.49***	.55***	.57***	.5***		
15: Smoothness (fluency)	.32**	-.02	.49***	.38**	.54***	.39**	.43***	.41***	.67***	.44***	.51***	.55***	.47***	.64***	
16: Pace (fluency)	.23	.09	.47***	.4**	.48***	.43***	.45***	.39**	.61***	.36**	.46***	.53***	.49***	.71***	.81***

Notes: \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$

It can be seen from Table 4.2 that the revised mispronunciations task was significantly correlated with the measures of phonological awareness as expected (rhyme  $r = 0.49$ ,  $p < 0.001$  and phoneme deletion  $r = 0.48$ ,  $p < 0.001$ ). Performance on the revised mispronunciations task was also strongly correlated with all of the reading measures at Time 2; word reading ( $r = 0.63$ ,  $p < 0.001$ ), spelling ( $r = 0.62$ ,  $p < 0.001$ ), comprehension ( $r = 0.61$ ,  $p < 0.001$ ), reading accuracy ( $r = 0.6$ ,  $p < 0.001$ ) and non-word reading ( $r = 0.56$ ,  $p < 0.001$ ). The strong relationships found between the revised mispronunciations task and the measures of word reading and comprehension are not surprising given their documented link in the literature. Furthermore, the revised mispronunciations task was significantly correlated with the phrasing component of the fluency measure ( $r = 0.45$ ,  $p < 0.001$ ), which was not surprising due to the prosodic nature of this task.

### *Regressions*

Hierarchical regression analyses were conducted in which vocabulary (standard scores) and age were entered at steps 1 and 2 respectively, phoneme deletion and rhyme detection entered at step 3 and speech rhythm sensitivity was entered as the final predictor in the model at step 4. Word reading, reading accuracy, reading fluency components (including phrasing, smoothness, and pace), reading comprehension, spelling, and non-word reading were used as dependent variables in separate analyses (see Table 4.3). A standard multiple regression was also conducted to investigate the unique contribution of speech rhythm sensitivity to the various reading-related dependent variables (Table 4.4). Prior to the main analysis, preliminary analyses were conducted to ensure that the data met the assumptions for a hierarchical regression

analysis. The sample size was adequate, there was no evidence of multicollinearity (although there was a fairly strong relationship between rhyme detection and phoneme awareness), there were no outliers, and there were no violations to the assumptions of normality, linearity, homoscedasticity, and independence of residuals, although it should be noted that phrasing, smoothness, and pace were marginally negatively skewed. Incidentally, the dependent variables of phrasing, smoothness, and pace are at ordinal level and, as a result, some might argue are unsuitable for a hierarchical multiple regression analysis. However, as Lord (1953, cited in Howell, 2002, p.8) notes, “the numbers do not remember where they came from” and the underlying measuring scales are not crucial to the statistical technique we chose to adopt.

**Table 4.3 The amount of variance in word reading, reading accuracy, reading fluency components, spelling, and non-word reading accountable to vocabulary, age, phonological awareness, and speech rhythm sensitivity (all at Time 1)**

	Dependent variables (columns show separate equations), $\Delta R^2$							
	Word Reading	Accuracy	Phrasing	Smoothness	Pace	Comprehension	Spelling	Non-word Read.
Step 1: Vocabulary	.008	.026	.013	0	.007	.091*	.005	.014
Step 2: Age	.198***	.241***	.047	.102**	.066*	.202***	.220***	.138**
Step 3: PA	.460***	.349***	.125*	.163**	.158**	.293***	.416***	.424***
Step 4: Mispronunciations	.021*	.012	.059*	.007	.033	.024 <sup>†</sup>	.018	.012

Notes: <sup>†</sup> $p=.05$ , \* $p<.05$ , \*\* $p<.01$ , \*\*\* $p<.001$

**Table 4.4 Regression coefficients (Beta) at Stage 4 for vocabulary, age, phonological awareness, and speech rhythm sensitivity**

	Dependent variables (columns show separate equations), $\beta$							
	Word Reading	Accuracy	Phrasing	Smoothness	Pace	Comprehension	Spelling	Non-word Read.
Vocabulary	-.109	.011	.011	-.108	-.006	.159	-.13	-.09
Age	.014	.125	-.077	.057	-.043	.095	.074	-.029
Phoneme	.461***	.399**	.211	.318 <sup>†</sup>	.314	.335**	.362**	.426**
Rhyme	.307*	.282*	.061	.135	.053	.247	.372**	.335*
Mispronunciations	.198*	.151	.331*	.116	.249	.214 <sup>†</sup>	.185	.15

Notes: <sup>†</sup> $p=.05$ , \* $p<.05$ , \*\* $p<.01$ , \*\*\* $p<.001$

It can be seen from Table 4.3 that after vocabulary and age had been accounted for, phonological awareness was able to account for an additional 46 percent of the variance in word reading,  $R^2$  change = 0.46,  $F(2, 64) = 44.035$ ,  $p < 0.001$ . However, speech rhythm sensitivity was able to account for an additional 2.1 percent of the variance in word reading,  $R^2$  change = 0.021,  $F(1, 63) = 4.224$ ,  $p = 0.044$ . This indicates that speech rhythm sensitivity can predict unique variance in word reading after controlling for vocabulary, age, and phonological awareness.

It can also be seen that after vocabulary and age had been accounted for, phonological awareness was able to account for an additional 29.3 percent of the variance in reading comprehension,  $R^2$  change = 0.293,  $F(2, 64) = 22.697$ ,  $p < 0.001$ . However, speech rhythm sensitivity was able to account for a further 2.4 percent of the variance in reading comprehension,  $R^2$  change = 0.024,  $F(1, 63) = 3.963$ ,  $p = 0.051$ .

Phonological awareness was able to account for an additional 12.5 percent of the variance in phrasing after age and vocabulary had been accounted for,  $R^2$  change = 0.125,  $F(2, 64) = 4.912$ ,  $p = 0.01$ , but, speech rhythm sensitivity was able to account for an additional 5.9 percent of variance,  $R^2$  change = 0.059,  $F(1, 63) = 4.877$ ,  $p = 0.031$ .

In summary, performance on the speech rhythm measure predicted a significant amount of unique variance in word reading, comprehension (marginal), and phrasing after vocabulary, age, and phonological awareness had been taken into account. However, speech rhythm was unable to predict unique variance in

- spelling ability one year later,  $R^2$  change = 0.018,  $F(1, 63) = 3.367$ ,  $p = 0.071$
- non-word reading,  $R^2$  change = 0.012,  $F(1, 63) = 1.849$ ,  $p = 0.179$

- reading accuracy.  $R^2$  change = 0.012.  $F(1, 63) = 2.074$ .  $p = 0.155$
- smoothness,  $R^2$  change = 0.007.  $F(1, 63) = 0.626$ .  $p = 0.432$ . or
- pace,  $R^2$  change = 0.033,  $F(1, 63) = 2.832$ .  $p = 0.097$ .

Moreover, from the standard multiple regression (Table 4.4) speech rhythm was found to be significantly and quite strongly related to word reading,  $\beta = 0.198$ ,  $t = 2.055$ ,  $p = 0.044$ , to phrasing,  $\beta = 0.331$ ,  $t = 2.208$ ,  $p = 0.031$ , and to comprehension (marginal),  $\beta = 0.214$ ,  $t = 1.991$ ,  $p = 0.051$ , although phoneme and rhyme awareness often made a unique contribution as well.

Due to the strong associations found between speech rhythm sensitivity, word reading (decoding) and reading comprehension, an exploratory analysis was undertaken to assess two questions raised by Schwanenflugel et al. (2004), that is, whether speech rhythm mediates the relationship between decoding and reading comprehension, and whether speech rhythm sensitivity can predict reading comprehension above and beyond decoding ability.

Word reading at Time 1 (decoding) when entered individually was able to account for 48% of the variance in reading comprehension,  $R^2$  change = 0.48,  $F(1, 67) = 61.956$ ,  $p < 0.001$ , and word reading at Time 2 (decoding), when entered individually, was able to account for 56.2% of the variance in reading comprehension,  $R^2$  change = 0.562,  $F(1, 67) = 86.077$ ,  $p < 0.001$ . However, after controlling for speech rhythm, decoding ability at Time 1 was able to account for an additional 14.7 percent of the variance in reading comprehension,  $R^2$  change = 0.147,  $F(1, 66) = 20.101$ ,  $p < 0.001$ , and decoding ability

at Time 2 was able to account for an additional 22.4 percent of the variance in reading comprehension,  $R^2$  change = 0.224,  $F(1, 66) = 36.426$ ,  $p < 0.001$ . This suggests that while speech rhythm sensitivity shares some of the explained variance in reading comprehension, it does not mediate the link between decoding and comprehension.

It was also found that when entered individually, speech rhythm sensitivity accounted for 36.9% of the variance in reading comprehension,  $R^2$  change = 0.369,  $F(1, 67) = 39.184$ ,  $p < 0.001$ . However, after controlling for word reading at Time 1, speech rhythm was able to account for an additional 3.6 percent of the variance in reading comprehension,  $R^2$  change = 0.036,  $F(1, 66) = 4.896$ ,  $p = 0.03$ . Similarly, after controlling for decoding ability at Time 2, speech rhythm was also able to account for an additional 3.1 percent of the variance in reading comprehension,  $R^2$  change = 0.031,  $F(1, 66) = 5.049$ ,  $p = 0.028$ . Therefore, the idea that speech rhythm can contribute to reading comprehension independently of decoding ability was supported by the data obtained in this study.

In a further exploratory analysis it was investigated whether speech rhythm sensitivity was significantly related to word reading at Time 2, after controlling for word reading at Time 1. This was to assess one of the criticisms from Castles and Coltheart (2004) of longitudinal studies in the phonological awareness literature. They argued that in order to assess for a direct relationship over time, one should control for the autoregressor, thus, in this case, the effect of prior word reading ability and post word reading ability should be partialled out in order to truly assess for a direct relationship between speech rhythm sensitivity and word reading ability one year later. While speech rhythm

sensitivity was strongly correlated with word reading at Time 2 without controlling for word reading at Time 1 ( $r = 0.63, p < 0.001$ ). once the effect of word reading at Time 1 had been partialled out, speech rhythm sensitivity was no longer correlated with word reading at Time 2 ( $r = 0.06, p < 0.623$ ). This perhaps suggests, using an extremely conservative analysis, that speech rhythm does not have a significant direct effect on word reading development over time.

### *Path analysis*

To assess the pathways in the model by Wood et al. (in press) concerning how speech rhythm relates to reading (through phonemes, rhymes, and vocabulary development), a path analysis was undertaken. Note that Wood et al. (in press) only proposed causal pathways to word reading and spelling, but the analysis presented here will involve the paths for all eight dependent variables used in this study. Due to the limited sample size it was only possible to include speech rhythm, the control variables (age, vocabulary, phoneme, and rhyme) and a single dependent variable in each analysis; otherwise, the sample size (or ratio between the number of cases and the number of parameters) would have been insufficient for a path analysis.

For each of the following path analyses the data were inspected prior to analysis to ensure it met the assumptions for a path analysis. The default model for each analysis was initially a poor fit and therefore had to be adjusted. In each case, Model 2 was a much better-fitting model, which allowed covariation between age and vocabulary, age and phoneme, vocabulary and rhyme, and phoneme and rhyme. For all eight subsequent path analyses (using Model 2), the Chi Square statistic (CMIN), known as the badness



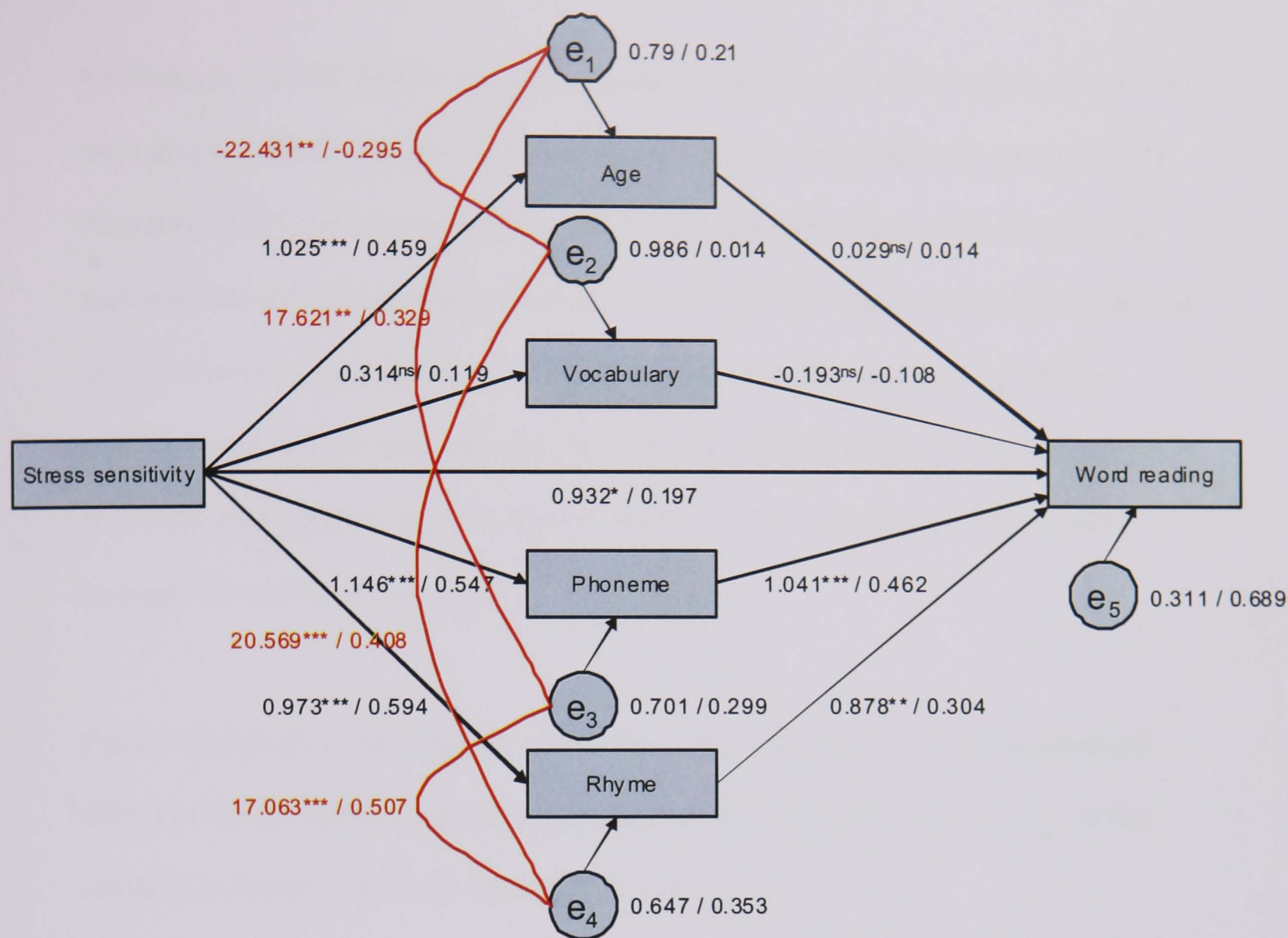
of fit statistic, was low and non-significant indicating that each model had similar covariances to the observed values and that there were no significant difference between observed and predicted covariances. The Bentler-Bonett normed fit index (NFI) was above 0.9, which is indicative of a good fitting model. The comparative fit index (CFI) was 1.0, and CFI values of 1.0 (or above 0.9) are indicative of good fit. The root mean square error of approximation (RMSEA), which provides a lower and higher value bounding the central value, was 0 and 0.131 respectively, and a lower bound value of less than 0.05 and an upper bound value that exceeds 0.10 suggest that the experimental model has a close approximate fit in the population. Lastly, Hoelter was 1958 and values above 200 suggest that the present sample size is adequate for a Chi Square test. In summary, there were no violations to the assumptions underpinning each path analysis.

It should however be noted that there are some limitations to the path analyses included in this section; most notably, non-significant pathways were not removed from the models, no exploratory or confirmatory factor analysis was undertaken to assist model development, or to help indicate relationships between variables, and there was no rationale for including all eight dependent variables. The reason for not removing non-significant pathways and for presenting a path analysis for all eight dependent variables was purely for exploratory and observational purposes. However, as a result, the following path analyses should be treated with caution.

In each path diagram there are arrows which represent pathways, and each pathway has two associated values. These values represent unstandardised and standardized

estimates for the effect of variable X on variable Y. The first value in each case is the unstandardised estimate; this indicates the effect that a one-point increase in X will have on Y, and whether this effect is significant. The second value is the standardized estimate (e.g. where the variable has been transformed so that it has a mean of zero and a standard deviation of 1).

Figure 4.1 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on word reading. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 11.

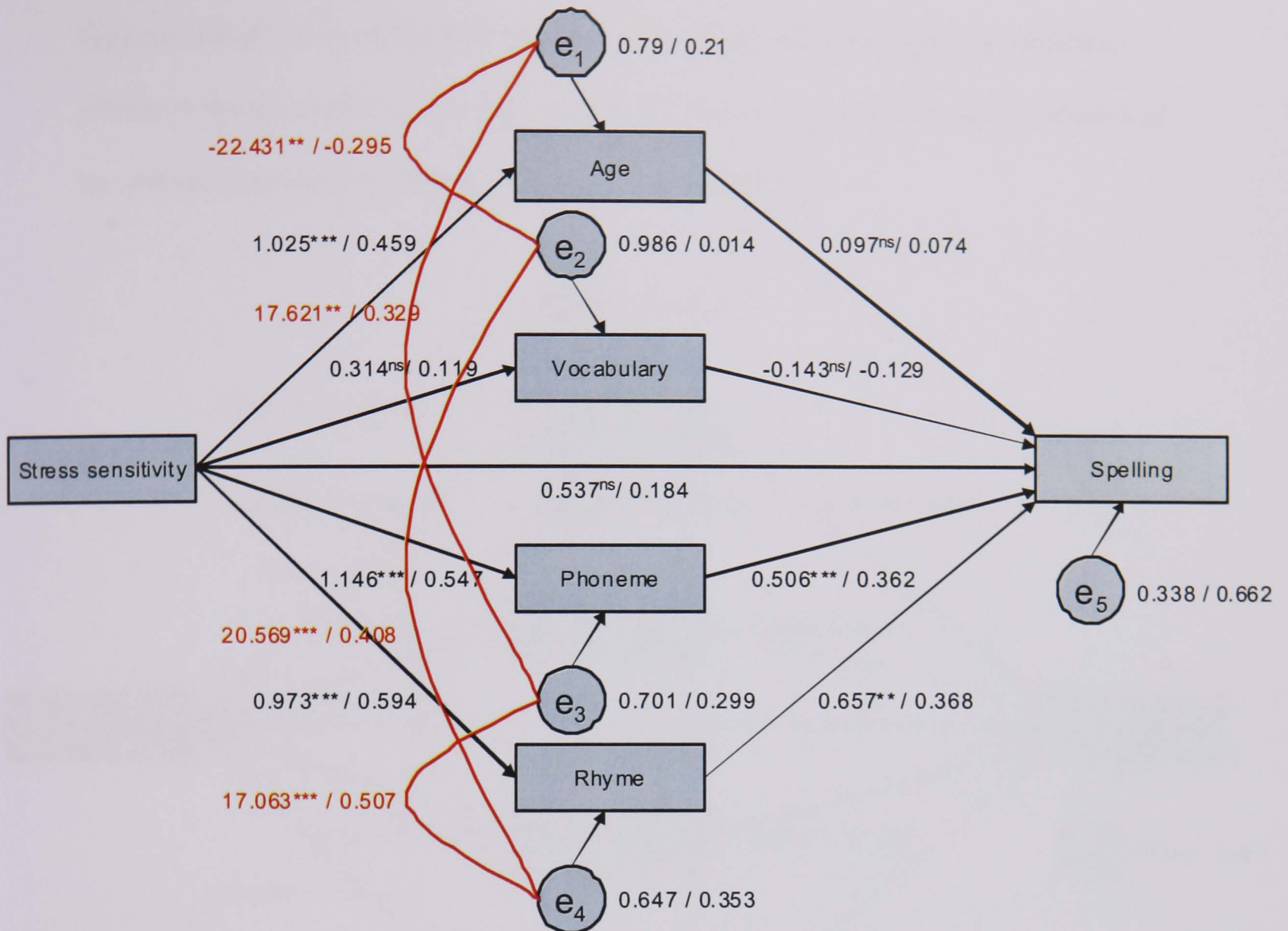


**Figure 4.1 Path diagram for word reading**

Figure 4.1 shows that the unstandardised estimate of the direct effect of speech rhythm (as measured by the revised mispronunciations task) on age is (1.025), on phoneme is (1.146), and on rhyme is (0.973), all of which were significant. The unstandardised estimate of the direct effect of speech rhythm on vocabulary (0.314) was not significant. The unstandardised and standardized estimates for these paths (e.g. speech rhythm to age, to vocabulary, to phoneme, and to rhyme) and the covariation statistics (between age and vocabulary, age and phoneme, vocabulary and rhyme, and phoneme and rhyme) remain the same for the entire subsequent path diagrams displayed in this section; so these will only be reported here.

Interestingly, speech rhythm has a significant direct effect on word reading ( $p = 0.031$ ) with an unstandardised path coefficient of (0.932) and a standardized path of (0.197). Phoneme (1.041) and rhyme (0.878) also had a significant effect on word reading as expected, but age and vocabulary did not. Moreover, the standardized indirect effect of speech rhythm on reading was (0.427). Thus, speech rhythm makes a significant contribution to word reading directly, but has more of a contribution to word reading indirectly, through phoneme (0.253) and rhyme (0.181) in particular. This model accounts for 68.9% of the variance in word reading.

Figure 4.2 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on spelling. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 12.



**Figure 4.2 Path diagram for spelling**

Figure 4.2 shows that the unstandardised estimate of the direct effect of speech rhythm on spelling is (0.537), which is marginally significant ( $p = 0.054$ ). The standardized path for speech rhythm on spelling is (0.184). Phoneme (0.506) and rhyme (0.657) have a significant effect on spelling, however, age and vocabulary did not. The standardized indirect effect of speech rhythm on spelling was (0.436). So, speech rhythm makes a significant contribution (marginal) to spelling directly, and also contributes to spelling indirectly, through phoneme (0.198) and rhyme (0.219) in particular. This model accounts for 66.2% of the variance in spelling.

Figure 4.3 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on comprehension. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 13.

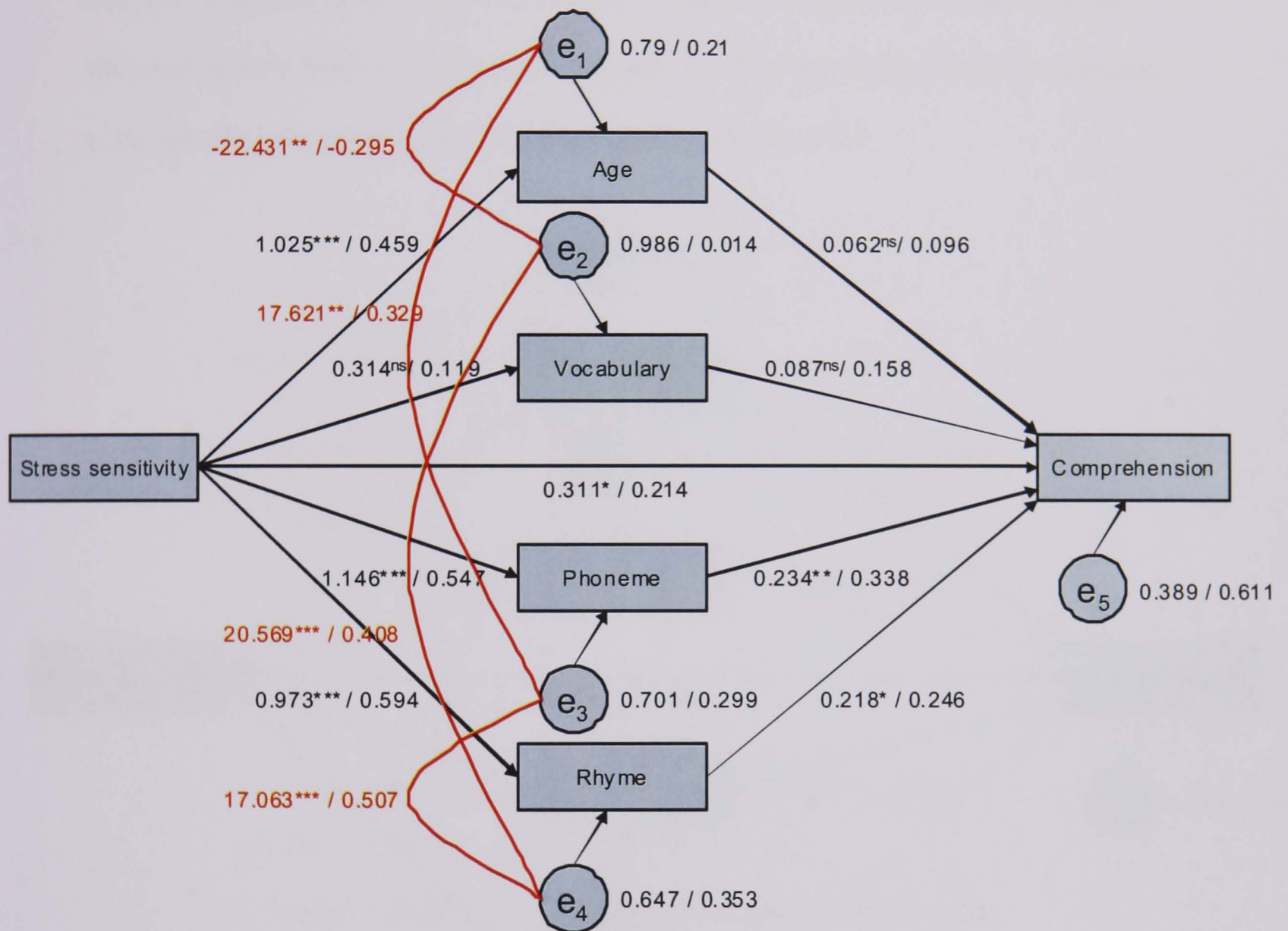


Figure 4.3 Path diagram for reading comprehension

Figure 4.3 shows that the unstandardised estimate of the direct effect of speech rhythm on comprehension is (0.311) and is significant ( $p = 0.037$ ). The standardized path for speech rhythm on comprehension was (0.214). Phoneme (0.234) and rhyme (0.218) also had a significant effect on comprehension. The standardized indirect effect of speech rhythm on comprehension was (0.394). Speech rhythm was therefore found to contribute significantly to reading comprehension directly, but also indirectly through

phoneme (0.185) and rhyme (0.146). This model accounts for 61.1% of the variance in reading comprehension.

Figure 4.4 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on non-word reading. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 14.

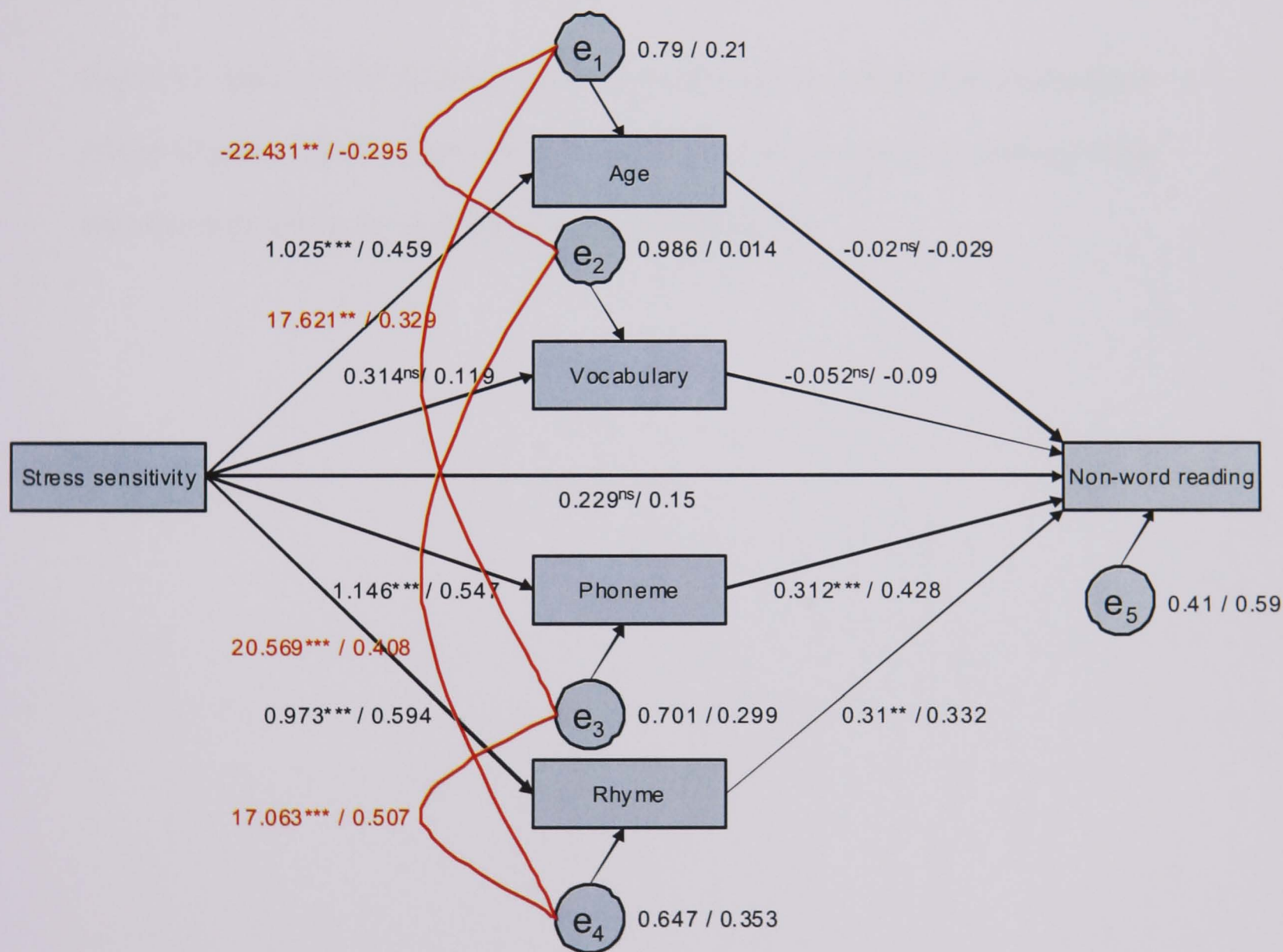


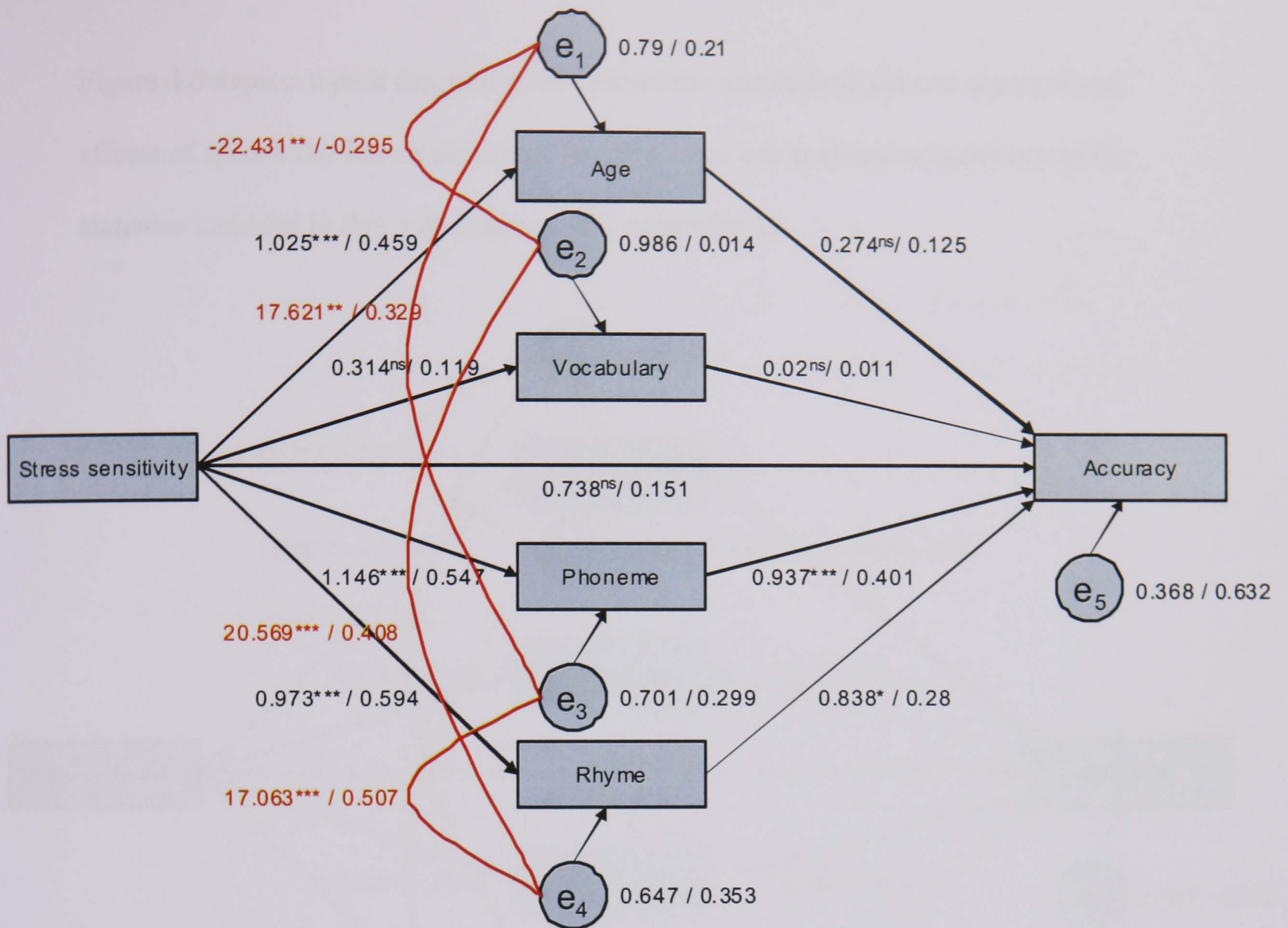
Figure 4.4 Path diagram for non-word reading

Figure 4.4 shows that the unstandardised estimate of the direct effect of speech rhythm on non-word reading is (0.229) and is not significant ( $p = 0.153$ ). The standardized path for speech rhythm on non-word reading was (0.15). Phoneme (0.312) and rhyme (0.31)

once again had a significant effect on the reading measure (non-word reading), while age and vocabulary did not. The standardized indirect effect of speech rhythm on non-word reading was (0.408). Therefore, speech rhythm does not contribute significantly to non-word reading directly, but speech rhythm has a standardized indirect effect on non-word reading through phoneme (0.234) and through rhyme (0.197). This model accounts for 59% of the variance in non-word reading.

Figure 4.5 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on accuracy. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 15.





**Figure 4.5 Path diagram for reading accuracy**

Figure 4.5 shows that the unstandardised estimate of the direct effect of speech rhythm on reading accuracy is (0.738), which is non-significant ( $p = 0.131$ ). The standardized path for speech rhythm on reading accuracy is (0.151). Phoneme (0.937) and rhyme (0.838) had a significant effect on reading accuracy, although age and vocabulary failed to do this. The standardized indirect effect of speech rhythm on reading accuracy was (0.444). So, speech rhythm was unable to contribute to reading accuracy directly, and had an indirect effect on reading accuracy through phoneme (0.219) and through rhyme (0.166). This model accounts for 63.2% of the variance in non-word reading.

Figure 4.6 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on phrasing. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 16.

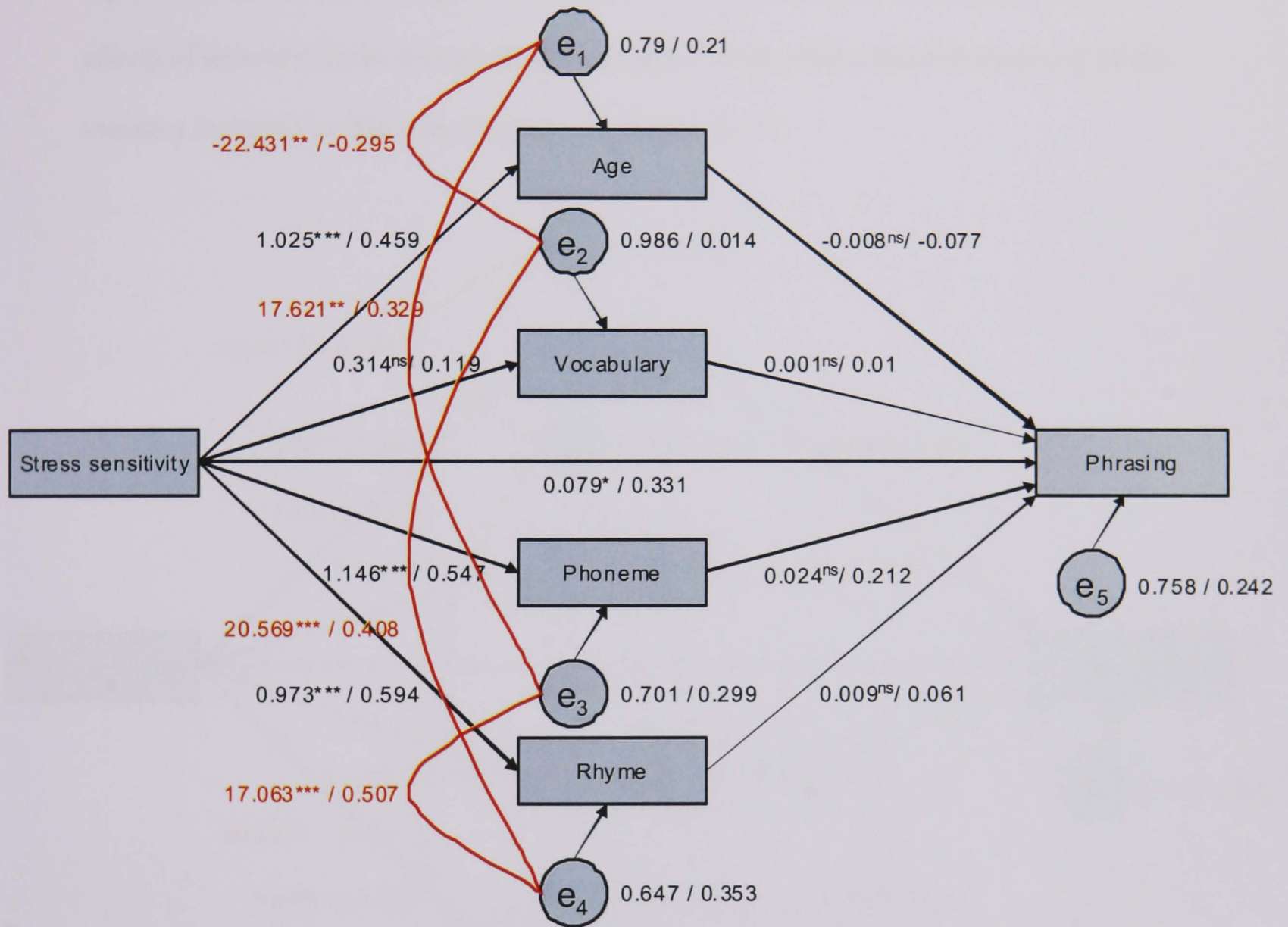


Figure 4.6 Path diagram for phrasing

Figure 4.6 shows that the unstandardised estimate of the direct effect of speech rhythm on phrasing is (0.079), and this was significant ( $p = 0.02$ ). The standardized path for speech rhythm on phrasing is (0.331). Age, vocabulary, phoneme, and rhyme all had a non-significant effect on phrasing. The standardized indirect effect of speech rhythm on reading accuracy was (0.118). Thus, speech rhythm was able to contribute to phrasing directly, and was most strongly related to phrasing indirectly through phoneme (0.116).

This model accounts for only 24.2% of the variance in phrasing, which suggests that there are many important predictors of phrasing that were not included in the model.

Figure 4.7 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on smoothness. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 17.

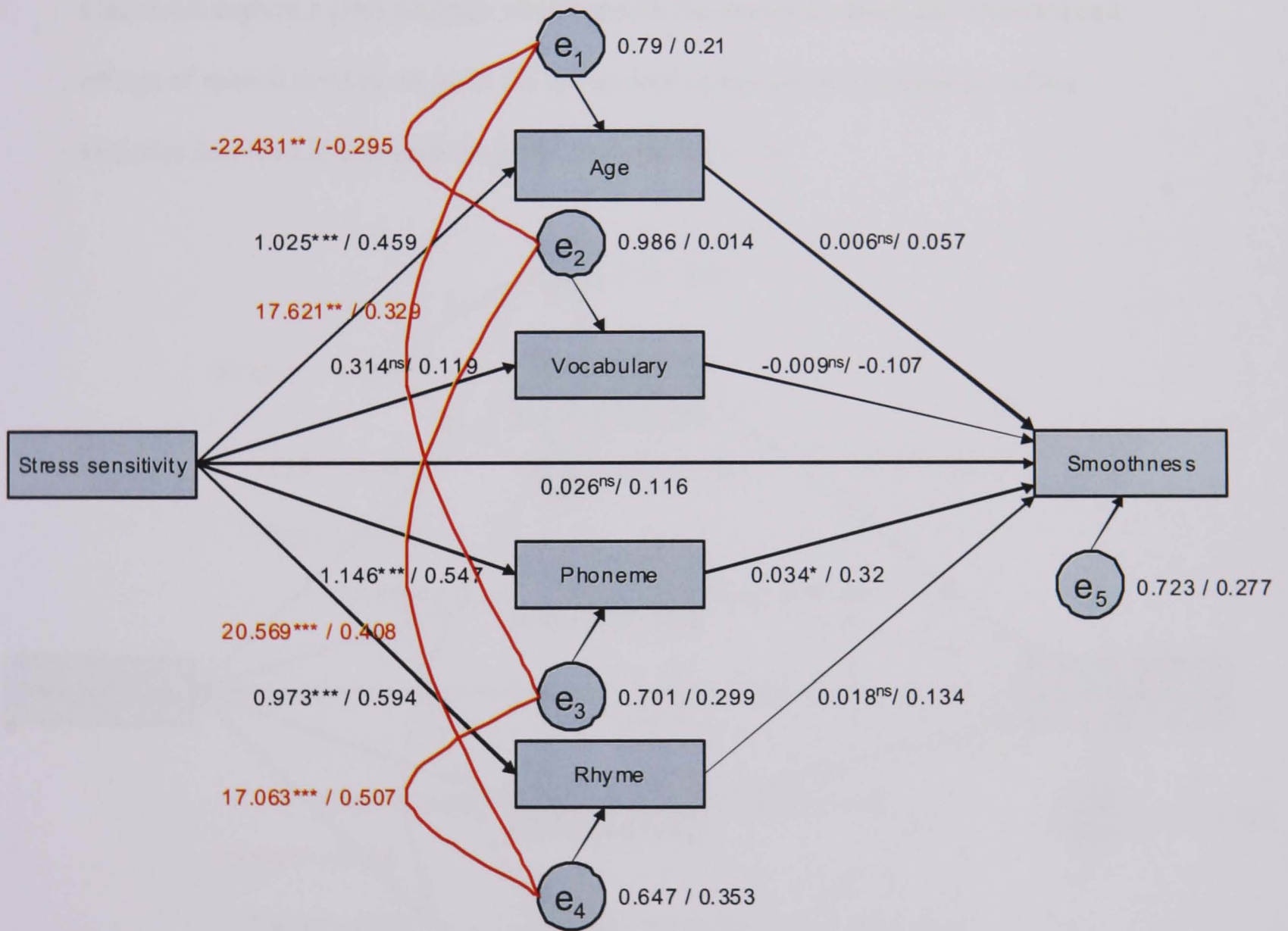


Figure 4.7 Path diagram for smoothness

Figure 4.7 shows that the unstandardised estimate of the direct effect of speech rhythm on smoothness is (0.026), which is non-significant ( $p = 0.406$ ). The standardized path for speech rhythm on smoothness is (0.116). Phoneme (0.034) had a significant effect

on smoothness, however, age, vocabulary, and rhyme did not. The standardized indirect effect of speech rhythm on smoothness was (0.268). Speech rhythm was therefore unable to contribute to smoothness directly. It had its biggest effect indirectly through phoneme (0.175). This model accounts for only 27.7% of the variance in smoothness, which suggests that other important predictors are missing from the model.

Figure 4.8 depicts a path diagram which shows the unstandardised and standardized effects of speech rhythm on pace. To see a more comprehensive summary of the statistics included in this path diagram, see Appendix 18.

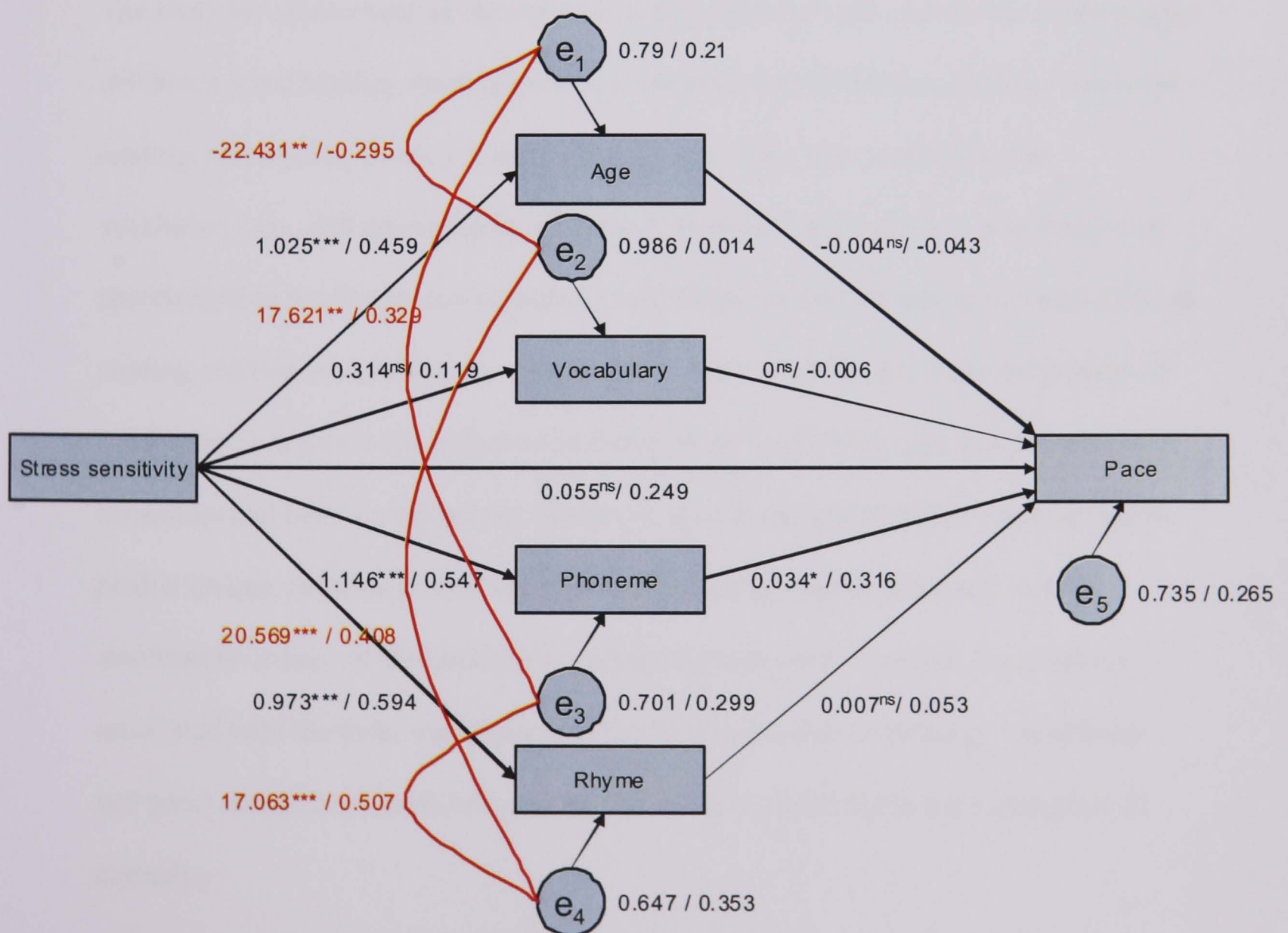


Figure 4.8 Path diagram for pace

Figure 4.8 shows that the unstandardised estimate of the direct effect of speech rhythm on pace is (0.055). This was non-significant ( $p = 0.077$ ). The standardized path for speech rhythm on pace is (0.249). Phoneme (0.034) once again had a significant effect on pace, while age, vocabulary, and rhyme failed to do this. The standardized indirect effect of speech rhythm on pace was (0.184). Thus, speech rhythm was unable to contribute to pace directly, and had an indirect effect on pace through phoneme (0.079). This model only accounts for 26.5% of the variance in pace.

#### 4.4. Discussion

The study set out to examine the extent to which speech rhythm sensitivity could predict children's word reading, reading accuracy, reading comprehension, spelling, non-word reading, and reading fluency components one year later, after controlling for vocabulary, age, and phonological awareness. From the regressions, it was found that speech rhythm sensitivity could predict a significant amount of unique variance in word reading, reading comprehension (marginal), and phrasing (the prosodic component of the fluency measure) after individual differences in vocabulary, age, and phonological awareness had been accounted for. However, speech rhythm sensitivity was unable to predict unique variance in spelling, non-word reading, reading accuracy, nor the smoothness or pace of the children's reading one year later. Note that the p-values associated with the three components of the fluency measure (phrasing, smoothness, and pace) should be treated with caution due to mild violations to the assumption of normality.

From the path analyses, speech rhythm was found to be significantly related to age, rhyme, and phoneme as anticipated, but it was not significantly related to vocabulary, which was unexpected. However, this could be due to the fact that word frequency was controlled for in the selection of target and distracter items in the development of this task. Speech rhythm was found to predict word reading, spelling (marginal), comprehension, and phrasing directly, but was also linked with the reading-related factors indirectly particular through phoneme awareness and rhyme awareness as anticipated in the model by Wood et al. (in press). This was anticipated because there is a phonological awareness component to the mispronunciations task used in this study.

The findings from these analyses demonstrate that speech rhythm sensitivity can predict unique variance in word reading; this was expected and is in line with a growing literature investigating this relation (Holliman et al., 2008; Gutierrez-Palma & Reyes, 2007; Wood & Terrell, 1998b; Goswami et al., 2002; Wood, 2006a; Study One). The strong associations found between speech rhythm and word reading support the model hypothesised by Wood et al. (in press); children who perform well on a task that demands sensitivity to stress, and the ability to reverse stress patterns in two syllable words, are better-able to identify and decode phonemes in words and then match these words to those stored in the mental lexicon (Wood, 2006a; Chiat, 1983; Kitzen, 2001). Sensitivity to stress may also help children to identify onset rhyme boundaries, which enables and facilitates analogy (Goswami, 2003; Goswami et al., 2002), and enhance spoken word recognition (Metsala, 1997; Wood & Terrell 1998; Lindfield et al., 1999; Kitzen, 2001) and all of these skills seem to facilitate the word reading process. However, based on the path analysis findings, the idea that speech rhythm facilitates

vocabulary and then reading was not supported by the data. It should also be noted that while these pathways (phoneme, rhyme, vocabulary) go some way to explaining the relationship between speech rhythm and word reading, the fact that speech rhythm sensitivity was able to account for unique variance in word reading after accounting for these skills suggests that speech rhythm is also linked to reading via an additional route.

Some researchers have argued that the link between speech rhythm and reading might be explained via its links with morphology (Wood et al., in press). Holliman et al. (2008) argued that sensitivity to stress and knowledge of stress rules plays an important role in decoding multisyllabic words; this is because the location of stress in a word varies depending on the word's suffix. Some variations have been demonstrated by Kitzen (2001) and Wade-Woolley (2007) who showed that words ending in 'ity' or 'tion' result in a stress shift, where the location of stress moves to the syllable immediately prior to the suffix of that word. Wade-Woolley theorised that children with a greater sensitivity to prosodic features of speech (such as stress) may be better-able to utilise these morphological rules when decoding polysyllabic words. However, no measure of morphology was included in this study, so the relationship can only be speculated here. More research is warranted to investigate the relationship between prosody, morphology, and reading.

A further explanation for the relationship between speech rhythm and reading could be explained via its links with fluency and comprehension. Recall that many researchers argue for the inclusion of prosodic components in the measurement of reading fluency (Schwanenflugel et al., 2004; Miller & Schwanenflugel, 2006; Dowhower, 1991; Kuhn

and Stahl, 2003). As a result, the Multidimensional Fluency Scale (Zutell & Rasinski, 1991) was used, which incorporated these components. While speech rhythm sensitivity was unable to predict reading fluency overall (combined scores of phrasing, smoothness, and pace) it was able to predict unique variance in the phrasing (prosodic) component of this task. Another major finding was that speech rhythm sensitivity could predict unique variance in reading comprehension, which has been demonstrated in the literature (Whalley & Hansen, 2006; Kitzen, 2001) and was expected. There are clear links between prosody, fluency, and comprehension, but the question is: how are these components related together to discriminate between good and poor readers and how might they explain the strong observed links between speech rhythm and reading? Schwanenflugel et al. (2004) hypothesized that an individual with proficient decoding skills should have spare attention resources for prosodic processing. Subsequently, this extra focus on prosodic components may further facilitate comprehension beyond decoding ability. The way in which prosody may facilitate comprehension has been speculated by Kuhn and Stahl (2003) who hypothesized that attention to stress and intonation implies knowledge of syntax, which enables the arrangement of text into hierarchically ordered elements, thus facilitating the comprehension of spoken language. Moreover, Whalley and Hansen (2006) argued that sensitivity to speech rhythm may facilitate the segmentation of words and help the individual to chunk spoken language into syntactically comprehensible units, so that the individual can comprehend the more relevant aspects of the text. So, sensitivity to speech rhythm may link (mediate) reading fluency and reading comprehension. However, the data obtained from this study suggests that while there is some overlap between speech rhythm sensitivity and decoding ability in the prediction of reading comprehension, speech



rhythm does not mediate the link between decoding and reading comprehension. Moreover, Schwanenflugel et al suggested that there was less support for the independent contribution of prosody to comprehension beyond decoding ability and noted stronger associations between prosody and decoding ability than between prosody and comprehension. However, the findings here suggest that speech rhythm sensitivity does make a unique contribution to reading comprehension above and beyond its relationship with decoding ability.

In summary, speech rhythm (prosody) may play an important role in children's reading development. It might facilitate decoding on different levels (phonemes, rhymes, word recognition, speech perception, and morphology) and may also help bind together reading fluency and reading comprehension. This paper makes some attempt to explain the nature of the relationship between speech rhythm sensitivity and reading, although the small sample size for the path analysis means that the findings from it should be treated with caution. More empirical research is warranted to consolidate these relationships, which includes a larger sample, and a more complex path analysis to disentangle the proposed links between speech rhythm, phonological processing, morphology, and reading. Another line of enquiry might also consider in depth precisely what is being manipulated or assessed in these 'stress sensitivity tasks'. A study which included a great number of prosodic tasks and investigated the link between them might shed light as to what precisely is predicting reading in the mispronunciations' task.

## 4.5. Conclusion

This study has added to the growing literature demonstrating the important, unique, yet neglected role of speech rhythm sensitivity in the development of children's phonological representations and reading development. After controlling for vocabulary, age, and phonological awareness, speech rhythm sensitivity was able to predict unique variance in some of the core reading-related skills (word reading, reading comprehension, and prosodic fluency) one year later. Speech rhythm sensitivity was also found to have a significant direct effect on word reading, spelling (marginal), comprehension, and phrasing. These results (and related discussions) suggest that speech rhythm sensitivity plays an important role in the identification of phonemes, the identification of vowels (rhyme awareness), and in the identification of words (speech perception and spoken word recognition), and subsequently facilitates word reading skills, comprehension of text, and reading fluency. The strength and consistency of these findings in the literature emphasize the need to consider speech rhythm sensitivity in models of reading development.

## **Chapter 5 - Study Three: A Cross-Sectional Study of Prosodic Sensitivity and Reading Difficulties**

### **5.1. Introduction**

While Study One has shown that speech rhythm is an important reading-related skill, and Study Two has shown that speech rhythm sensitivity can predict reading over time, we do not yet know whether the speech rhythm deficits observed in children with reading difficulties represents a specific deficit or a general developmental delay. This was addressed in Study Three.

Developmental Dyslexia has been defined in DSM-IV-TR as ‘reading achievement (i.e., reading accuracy, speed, or comprehension as measured by individually administered standardised tests) that falls substantially below that expected in relation to the individual’s chronological age, measured intelligence, and age appropriate education’ (American Psychiatric Association, 2000, p. 51). Although speculation regarding the aetiology of the disorder has continued into the 21<sup>st</sup> century, one of the most popular and widely accepted explanations underlying the cause of developmental dyslexia is the phonological representations hypothesis (Snowling, 2000) and this has been supported by the vast amount of research evidence demonstrating phonological processing deficits in dyslexic samples and in children with reading difficulties.

Despite the well established link between phonological awareness and reading (see Snowling, 2000 for review), “the underlying neural factors leading to these characteristic difficulties in representing phonology are still under debate” although “one logical precursor of these difficulties with phonology is a deficit in basic auditory

processing” (Thomson et al., 2006, p.334). One component of the auditory domain which has gained a great deal of attention from the recent literature (see Wade-Woolley & Wood, 2006) is rhythmic sensitivity in speech. and a growing literature has supported this (Holliman et al., 2008; Wood, 2006a; Wood 2006b; Kitzen, 2001; Whalley & Hansen, 2006; De Bree et al., 2006; Goswami et al., 2002; Gutierrez-Palma & Reyes, 2007). Links between speech rhythm and reading have also been replicated in atypical developers using dyslexic samples (Wolff, 2002; Thomson et al., 2006). However, most of the group comparison studies investigating the relationship between speech rhythm and reading (e.g. Wolff, 2002) only make comparisons between dyslexic children and chronological-age matched controls, and do not include a reading-age matched control group. Therefore, it remains unknown whether these speech rhythm deficits are a specific characteristic of dyslexia (the disorder) or whether they are due to a general developmental delay and research which could answer this question would be timely.

Few major studies have investigated whether reading-age matched controls also outperform reading disabled samples on measures of speech rhythm. Wood and Terrell (1998b) found that poor readers displayed rhythmic insensitivity on the sentence matching task (speech rhythm measure) and were outperformed by the chronological-age matched control group, but not by the younger reading-age matched group, which is suggestive of a maturational lag. However, the findings from Wood and Terrell were confounded by some methodological limitations: for instance, the speech rhythm measure was very memory intensive and there was a broad age range in the poor readers group, representing a diverse group of children.

More recently Goswami et al. (2002) theorised that the acoustic beats in spoken language (comparable to stress and intonation in terms of speech rhythm) are marked by amplitude peaks in the speech signal and that these peaks correspond to vowel location in words. Subsequently, an individual that is more sensitive to these beats would be better equipped to identify vowels in spoken words and would have an increased potential to identify onset rhyme boundaries, which have been discussed in models of typical reading development (Goswami & Bryant, 1990). Goswami et al found, as expected, that dyslexic children displayed significant deficits in beat perception in comparison to their non-dyslexic counterparts. However, no significant differences were reported between the dyslexic children and the reading-level controls.

These findings have been replicated by Richardson et al. (2004) who compared the performance of dyslexic children with both chronological-age matched controls and younger reading-level matched controls on some auditory processing tasks, including a measure of rise time sensitivity (beat detection) similar to Goswami et al. (2002). While children with dyslexia displayed significant beat detection deficits when compared with chronological-age matched controls, no significant auditory deficits were observed when compared with younger reading-level matched controls. This is suggestive of a maturational lag as opposed to a specific auditory, rhythmic deficit in children with dyslexia. Moreover, similar findings have been implicated using children with specific language impairment; for instance, Corriveau et al. (2007) compared the performance of children with SLI, chronological-age matched controls, and language-ability matched controls on a variety of non-speech auditory tasks. A more pronounced auditory deficit was found in the SLI children when compared with chronological-age matched controls,

however, few differences were observed between the children with SLI and the language-ability matched controls. While the assessments consisted predominantly of non-speech rhythm tasks and contained children with additional deficits other than reading disorder per se, these findings lend further support for a maturational lag explanation for the speech rhythm deficits witnessed in children with reading difficulties.

Collectively, these findings suggest that speech rhythm deficits are more likely to represent a maturational lag as opposed to a specific deficit. However, both Goswami et al., and Wood and Terrell only measured specific aspects of speech rhythm sensitivity and this means that we do not yet know whether deficits in *all aspects* of speech rhythm are attributable to a maturational lag; indeed it remains conceivable that specific deficits might exist in some areas more than others if we were to measure the different components of speech rhythm. A study which employed a comprehensive battery of speech rhythm measures would be timely to resolve this question.

In summary, there is now a great deal of empirical evidence to suggest that speech rhythm sensitivity is related to reading and that it is predictive of reading after accounting for individual differences in phonological awareness. It is not disputed that speech rhythm is strongly related to phonological awareness; indeed, speech rhythm sensitivity has been found to predict significant variance in common phonological awareness tasks, such as phoneme deletion and rhyme detection (Wood, 2006b) and given the well documented link between phonological awareness and reading, Wood et al. (in press) argue that we should expect to find an association between segmental

phonological awareness and speech rhythm sensitivity (supra-segmental phonology). Despite this acknowledged relationship between speech rhythm and phonological awareness, the fact remains that speech rhythm has been found to have a unique contribution to reading, beyond phonological awareness (e.g. Holliman et al., 2008). However, we do not yet know whether these speech rhythm deficits represent a maturational lag or are characteristic of a specific deficit. As noted, most of the evidence linking speech rhythm to reading omitted a reading-age matched control group and only used chronological-age matched controls. This is problematic because a specific deficit cannot be argued for without the inclusion of reading-age matched controls in addition to chronological-age matched controls. Given the heterogeneous nature of reading disorder, we cannot assume that deficits witnessed in children with developmental dyslexia (e.g. speech rhythm deficits) when compared to chronological-age matched controls demonstrate a specific deficit in these children. It is possible that they are still only showing maturational lags in these under-developed areas. Moreover, those studies that did include reading-age matched controls in addition to chronological-age matched controls (Goswami et al., 2002; Wood & Terrell, 1998) had some methodological limitations and did not employ a comprehensive battery of speech rhythm measures to assess the different components of speech rhythm. This means that specific deficits in certain aspects of speech rhythm remain unexplored.

The purpose of this study therefore is to include a reading-age matched control group in addition to a chronological-age matched control group, which is necessary to inform this debate as to whether the observed deficits in speech rhythm sensitivity represent a specific deficit in children at risk of dyslexia, or whether the relationship is due to

general developmental delay. Furthermore, no study to date has included an 'at risk' sample of English speaking children to investigating for a specific speech rhythm deficit. To account for a range of speech rhythm measures, five different assessments of speech rhythm sensitivity from the recent literature were included in this study: *The Revised Stress Mispronunciations Task*, *The DEEdee Task* (Whalley & Hansen, 2006), *The Compound Noun Task* (Whalley & Hansen, 2006), *The Aural Suffix Judgment Task* (Wade-Woolley, 2007), and *The Stress Assignment Task* (Wade-Woolley, 2007).

The two major research questions are as follows:

1. Are there significant group differences between the 'at risk of dyslexia' group and the chronological-age matched and reading-age matched controls in terms of their speech rhythm sensitivity after accounting for individual differences in receptive vocabulary and phonological awareness?
2. How do the various measures of speech rhythm sensitivity relate to each other, to reading, and how do they relate to phonological awareness (segmental phonology)?

It was predicted, based particularly on the cross-sectional research findings from Wood and Terrell (1998b) and Goswami et al. (2002), that children at risk of dyslexia would be significantly outperformed on all measures of speech rhythm sensitivity by the chronological-age matched controls. Moreover, it was predicted based on this research, that there would be no significant differences between children at risk of dyslexia and reading-age matched controls on the speech rhythm measures. In line with Wood et al. (in press), it was further predicted that speech rhythm sensitivity would be significantly



related to each other, to phonological awareness, and to reading in children with typical reading development (e.g. the chronological-age matched and reading-age matched control groups). However, it was predicted that there would be no significant relationships between speech rhythm sensitivity, phonological awareness, and reading ability in the children at risk of dyslexia.

## **5.2. Method**

### **5.2.1. Participants**

For this study, fourteen children identified as ‘at risk of dyslexia’ were recruited from a single combined school in Buckinghamshire, UK, in the year 2007. Their ‘at risk of dyslexia’ status was based on them having a word reading age equivalent and a digit span (short term memory) age equivalent at least two years behind their chronological age, as indicated by the British Ability Scales II word reading subtest (Elliot et al., 1996) and the digit span subtest from the British Ability Scales II (Elliot et al., 1996). Note that poor verbal short-term memory is a consistent characteristic of individuals with dyslexia (Snowling, 2000). Fourteen age-matched controls and fourteen reading matched controls were obtained from the same combined school. Children with extremely high or low reading or digit span scores were excluded from the data in order to obtain well-matched control groups.

Table 5.1 shows the mean and standard deviation of the age, reading raw scores, digit span raw scores, and vocabulary standard scores of the children at risk of dyslexia, the age-matched controls, and the reading-matched controls.

**Table 5.1 Mean and standard deviation of the age, reading raw scores, and digit span raw scores of the 'at risk' group, age-matched control group, and reading-matched control group**

		Age	Reading (RS)	Digit Span (RS)	BPVS (SS)
'At risk' group ( <i>n</i> = 14)	Mean	10.6	47.86	20.21	92.86
	S.D.	6.84	8.68	4.08	5.93
Controls (Age) ( <i>n</i> = 14)	Mean	10.5	70.5	23.43	99.21
	S.D.	6.51	9.16	3.65	10.91
Controls (Reading) ( <i>n</i> = 14)	Mean	7	48.57	19.43	107.14
	S.D.	4.8	13.04	3.52	10.53

It can be seen from Table 5.1 that the 'at risk' group (males *n* = 7, females *n* = 7) and the chronological-age matched controls (males *n* = 6, females *n* = 8) are well-matched on age with only a one-month difference between them and a similar standard deviation; the difference in age was not significant,  $F(1, 26) = 0.065, p = 0.801$ . The 'at risk' group and the reading-age matched controls (males *n* = 9, females *n* = 5) are well-matched on their reading raw scores, although the control group has a larger standard deviation; the difference in reading ability was not significant,  $F(1, 26) = 0.029, p = 0.866$ . These groups were also well-matched on their digit span raw scores, although once again, there was a larger standard deviation in the control group; the difference in short-term memory was not significant,  $F(1, 26) = 0.297, p = 0.590$ . Additionally, the 'at risk' group had a mean standardised vocabulary score of 92.86 ( $SD = 5.93$ ) which falls in the 'lower' part of the 'average score' range. The chronological-age matched controls had a mean standardised vocabulary score of 99.21 ( $SD = 10.91$ ) which falls in the 'average score' range. Lastly, the reading-age matched controls had a mean standardised vocabulary score of 107.14 ( $SD = 10.53$ ) which falls in the 'higher' part of the 'average score' range. All participating children in this study had English as their first language and were approached to participate only once both their parents and head-teachers had provided informed consent to take part.

### 5.2.2. Materials

The following assessments were used in this study:

- The revised mispronunciations task
- Vocabulary (BPVS)
- Phoneme deletion
- Rhyme detection
- Digit Span
- Word reading
- DEEdee task
- Compound nouns task
- Aural suffix judgement task
- Stress assignment task

Details of these measures can be found in the Methodology Chapter. These assessments were administered over three sessions to minimise the length of testing period in a quasi-randomised order. The first session always consisted of the digit span test and the word reading test only. This was important for screening purposes so that children could get assigned to their appropriate groups based on their scores. This was followed by two batches one of which included the computerised tasks (e.g. the revised mispronunciations task, deede task, compound nouns task, and the aural suffix judgement task), and the other consisted of the non-computerised tasks (e.g. vocabulary, phoneme deletion, rhyme detection, and the stress assignment task). The order of these batches was randomised, and the order of tasks within each batch was also randomised. Participants performed individually and were sat on a chair next to the researcher against a table.

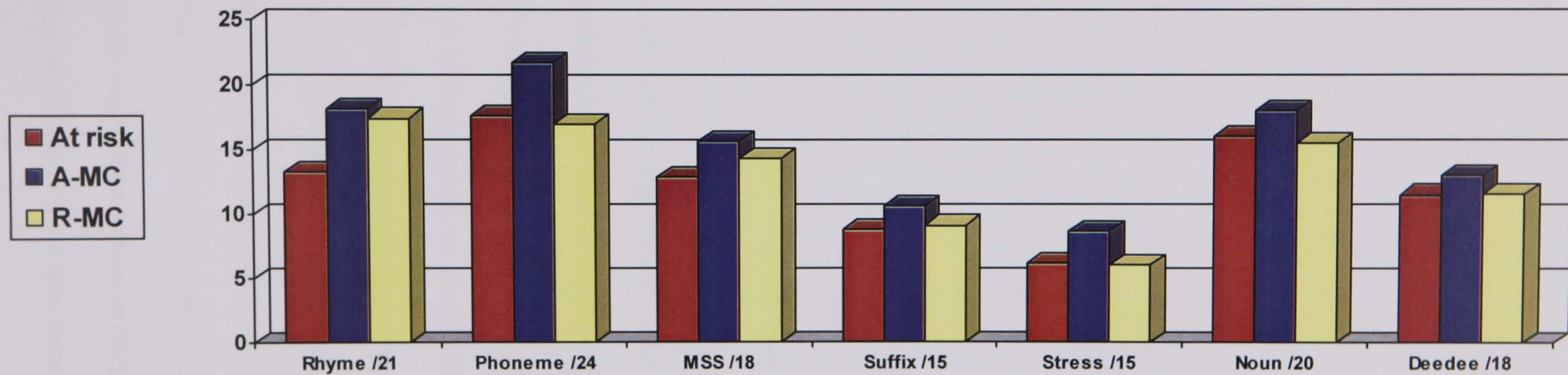
### 5.3. Results

This section begins with some descriptive statistics presenting the mean and standard deviation scores for each of the three groups on the measures of phonological awareness and speech rhythm sensitivity. It then presents a series of ANCOVAs to see whether there was a significant main effect of group on any of the speech rhythm measures after controlling for receptive vocabulary and phonological awareness. This is followed by a correlation matrix for the ‘at risk’ group, which includes all of the measures used in this study, along with a separate correlation matrix for the typical readers, which also includes all of the measures used in this study.

Table 5.2 shows the mean and standard deviation scores for the ‘at risk’ group, the chronological-age matched controls, and the reading-age matched controls on the measures of phonological awareness, vocabulary, and speech rhythm, and these are presented in Figure 5.1.

**Table 5.2 Summary statistics for the 'at risk' group, the chronological-age matched controls (AMC), and the reading-age matched controls (RMC) on the measures of phonological awareness and speech rhythm, along with the internal reliability of each test**

		Rhyme /21 a = N/A	Phoneme /24 a = 0.89	MSS /18 a = 0.6	Suffix /15 a = 0.15	Stress As /15 a = 0.73	Noun /20 a = 0.83	Deedee /18 a = 0.37
At risk	Mean	13.29	17.64	12.93	8.79	6.14	16.07	11.5
	SD	5.89	3.18	2.81	2.49	2.57	3.91	2.35
A-MC	Mean	18.21	21.71	15.71	10.64	8.71	18.07	13
	SD	4.42	2.02	1.64	1.22	3.87	3.17	2.45
R-MC	Mean	17.43	17	14.36	9.14	6	15.5	11.57
	SD	3.44	6.89	1.86	1.61	2.75	3.48	2.44



**Figure 5.1 Graphical representation of the mean scores displayed in Table 5.2**

It can be seen from Table 5.2 and figure 5.1 that the chronological-age matched controls outperformed both the 'at risk' group and the reading-age matched controls on all measures of phonological awareness and speech rhythm, as expected. The chronological-age matched controls scored in the upper range on all tasks with the exception of the stress assignment task where they obtained a score in the middle range.

Interestingly, the reading-age matched controls obtained a higher score on the rhyme awareness measure (mean = 17.43, SD = 3.44) than the 'at risk' group (mean = 13.29, SD = 5.89), although similar scores were obtained between the two groups on the phoneme deletion measure. With respect to the speech rhythm assessments, the reading-age matched controls obtained a higher score on the revised stress mispronunciations task (mean = 14.36, SD = 1.86) than the 'at risk' group (mean = 12.93, SD = 2.81).

Similarly, the chronological-age matched controls obtained marginally higher scores on the aural suffix judgment task (mean = 9.14, SD = 1.61) than the 'at risk' group (mean = 8.79, SD = 2.49). Moreover, an inspection of the alpha values indicates that while the stress assignment and the compound noun tasks have acceptable internal reliabilities ( $\alpha = 0.73$  and  $\alpha = 0.83$  respectively), the aural suffix judgment and the Deedee task have poor internal reliabilities ( $\alpha = 0.15$  and  $\alpha = 0.37$  respectively), so analyses including these measures should be treated with caution. Furthermore, while the internal reliability of the revised stress mispronunciations task was relatively low ( $\alpha = 0.6$ ), using a much larger sample found the internal reliability of this task to be much higher ( $\alpha = 0.82$ ). It should be noted that the internal reliability statistics were based on the scores from all three groups. When the analysis included the typical developers only (e.g. excluding the 'at risk' group) the internal reliability of most tests increased.

For the analyses of variance, 'phonological awareness' was a composite measure that was constructed by obtaining z-scores for the phoneme deletion task and the rhyme awareness task and then adding them together. Also, due to the fact that a significant main effect of group was found on both measures of vocabulary,  $F(2, 39) = 8.112$ ,  $p = 0.001$ , partial  $\eta^2 = 0.294$  and the phonological awareness composite measure,  $F(2, 39) = 4.642$ ,  $p = 0.016$ , partial  $\eta^2 = 0.192$ , these variables were controlled for in the subsequent Analyses of Covariance. Prior to analysis, the data were inspected to ensure that they met the assumptions for these analyses. Despite mild violations to the assumption of homogeneity of variance for the aural suffix judgement task, all other analyses satisfied the assumptions of normality and homogeneity of variance. there were no correlations between covariates exceeding 0.8, there was a linear relationship between the covariates and each of the dependent variables, and there was homogeneity of regression slopes given that there were no significant interactions between the treatment and the covariates.

The results of the ANCOVA showed that after controlling for receptive vocabulary and phonological awareness, there was a main effect of group on the children's overall performance on the revised stress mispronunciations' task,  $F(2, 37) = 3.727$ ,  $p = 0.034$ , partial  $\eta^2 = 0.168$ . However, a significant main effect of group was not found on the aural suffix judgment task,  $F(2, 37) = 7.402$ ,  $p = 0.120$ , the stress assignment task,  $F(2, 37) = 1.466$ ,  $p = 0.244$ , the noun task,  $F(2, 37) = 1.907$ ,  $p = 0.163$ , nor the Deedee task,  $F(2, 37) = 0.876$ ,  $p = 0.425$ . The significant main effect of group found on the revised stress mispronunciations' task was explored further using a post hoc analysis (Tukey LSD) to see whether there were significant group differences between the poor readers

and the reading-age matched controls, which would be indicative of a specific speech rhythm deficit in children at risk of dyslexia. It was found that although significant group differences were found between the poor readers and the chronological-age matched controls ( $p = 0.012$ ), no significant group differences were found between the poor readers and the reading-age matched controls on the revised stress mispronunciations task ( $p = 0.519$ ). This is indicative of a maturational lag as opposed to a specific speech rhythm deficit in children at risk of dyslexia.

To investigate the correlations between the revised stress mispronunciations tasks and the other measures of speech rhythm, phonological awareness and reading, two correlation matrices were inspected, one of which only includes the atypical developers (poor readers at risk of dyslexia) and the other of which only includes the typical developing children (chronological-age matched controls and the reading-age matched controls).

Table 5.3 shows the correlation matrix for the poor readers on all measures of speech rhythm, reading and phonological awareness.



**Table 5.3 Correlation matrix between age, speech rhythm, vocabulary, phonological awareness, and reading for the 'at risk' group**

Variables	1	2	3	4	5	6	7	8
1. Age								
2. MSS	-.055							
3. Suffix	.613*	.218						
4. Stress Ass	-.015	.364	-.236					
5. Noun	-.064	.147	.112	.114				
6. Deedee	.036	-.192	-.231	.447	-.055			
7. BPVS SS	-.445	.336	-.07	.213	.093	-.265		
8. PA comp	.654*	-.097	.266	.074	-.168	.327	-.18	
9. Reading	.822***	.1	.355	.308	.182	.162	-.233	.751**

Notes: Age, Age; MSS, stress mispronunciations' task; Suffix, Aural suffix judgement task; Stress Ass, Stress assignment task; Noun, Noun task; Deedee, Deedee task; BPVS, Vocabulary standard scores; PA comp, Phonological awareness composite; Reading, Reading.

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

It can be seen from Table 5.3 that the revised stress mispronunciations task was not significantly correlated with any of the measures of speech rhythm for the children at risk of dyslexia. Furthermore, a weak, non-significant correlation was found between the revised stress mispronunciations task and the phonological awareness composite ( $r = -0.097$ ,  $p = 0.742$ ) and between the revised stress mispronunciations task and reading ( $r = 0.1$ ,  $p = 0.733$ ). This absence of a relationship was not surprising because we would expect children with atypical reading development to have supra-segmental phonology that does not map on to segmental phonological awareness in the way expected with proficient readers, hence why they have been found to be deficient on both speech rhythm and phonological awareness measures. In support of this, we would expect to see stronger, significant relationships between the revised stress mispronunciations task and the measures of phonological awareness and reading in particular, in typically developing reading.

Table 5.4 shows the correlation matrix for the chronological-age matched controls and reading-age matched controls (typical developers) on all measures of speech rhythm, reading and phonological awareness.

**Table 5.4 Correlation matrix between age, speech rhythm, vocabulary, phonological awareness, and reading for the chronological-age and reading-age matched controls**

Variables	1	2	3	4	5	6	7	8
1. Age								
2. MSS	.425*							
3. Suffix	.472*	.076						
4. Stress Ass	.447*	.406*	.475*					
5. Noun	.398*	.455*	.114	.268				
6. Deedee	.334	.444*	.193	.513**	.217			
7. BPVS SS	-.334	.081	-.368	-.097	.104	.311		
8. PA comp	.335	.384*	.236	.398*	.399*	.461*	.373	
9. Reading	.739***	.57**	.361	.481*	.651***	.393*	.067	.627***

Notes: Age, Age; MSS, stress mispronunciations' task; Suffix, Aural suffix judgement task; Stress Ass, Stress assignment task; Noun, Noun task; Deedee, Deedee task; BPVS, Vocabulary standard scores; PA comp, Phonological awareness composite; Reading, Reading.

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

It can be seen from Table 5.4 that the revised stress mispronunciations task was indeed significantly correlated with phonological awareness ( $r = 0.384$ ,  $p = 0.043$ ) and reading ( $r = 0.57$ ,  $p = 0.002$ ), as expected. This was expected given the emerging evidence linking speech rhythm sensitivity to reading and phonological awareness. The revised stress mispronunciations task was also significantly correlated with most of the other speech rhythm measures; stress assignment ( $r = 0.406$ ,  $p = 0.032$ ), noun task ( $r = 0.455$ ,  $p = 0.015$ ), Deedee task ( $r = 0.444$ ,  $p = 0.018$ ), apart from the Aural Suffix Judgment task ( $r = 0.076$ ,  $p = 0.699$ ). This strengthens the validity of the revised stress mispronunciations task as a measure of speech rhythm sensitivity.

## 5.4. Discussion

The overall findings from this study emphasise the importance of speech rhythm in children's reading development. Chronological-age matched controls outperformed the poor readers at risk of dyslexia on all assessments in this study. However, from the comprehensive battery of speech rhythm measures, the results yielded significant group differences only on the stress sensitivity measure (revised stress mispronunciations task) from the speech rhythm battery after accounting for individual differences in receptive vocabulary and phonological awareness. This perhaps suggests that the revised mispronunciations task is the most sensitive measure of speech rhythm from this battery. Post hoc analyses revealed no significant group differences between the children at risk of dyslexia and the reading-age matched controls, which suggests that the speech rhythm deficits witnessed in children with reading difficulties (Gutierrez-Palma & Reyes, 2007; Wood, 2006a; Whalley & Hansen, 2006; Wolff, 2002; Goswami et al., 2002; Wood & Terrell, 1998b; Holliman et al., 2008) are more likely to be representative of a maturational lag in development as opposed to a specific deficit, which supports the findings from Goswami et al. (2002) and Wood and Terrell (1998b). It should be noted that some of the other speech rhythm measures (e.g. the aural suffix judgment task) had a relatively low, but non-significant *p*-value. Given the limited sample size and subsequent lack of statistical power in this study, we should be careful with our interpretation of this 'lack of significance'.

Interestingly, in children with typical reading development (chronological-age matched controls and reading-age matched controls) speech rhythm was found to be significantly correlated with reading and phonological awareness, however, these relationships were

not found in children with atypical reading development (poor readers at risk of dyslexia sample). This relationship was anticipated by Wood et al. (in press). To explain these relationships, the authors speculate that sensitivity to speech rhythm (supra-segmental phonology) is an important reading-related skill because it helps bind with phonological processing (segmental phonology). Children with proficient speech rhythm sensitivity would find these skills to be more easily transferable to phonological processing, which would allow for an increased capacity and potential to decode words. Moreover, in children at risk of dyslexia, their supra-segmental phonology does not map onto their segmental phonology, and their reading development might be impaired as a result of this. However, while these findings may contribute to our understandings regarding the role of segmental phonology and supra-segmental phonology in reading, the interpretations offered here should be treated with caution, especially due to the limited sample size in this study. More empirical evidence is required to support these claims.

There are some limitations to this study concerning the 'at risk' group classification criteria and the speech rhythm measures, which will be considered in turn. Firstly, the 'at risk of dyslexia' group was selected on the basis of having a reading and short-term memory age equivalent that fell at least two years behind their chronological age. However, while this criteria fulfils part of the APA's (2000, p.51) criteria for reading failure (reading accuracy that falls substantially below that expected in relation to the individual's chronological age, and age appropriate education) no assessment of intelligence was taken; intelligence should be in the normal range in this sample, although this has been disputed (Siegel, 1989; Stanovich, 1996). While the vocabulary

(a correlate of IQ) of each group fell in the normal range, the poor readers scored significantly lower than their reading-age matched counterparts on this task. so it is possible that the at-risk group are garden variety poor readers. In addition to this, we can only say, at most, that these children were ‘at risk of dyslexia’ because no formal classification had been made in these children. With regard to the speech rhythm assessments in this study, both the Deedee task and the Aural Suffix Judgment task had poor internal reliabilities and therefore the findings surrounding these tasks should be treated with caution. Recall that the original Aural Suffix Judgment task had 30 items rather than 15 and this adjustment to the task might have compromised its internal reliability in this study. Nevertheless, this study is the first to employ a comprehensive battery of speech rhythm measures and include both chronological-age and reading-age matched controls to investigate whether the observed speech rhythm deficits in children at risk of dyslexia are likely to be a specific deficit associated with the disorder or a mere general developmental delay.

## **5.5. Conclusion**

The findings from this study suggest that the relationship between speech rhythm and reading is more likely to be accountable to a general developmental delay, although more research is warranted to resolve this debate. The findings from this study also provide more evidence to suggest that speech rhythm sensitivity is related to reading: clear differences in terms of the relationship between speech rhythm (supra-segmental phonology) and phonological processing (segmental phonology) were found between typical and atypical developers. Speech rhythm sensitivity and sensitivity to stress provides reliable cues which help the individual to break up the speech stream into

interpretable units (spoken word recognition), enhance phoneme identification (Wood, 2006a), and facilitate the identification of onset rhyme boundaries (Goswami et al., 2002) and these supra-segmental skills, when proficient, help map onto the individual's segmental phonology, enabling more transparent, comprehensive segmental awareness and more complete phonological representations of words. Sensitivity to speech rhythm is implicated in successful reading development and should therefore be included into current models of successful reading development.

## Chapter 6 - General Discussion

This thesis set out to examine whether speech rhythm sensitivity is related to children's reading development, phonological awareness, and non-speech rhythm sensitivity (that is, the extent to which they are assessing different components of the same skill). The second major aim of this thesis was to examine whether speech rhythm sensitivity could predict the different components of children's reading over time. The third major aim was to investigate whether apparent speech rhythm sensitivity deficits in children at risk of dyslexia represent a specific deficit associated with the disorder, or whether they are due to a general developmental delay. The overarching aim was to investigate the role of speech rhythm sensitivity in children's reading development.

In terms of empirical evidence, there is a growing literature linking speech rhythm sensitivity to reading development (Wood & Terrell, 1998b; Kitzen, 2001; Goswami et al., 2002; Schwanenflugel et al., 2004; Wood, 2006a; Whalley & Hansen, 2006; De Bree et al., 2006; Ravid et al., 2007; Gutierrez-Palma & Reyes, 2007; Holliman et al., 2008; Thomson & Goswami, 2008; Thomson et al., 2006). However, many of these studies were not conducted in the English language (e.g. De Bree et al., 2006; Ravid et al., 2007; Gutierrez-Palma & Reyes, 2007). Others (e.g. Whalley & Hansen, 2006; Wood, 2006a) did not control for vocabulary, which is problematic given that vocabulary knowledge has been suggested to mediate the links between speech perception skills and reading (Walley, 1993). Some of the studies included speech rhythm tasks that placed heavy demands on memory (e.g. Wood & Terrell, 1998b; Whalley & Hansen, 2006). Moreover, only two studies have investigated whether speech rhythm sensitivity represents a specific deficit in children with reading

difficulties, by including both chronological-age matched and reading-age matched controls (Goswami et al., 2002; Wood & Terrell, 1998b). So, even studies which have found links between speech rhythm sensitivity and reading cannot conclude that this represents a specific disability in children who are at risk of dyslexia, and this means that the potential of this skill to be used for early identification of reading disorder in unexplained in English. The review of the speech rhythm measures discussed in the Methodology Chapter concluded that a revised form of the stress mispronunciations task used in Wood (2006a) and Holliman et al. (2008) would be best for assessing speech rhythm sensitivity (stress in particular) in young English-speaking children. However, because this revised task could be argued to tap into phonological awareness, in order to assess the uniqueness of speech rhythm sensitivity in children's reading development, phonological awareness would need to be controlled for in subsequent analyses.

To assess whether speech rhythm sensitivity deficits are implicated in normal reading development and reading difficulties, the following criteria would need to be met:

- Speech rhythm sensitivity would need be able to account for a significant amount of unique variance in reading attainment (concurrently and longitudinally) after controlling for vocabulary and phonological awareness
- To assess for a specific deficit, children at risk of dyslexia would need to be outperformed by both chronological-age matched controls and reading-age matched controls on measures of speech rhythm sensitivity



The three main studies in this thesis will now be discussed in relation to the theoretical and methodological contributions to the field of reading development.

## **6.1. Contribution of this Thesis**

This section will consider the unique contribution of this thesis to the field of psychology, and more specifically, to the field of reading development. The three studies included in this thesis will be considered in turn.

Recall that at the beginning of this thesis, it was argued that no study to date had looked at the relationship between speech rhythm and non-speech rhythm: there had been no longitudinal studies investigating the relationship between speech rhythm and reading development over time; no studies had investigated the link between speech rhythm and reading fluency; and no study to date investigated for a specific speech rhythm sensitivity deficit by including an ‘at risk’ sample of English-speaking children and a battery of speech rhythm measures.

Study One investigated the relatedness of speech rhythm, non-speech rhythm, reading ability and phonological awareness (that is, the extent to which they are assessing different components of the same skill) using a sample of 102 five- to seven-year-old English-speaking children. To assess speech rhythm sensitivity, a revised mispronunciations task was developed to overcome some of the problematic aspects of the original task used in Wood (2006a) and Holliman et al. (2008). This new measure was simpler, it included more distracter items with the same initial letter and phoneme, and it also included the digit span test to control for short-term memory. To assess non-

speech rhythm sensitivity, the rhythm copying task was developed, which required children to copy a rhythm that they had heard using a computer keypad (see the Methodology Chapter for more detail regarding these measures). There were three major research questions for Study One. Firstly, the relationship between speech rhythm sensitivity and non-speech rhythm sensitivity was investigated. Despite the growing literature linking speech rhythm to reading, and the more established literature linking non-speech rhythm to reading, it was not yet known whether speech rhythm sensitivity was related to non-speech rhythm sensitivity. Links between speech rhythm sensitivity and non-speech rhythm have been debated but have rarely been empirically examined. Wolff (2002) argued that non-speech rhythm and speech rhythm share many characteristics and properties and speculated that deficits in non-speech rhythm sensitivity might be related to speech rhythm sensitivity deficits. Although there is a lack of evidence investigating whether speech rhythm sensitivity is related to non-speech rhythm sensitivity, there is some support for this theory. For instance, Patel (1998) found similar ERPs for the processing of language and music (although this is not necessarily speech rhythm and non-speech rhythm), and Patel et al. (1998) found strong relationships between prosodic and musical perception in participants with amusia. However, a link between the two domains is not implicated in the neurological literature (Peretz, 1993; McMullen & Saffran, 2004). If speech rhythm does have links with non-speech rhythm, then it remains plausible that speech rhythm sensitivity might be affected in a similar way to that proposed for non-speech rhythm deficits; namely, that a temporal processing deficit might underlie the deficit (Farmer & Klein, 1995; Tallal, 1980; Tallal, 1984).

It was found that the revised stress mispronunciations task was not significantly correlated with the non-speech rhythm measure. Non-speech rhythm also had a weak factor loading on the reading-related factor, which did incidentally include the speech rhythm sensitivity measure. While some limitations to this study were considered which might explain this lack of relatedness (e.g. the non-speech rhythm task only measured duration, which is one component of non-speech rhythm, and because the speech rhythm task was a receptive measure and the non-speech rhythm task was a productive measure), the relationship between the two assessments was very weak, indicating a lack of similarity between the two domains.

Secondly, it was investigated whether speech rhythm sensitivity could predict unique variance in reading attainment, beyond its relationship with non-speech rhythm sensitivity. This relates to the first question; if the relationship between speech rhythm and non-speech rhythm is extremely strong, then we would anticipate that speech rhythm would be unable to account for unique variance in reading once non-speech rhythm had been controlled.

There was a distinct lack of research investigating whether speech rhythm could predict reading independently of non-speech rhythm. In addition to controlling for non-speech rhythm, it was important to see whether speech rhythm sensitivity could predict unique variance in reading after controlling for phonological processing. This is important because the nature of the revised stress mispronunciations task does carry a phonological component, and links have been documented between speech rhythm and phonological awareness (Goswami et al., 2002; Corriveau et al., 2007; Wood, 2006b).

Moreover, many of the ways in which speech rhythm sensitivity has been related to reading development theoretically (e.g. that it enhances phoneme awareness, facilitates onset-rime awareness etc) suggest that the link between speech rhythm sensitivity and reading might be mediated by phonological awareness. While a handful of studies have found that speech rhythm sensitivity can predict reading beyond its relationship with phonological awareness (e.g. Holliman et al., 2008; Whalley & Hansen, 2006; Wood, 2006a) more research was warranted to consolidate this finding. It was found that speech rhythm sensitivity could predict a significant amount of unique variance after non-speech rhythm and phonological awareness had been accounted for, and was still able to do this after controlling for age, vocabulary, and short-term memory.

These findings suggest that speech rhythm sensitivity is not merely a skill which can be subsumed by phonological awareness or non-speech rhythm; it is a skill which is explaining new variance in reading ability. It was suggested that the way in which speech rhythm might facilitate reading beyond phonological awareness, may be explained via its 'potential' relationship with morphological awareness or comprehension processes, however, there was no assessment of morphology included in this thesis. The third and final question for Study One concerned whether non-speech rhythm could predict significant, unique variance in reading attainment after speech rhythm sensitivity and phonological awareness had been controlled. Many studies have demonstrated non-speech rhythm deficits in poor readers (e.g. Overy, 2000; Overy et al., 2003; Wolff, 2002), and these have often been explained by the temporal processing deficit hypothesis; that is, that deficits in rhythm, sequencing, timing, and duration (temporal properties) might contribute to difficulties with phonemic perception and

discrimination, which would have an adverse effect on phonemic awareness (Farmer & Klein, 1995), which has been consistently linked to reading development. Despite this relationship between non-speech rhythm and reading, there was a distinct lack of research investigating whether non-speech rhythm is predictive of reading ability beyond its relationship with speech rhythm sensitivity and more research was warranted to inform this claim. It was found that while non-speech rhythm was indeed significantly related to reading, it was unable to predict unique variance in reading attainment after phonological awareness and speech rhythm had been controlled. This perhaps indicates that the way in which non-speech rhythm relates to reading can be explained via its relationship with speech rhythm, but more so with phonological awareness for which the correlation was stronger. Despite some short-comings with the non-speech rhythm task (noted earlier on in this section), these findings suggest that speech rhythm sensitivity contributes independently to reading development, whereas non-speech rhythm failed to do this.

There were some outstanding questions from Study One; for instance, only one type of reading assessment had been used so far from Study One (a word reading test, along with one simplified fluency assessment). Therefore, the relationship between the measure of speech rhythm sensitivity used in this study and the different components of reading (e.g. word reading, reading accuracy, reading fluency, reading comprehension, spelling, and non-word reading) remains unknown and has not yet been assessed. This might help to inform precisely how speech rhythm sensitivity relates to reading development. It is also not known how speech rhythm sensitivity relates to reading over

time, and whether it can be predictive of children's reading attainment later on. These issues were addressed in Study Two.

Study Two investigated whether speech rhythm sensitivity could predict different components of reading ability (e.g. word reading, reading accuracy, reading fluency, reading comprehension, spelling, and non-word reading) one-year later after controlling for receptive vocabulary, age, and phonological awareness. Of the 102 children that took part at Time 1 (in Study One), 69 six- to eight-year-old English-speaking children took part at Time 2. These children completed the revised stress mispronunciations task at Time 1 along with some other cognitive assessments, and then completed the various reading assessments at Time 2 (see the Methodology Chapter for more detail regarding these measures). There was a single, general research question for Study Two, which was whether speech rhythm sensitivity could predict children's word reading, reading accuracy, reading comprehension, spelling, non-word reading, and reading fluency components one year later after controlling for vocabulary, age, and phonological awareness. Using a path analysis, it was also investigated whether speech rhythm was directly related to these reading components and how it was related through various potential mediating variables (e.g. age, vocabulary, phoneme, and rhyme). This would help to inform the legitimacy of the model proposed Wood et al. (in press), from Chapter 1. A great deal of the literature investigating the relationship between speech rhythm and reading has found links between speech rhythm sensitivity and word reading ability (Whalley & Hansen, 2006; Holliman et al., 2008; Wood and Terrell, 1998b; Wood, 2006a; Goswami et al., 2002; Gutierrez-Palma & Reyes, 2007). This is supported theoretically and has been discussed earlier in this thesis.

Moreover, speech rhythm sensitivity has also been implicated in fluent reading (Kuhn & Stahl, 2003; Schwanenflugel et al., 2004; Dowhower, 1991; Miller & Schwanenflugel, 2006) and Whalley and Hansen (2006) have found that speech rhythm could predict reading comprehension, and argued that speech rhythm sensitivity might convey meaning and highlight the more important aspects of the text. To link prosody, fluency, and comprehension together, Kuhn and Stahl (2003) argued that proficient speech rhythm (phrasing, intonation, and stress) while reading suggest that the child is reading fluently, and that if a child demonstrates these rhythmical skills while reading, it also suggests that they understand (comprehend) what has been read because they are selectively parsing the text and grouping it into syntactically appropriate phrases.

Additionally, links have also been found between speech rhythm and spelling (Wood, 2006a; Goswami et al., 2002) and between speech rhythm and non-word reading (Goswami et al., 2002; Kitzen, 2001), however, there is a general lack of empirical evidence investigating the relationship between speech rhythm and the different components of reading. The question of how speech rhythm relates to the different components of reading is an important one, because it might help to ascertain how speech rhythm is related to reading development and indicate the component skills it relates to the most. It was found that speech rhythm sensitivity was able to account for a significant amount of variance in measures of word reading, reading comprehension, and the phrasing component of the reading fluency measure after receptive vocabulary, age, and phonological awareness has been controlled. This was in line with the literature, where links between speech rhythm and reading (Whalley & Hansen, 2006; Holliman et al., 2008; Wood and Terrell, 1998b; Wood, 2006b; Goswami et al., 2002;

Gutierrez-Palma & Reyes, 2007), comprehension (Whalley & Hansen, 2006; Kitzen, 2001; Kuhn & Stahl, 2003), and fluency (Kuhn & Stahl, 2003; Schwanenflugel et al., 2004; Dowhower, 1991; Miller & Schwanenflugel, 2006) have been found. This once again, highlights the importance of speech rhythm sensitivity in children's later reading development, particularly in decoding words, reading fluently, and comprehending what has been read. Most theoretical links between speech rhythm and reading development were implicated via these reading components in particular, so the empirical evidence was in support of the theoretical literature.

There were some outstanding questions from Study One and Study Two: for instance, only one type of speech rhythm sensitivity measure was used (the original and revised stress mispronunciations task, which both involved stress reversal) and it is important for construct (convergent) validity that poor readers are found to have deficits on other measures of speech rhythm sensitivity. However, it must be noted that there are relatively few speech rhythm assessments suitable for this age group in the literature. It is also important to carry out a group difference study using atypical developers, to see whether children at risk of dyslexia have speech rhythm sensitivity deficits in comparison to chronological-age and reading-age matched controls. These outstanding questions were addressed in Study Three.

Study Three investigated whether apparent speech rhythm sensitivity deficits in a group of poor readers identified as at risk of dyslexia represent a specific deficit, or whether the relationship is due to general developmental delay. The sample consisted of 14 English-speaking children aged nine- to eleven-years-old and classified as 'at risk of



dyslexia' on the basis of them having a reading age and short-term memory age equivalent at least two years behind their chronological age. Additionally, 14 chronological-age matched controls were recruited along with 14 younger, reading-age matched controls. In accordance with Study One, the revised mispronunciations task was used to assess speech rhythm sensitivity. However, four additional measures of speech rhythm sensitivity were also included, which were obtained from the recent literature. These included the DEEdee task (Whalley & Hansen, 2006), which assessed children's ability to match the correct nonsense phrase (deedee) to a spoken phrase based on its prosodic features (for instance, the word *Sofa* would be DEEdee rather than deeDEE, and *appear* would be deeDEE rather than DEEdee), the Compound Noun task (Whalley & Hansen, 2006), which assessed children's ability to discriminate between noun phrases and compound nouns based on prosody (e.g. between chocolate, cake and honey and chocolate-cake and honey), the Aural Suffix Judgment task (Wade-Woolley, 2007), which assessed children's ability to choose the correct non-word from a choice of two non-words which sounds the best in a sentence based on the regularity of stress, and the Stress Assignment task (Wade-Woolley, 2007), which assessed children's ability to identify the stress in spoken words by clapping on the appropriate syllable (e.g. ap-pear). These measures broadly tapped into various speech rhythm sensitivity components (see the Methodology Chapter for more detail regarding these measures).

There were two major research questions for Study Three. Firstly, it was investigated whether there were significant differences between the children 'at risk of dyslexia' and the chronological-age matched and reading-age matched controls in terms of their speech rhythm sensitivity (using the different measures) after controlling for receptive

vocabulary and phonological awareness. In assessing for a specific deficit, it was important to include both a chronological-age matched control group and a reading-age match control group to rule out the idea that the observed speech rhythm sensitivity deficits are merely part of a general developmental delay. For a specific deficit we would expect the 'at risk' group to be outperformed by both control groups. While a growing literature has related speech rhythm sensitivity to reading development without including a dyslexic sample per se, it should be noted that children with dyslexia have also been found to be less sensitive to speech rhythm than 'chronological-age matched' controls (e.g. Wolff, 2002), although a reading-level matched control group was not included. In fact, only two studies to date have investigated whether speech rhythm deficits are likely to represent a specific deficit or general developmental delay by including a reading-level matched control group in addition to a chronological-age matched control group (Goswami et al., 2002; Wood & Terrell, 1998b). Both of these studies found support for the 'maturation lag' idea, where the poor readers group was only outperformed by the chronological-age matched controls. Therefore further research was warranted to help resolve this line of enquiry. It was found that after controlling for receptive vocabulary and phonological awareness, there were significant group differences on the revised stress mispronunciations task from the speech rhythm battery. However, post hoc analyses revealed that significant group differences only existed between the 'at risk' group and the chronological-age matched and not between the poor readers and the reading-age matched controls. There were no significant main effects of group on any of the other speech rhythm sensitivity measures from the speech rhythm battery. These findings were in line with Goswami et al. (2002) and Wood and Terrell (1998b) and are suggestive of a maturational lag, rather than a specific deficit.

Nevertheless, the chronological-age matched controls outperformed the 'at risk' group on all speech rhythm measures, which suggests that speech rhythm is related to reading.

There were some noted short-comings to this study; for instance, the 'at risk' group were classified based only on having a reading and short-term memory age equivalent at least two years behind their chronological age. However, these children may or may not go on to be classified as dyslexic. An IQ measure might have been included to help classify this group to ensure that they represent an 'at risk' sample rather than garden variety poor readers. However, there is much controversy over the idea that to be dyslexic, children should have an average or above average IQ (e.g. Siegel, 1989; Stanovich, 1996). Additionally, the internal reliability of some of the speech rhythm tasks (e.g. the DEEdee task and the Aural Suffix Judgement task) had unacceptable alpha levels, which means that the interpretation of the findings related to these tasks should be treated with caution. So, speech rhythm sensitivity was once again found to be related to reading development, but the observed speech rhythm difficulties are more likely to represent a developmental delay in poor readers. Moreover, the fact that the revised stress mispronunciations task was the only speech rhythm measure to yield a significant main effect, perhaps suggests that this is the most sensitive measure of speech rhythm, which is a testament to its design.

The second question for Study Three, concerned how the various measures of speech rhythm sensitivity relate to each other, to reading, and to phonological awareness. We would expect speech rhythm sensitivity to be related to phonological awareness given their documented relationship (Goswami et al., 2002; Corriveau et al., 2007; Wood,

2006a). We would also expect speech rhythm to be related to reading, given the growing literature reporting this. In terms of construct (convergent) validity we would also perhaps expect the different measures of speech rhythm sensitivity to relate closely together, if they are indeed tapping into the same skill. It was found that for typical readers (that is, the chronological-age and reading-age matched controls) the revised stress mispronunciations task (the main speech rhythm assessment) was indeed significantly correlated with most of the speech rhythm assessments, the phonological awareness assessments, and the reading measure. However, for the 'at risk' group, the revised stress mispronunciations measure was not significantly correlated with any of the other speech rhythm measures, nor the phonological awareness or reading measure. It was argued that proficient speech rhythm sensitivity (suprasegmental phonology) might aid the development of segmental phonology, and this has been supported here. Conversely, we would expect poor readers to have suprasegmental phonology that does not map onto their segmental phonology, and this was supported by the findings. This also supports the predictions made by Wood et al. (in press). It should be noted that any lack of significance reported in this study should be treated with caution due to the small sample size and lack of statistical power. Also, recall that some of the speech rhythm tasks had poor internal reliability. Despite this, the findings suggest that speech rhythm sensitivity is an important reading-related skill, and that suprasegmental phonology maps onto segmental phonology in typical readers thus typifying the importance of both segmental and suprasegmental phonology in children's reading development.

In summary, the evidence from Studies One, Two, and Three indicate that speech rhythm sensitivity (as assessed using the stress mispronunciations task) plays an important role in children's reading development. So what can we say about this role and the relationship speech rhythm sensitivity and reading development based on the evidence from the studies included in this thesis? It is likely that sensitivity to aspects of speech rhythm, such as stress, might make it easier to decode the phonemes in words, and phonemic awareness has been linked extensively with children's reading development (Muter et al., 1998; Lundberg, 1991; Pratt & Brady, 1988; Hulme et al., 1998). As Chiat (1983) and Wood and Terrell (1998b) argued, it is easier to decode phonemes in stressed rather than unstressed syllables. For instance, using the British received pronunciation accent, Wood (2006, p.271, 272) demonstrates that the schwa sound /ə/ can be written as 'a' in 'about', 'o' in 'today', 'er' in 'lower', 'e' in 'cinema', 'ou' in 'notorious', and 'ure' in 'pleasure'. Thus, it is often difficult to identify the correct phoneme-grapheme correspondence in unstressed syllable in the English language. Moreover, the ability to manipulate and apply stress to unstressed syllables will help to clarify ambiguous phonemes (Chiat, 1983) and also help to match mispronounced words to those stored in the lexicon (Kitzen, 2001). For instance, to successfully decode the words in Wood's example, the reader might have to apply stress to the schwa sounds so that they are pronounced; *About*, *tOday*, *cinEma*, *notoriOUs*, *pleasURE*. Such sensitivity to, and manipulation of, stress might enhance phoneme identification and facilitate the matching process between the input and the word stored in memory. Recall that speech rhythm was most often assessed using the stress mispronunciations task in this thesis, which contained incorrectly stressed words. It was thought that to succeed at this task, children would need to be sensitive to the fact that

the stress of the word had been manipulated (or reversed) and be able to reverse, or apply stress to the unstressed syllables in order to match the input with the appropriate word stored in the lexicon. Given the nature of this task, and the relationship found between performance on this task and reading ability, this theoretical explanation is supported in this thesis.

Another explanation is that sensitivity to stress might make it easier to identify onset-rime boundaries, and onset-rime is a skill that has been linked with reading development (Goswami, 2003; Goswami et al., 2002; Goswami & Bryant, 1990; Bryant, 1998; Bradley & Bryant, 1978; Bryant et al., 1990; Wood & Terrell, 1998b). Goswami and colleagues have shown that peak of loudness in a syllable corresponds to vowel location in spoken words. Therefore, if an individual is more sensitive to stress, they will be more likely to identify the onset and rime within a word, decode it, and be able to make analogies between other similarly sounding words. Thus, sensitivity to suprasegmental components of speech (e.g. rhythm and stress) are likely to facilitate phonological processing (Goswami et al., 2002), and phonological awareness has been consistently linked with reading development (see Adams, 1990; Snowling, 2000 for reviews).

It is also likely that speech rhythm sensitivity might have perceptual implications and facilitate spoken word recognition, which are important skills in the reading development literature. For instance, basic speech processing ability has been linked with reading development in the literature (e.g. McBride-Chang, 1995; McBride-Chang, 1996; Studdert-Kennedy, 2002; Manis et al., 1997; Wood & Terrell, 1998b; Brady et

al., 1983; Reed, 1989), and one specific aspect of speech perception is spoken word recognition, which literally refers to the identification of a word (or words) in speech. However, during fluent speech, it can be very difficult for young children to identify where one word ends and another begins, because there are few audible pauses between words (Wood & Terrell, 1998b). It has been argued that sensitivity to the rhythmic properties of native language (such as stress) might facilitate the word recognition process (Wood & Terrell, 1998b; Cutler & Norris, 1988; Cutler, 1994; Cutler & Carter, 1988), and the ability to identify words in speech (spoken word recognition) has been linked to reading development in the literature (e.g. Metsala, 1997). Indeed, as English is a stress-timed language, and because strong syllable mark the beginnings of words in most cases in English (Cutler, 1994; Cutler & Norris, 1988; Cutler & Carter, 1987), sensitivity to stress would help with the identification of word boundaries in fluent speech (Cutler & Butterfield, 1992; Wood & Terrell, 1998b; Lindfield et al., 1999) and aid the retrieval of words from the lexicon (Lindfield et al., 1999). So, sensitivity to speech rhythm might facilitate the identification of words from the speech stream and enhance lexical access and arguably, vocabulary development, although the relationship between speech rhythm sensitivity and vocabulary may be bidirectional (Walley, 1993). However, it should be noted that while there are many theoretical links between speech rhythm sensitivity and vocabulary development in the literature and in models of reading development (e.g. Wood et al., in press), the path analysis from Study Two yielded a very weak, non-significant relationship between the two skills. However, it was noted that this could have been due to the fact that word frequency was controlled for in the selection of target and distracter items in the development of this task.

Speech rhythm sensitivity is also implicated in fluent reading, especially if we consider fluency to comprise of prosody as well as rate, which is a superior measure of fluency according to most theorists (e.g. Kuhn & Stahl, 2003; Schwanenflugel et al., 2004; Dowhower, 1991; Miller & Schwanenflugel, 2006). Some theorists (e.g. Kuhn & Stahl, 2003) argue that speech rhythm, fluency, and reading comprehension might all be linked together to facilitate reading development. Kuhn and Stahl (2003, p.6) noted that “appropriate phrasing, intonation, and stress are all considered to be indicators that a child has become a fluent reader...they act as indicators of the reader’s comprehension...given that a fluent reader is one that groups text into syntactically appropriate phrases, this parsing of text signifies that the reader has an understanding of what has been read”. Related to this, Whalley and Hansen (2006) have argued that speech rhythm sensitivity might facilitate the segmentation of speech (noted previously), but also the chunking of spoken language into syntactically comprehensible units. This would likely reduce memory load and also enable the reader to focus on the more relevant aspects of the text, in turn facilitating reading comprehension. Moreover, the relationship between speech rhythm, fluency, and comprehension may be bidirectional related. For instance, Schwanenflugel et al. (2004) noted that proficient decoding skills should free up attention resources, and that these additional resources could then be made available to prosodic processing, and subsequently have some additional contribution to reading comprehension. So, speech rhythm sensitivity might facilitate and be facilitated by decoding skills and reading comprehension, and there is evidence in the literature for a strong relationship between speech rhythm and reading comprehension (e.g. Whalley & Hansen, 2006; Kitzen, 2001).



One other ‘potential’ explanation of how speech rhythm relates to reading development might be explained via morphology, although this was not assessed in this thesis. Multisyllabic words are made up of different morphological components, such as affixes, suffixes, and root words (Jarmulowicz et al., 2008; Casalis et al., 2004). Performance on tasks assessing knowledge of such morphological components has been related to reading development in the literature (Carlisle, 2000; Nagy et al., 2006; Nagy et al., 2003; Ravid & Mashraki, 2007; Green et al., 2003; Deacon & Kirby, 2004; Siegel, 2008; Mahony et al., Mann, 2000). While strong associations exist between morphology and phonological awareness (e.g. Casalis et al., 2004; Nagy et al., 2006), morphological awareness has been found to predict reading ability beyond phonological awareness (e.g. Deacon & Kirby, 2004; Siegel, 2008; Mahony et al., 2000). Thus, it might be the case that the core findings in this thesis; that speech rhythm sensitivity was able to predict reading development independently of phonological awareness, might be because it is contributing to morphology knowledge, which seems to be related to reading development in a different way to that of phonological awareness. Recall that in multisyllabic word reading, stress rules becomes more important because there is sometimes a stress-shift depending on the suffix of that word (Wade-Woolley, 2007; Clin & Wade-Woolley, 2007), for instance, words ending with the suffix *ity* or *tion*, result in a shift of stress to the syllable immediately before that suffix (Wade-Woolley, 2007), thus the stress location in the word *universe* shifts in the word *university*. Thus, sensitivity to stress might be related to morphology and assist in matching the input to words stored in the mental lexicon (Kitzen, 2001), which would, in turn, have a positive impact on literacy development. Related to this line of argument, Clin and Wade-Woolley (2007) found that speech rhythm sensitivity was no longer able to predict

reading attainment after morphological awareness had been controlled, which supports the suggested link between speech rhythm, morphology, and reading. While this study used a slightly older sample than that included in this thesis, it remains plausible that morphological awareness might mediate the observed relationship between speech rhythm sensitivity and reading development. Moreover, the need to consider speech rhythm sensitivity (and stress in particular) has been acknowledged by researchers in the field. For instance, Protopapas (2006, p.418) has argued that “reading models must be extended to account for multisyllabic word reading including, in particular, stress assignment” and that “if stress assignment is an important and necessary step in reading aloud, then cognitive models of reading must be extended to include it” (Protopapas, 2006, p.428-429). More research is warranted to investigate whether speech rhythm sensitivity, and stress in particular, facilitate the development of reading through morphological awareness development.

## **6.2. Limitations and Outstanding Questions**

This thesis included three studies to investigate the role of speech rhythm sensitivity in children’s reading development. This thesis included concurrent, longitudinal, and cross-sectional data, a range of reading measures, along with a battery of speech rhythm assessments from the recent literature, including a credible speech rhythm sensitivity assessment (the revised stress mispronunciations task) that was developed as part of this thesis. While the relationship between speech rhythm and children’s reading development has been informed on many levels as a result of the studies included in this thesis, there are many avenues for further research that were not sufficiently addressed in this thesis. This might have been due to inclusive methodological limitations or due

to the findings and theoretical implications of the studies included in this thesis. These various avenues for further research will now be considered in turn.

To investigate speech rhythm sensitivity in this thesis, the main task that was developed and used in all three studies was the revised stress mispronunciations task. This task was carefully chosen and developed as a result of a review of the speech rhythm tasks currently in the literature. This task was selected mainly because it would assess stress, which seems to be the key aspect of speech rhythm and is the aspect of speech rhythm that has been most commonly assessed in the literature; thus, this will enable a more direct comparison with the literature. It would also be suitable for younger children, without being confounded by memory demands, as it was used by Wood (2006b) and Holliman et al. (2008) and worked well with beginning readers. This revised task was developed to overcome some problems with the original version of this task. The revised task was simpler so that it would be more appropriate for beginning readers and young children, it contained distracter items which began with the same initial letter and phoneme, and the target and distracter items were used of similar frequency, to help control for vocabulary knowledge. Incidentally, given the nature of this task it was felt necessary to control for vocabulary and phonological awareness throughout the analyses to help isolate speech rhythm sensitivity. Moreover, this task was shown to have good internal reliability in Study One ( $\alpha = 0.82$ ). Despite these positive aspects of the task, there are a few inherent problems. For instance, the revised stress mispronunciations task could be seen as a problem solving task, which demanded more intellectual skills that may have been less well-developed in poor readers. This is possible, given that Study Three indicated that poor readers have a maturational lag.

Also, it is entirely possible that some of the 'at risk' children in Study Three were garden variety poor readers as opposed to children at risk of dyslexia, and this idea cannot be totally ruled out because no measure of IQ was taken. Although an IQ measure would have been useful, it should be noted that vocabulary was always controlled for in the analyses in this study, which has commonly been used as a proxy for IQ (e.g. Wood & Terrell, 1998b). Nevertheless, if the children in Study Three were indeed garden variety poor readers rather than potential dyslexics, the findings from the study should be treated with caution with respect to generalizing them to the field of dyslexia. Moreover, given the nature of the revised task, and the fact that children listen to mispronounced words with irregular stress in order to identify the target items, some might argue that this task is more a measure of stress insensitivity rather than stress sensitivity. However, many researchers argue that children need to be sensitive to the fact that the stress has been manipulated and must be capable of making a stress-shift to help clarify ambiguous phonemes, and match the input to a word stored in the mental lexicon (Kitzen, 2001; Wood, 2006b; Holliman et al., 2008; Chiat, 1983). Additionally, as *positive* relationships were found between performance on the revised task and other stress sensitivity measures, along with reading ability, this also suggests that this task is a measure of stress sensitivity, and not a measure of stress insensitivity.

A further limitation was that the target and distracter items in this task could have been better matched so that there was an equal ratio of words ending in schwa sounds, in open syllables, the type of affix etc. However, matching words on this basis would have been very difficult. It was important to control for the most problematic aspects of the original task; that is, to include distracter items, which began with the same phoneme as

the target item to rule out any phonemic explanation, and to ensure that the target and distracter items were used of similar frequency to rule out vocabulary explanations (Holliman et al., 2008). To match the distracter items on other additional factors would have been too difficult if not impossible, so the decision was made to control only for the most problematic aspects of the task.

Recall from Study Three that four additional speech rhythm assessments were also adopted from the recent literature; however, two of these tasks had unacceptable internal reliability. Given some of the limitations of the revised stress mispronunciations tasks, coupled with the poor internal reliability of some of the other speech rhythm tasks used, one avenue for further research would be to develop a better speech rhythm sensitivity task than that used in this thesis. This new task might assess different components of speech rhythm, other than stress, and might be standardised and have increasing difficulty levels to enable use with different age groups. There are few speech rhythm assessments in the literature which are suitable for children and adults, so such a new, improved speech rhythm sensitivity measure would be extremely useful.

There were also problems with the non-speech rhythm measure from Study One. The only aspect of non-speech rhythm that was assessed in the productive non-speech rhythm task was duration/timing to help isolate the temporal processing deficit. However, non-speech rhythm consists of many other components such as pitch, intensity, rate, frequency (Patel et al., 1998). Perhaps a more comprehensive non-speech rhythm task would have been better able to assess the relationship between non-speech rhythm and speech rhythm, and between non-speech rhythm and reading. Moreover, the

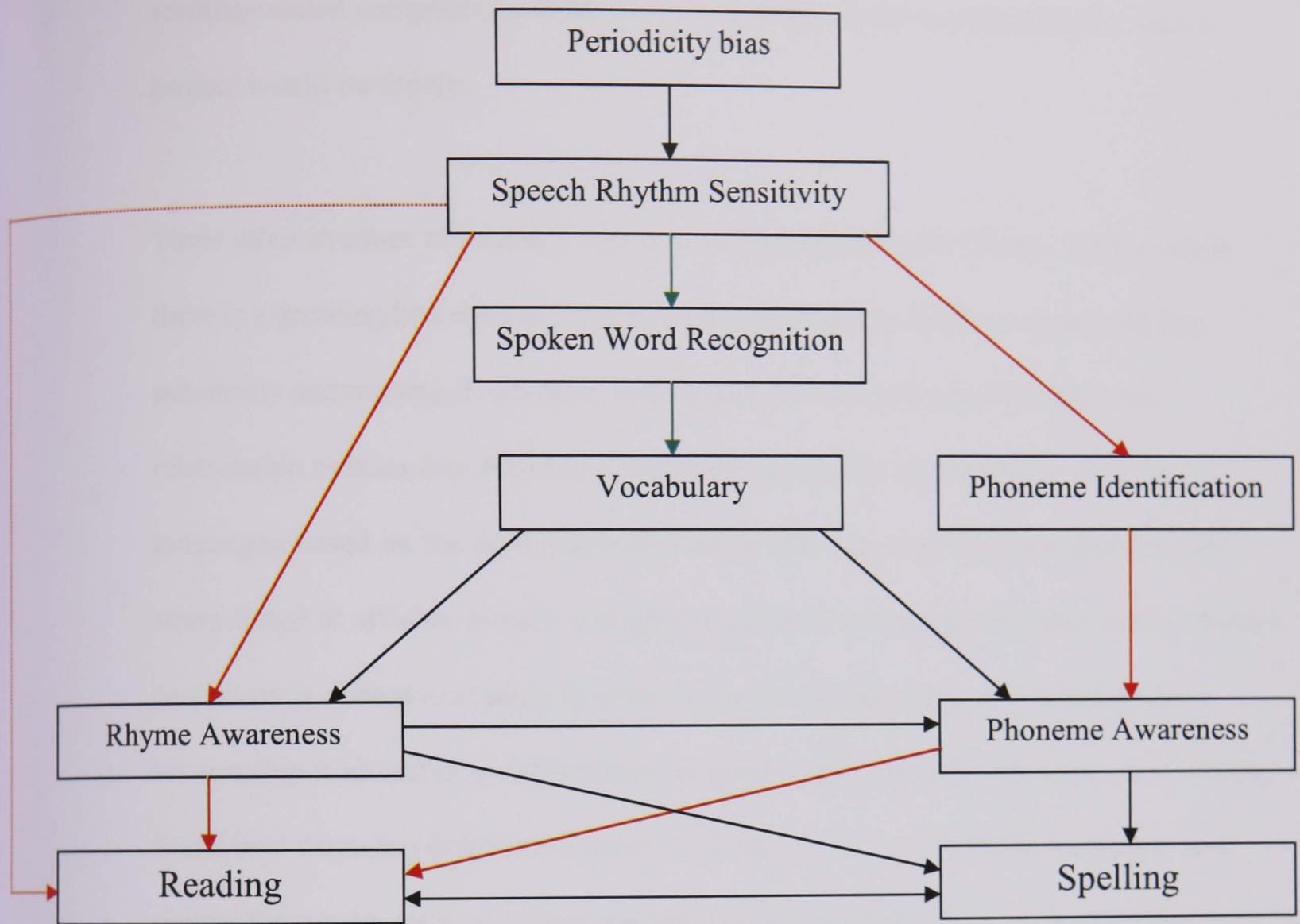
receptive non-speech rhythm task was found to have unrecoverable, unacceptable internal reliability and was therefore not included in the main analyses. Perhaps the inclusion of a better receptive non-speech rhythm measure might also have produced different results to those obtained here.

In Study Three, it was investigated whether speech rhythm sensitivity deficits in a group of poor readers at risk of dyslexia represent a specific deficit, or whether it is likely due to a developmental delay. 14 children at risk of dyslexia were obtained, along with 14 age-matched controls and 14 reading-age matched controls. While some potential problems with the classification of the 'at risk' group have already been noted (see Section 6.1), this study also had a very small sample size and lack of statistical power. It should be noted that the younger, reading-age matched controls did outperform the 'at risk' group on three of the speech rhythm assessments; however, due to the lack of statistical power this did not reach significance. Therefore, the findings from Study Three informing the question as to whether speech rhythm sensitivity deficits are likely to be a specific deficit or maturational lag should be treated with caution.

As noted many times throughout this thesis, one alternative explanation for the observed relationship between speech rhythm sensitivity and reading, independently of phonological awareness is that speech rhythm sensitivity might contribute to morphology. This seems plausible and yet has rarely been empirically assessed. This thesis did not include a measure of morphology and therefore it cannot inform this claim. Indeed, morphological explanations for this relationship are very new to the literature and very few studies have investigated this (e.g. Clin & Wade-Woolley,

2007). Therefore, one avenue for further research would be to include a speech rhythm sensitivity measure, along with an assessment of phonological awareness, morphological awareness, and reading, to see whether speech rhythm sensitivity can still predict unique variance in reading after controlling for the other two, but also to see whether speech rhythm sensitivity is more related to phonology or morphology. The literature on speech rhythm sensitivity also demands a path analysis to help unpick the relationships between speech rhythm, phonological awareness, speech perception, morphology, and reading ability (word reading, comprehension, fluency). While, this has been informed to some extent via the hierarchical multiple regression analyses and the path analyses included in this thesis, to date, no study has included a more comprehensive path analysis, which includes the speech rhythm measure, the various mediator variables, and all of the reading measures in the same diagram. This would better our understandings of the relationship between speech rhythm, other cognitive measures, and the various reading measures. However, such an analysis would require a much larger sample of children and was not possible to do in this thesis.

Recall the hypothesised model regarding how speech rhythm might be related to reading, proposed by Wood et al. (in press), that was shown in Chapter 1. This has been slightly edited in Figure 6.1; the relationships supported by the data included in this thesis are represented by hard red lines, the relationships that were not supported by the data in this thesis are represented by hard black lines, the relationships that we expected to find, but were not supported by the data in this thesis are represented by hard green lines, and the relationships that were not assessed for in this thesis, but are theoretically plausible are represented in dotted red lines.



**Figure 6.1** How speech rhythm sensitivity might be related to reading development

In this thesis, these explanations (paths) have been considered theoretically and/or empirically. Speech rhythm was unable predict unique variance in spelling after controlling for phonological awareness, however, it was able to predict reading ability (word reading, reading comprehension, and fluency). Thus, it is likely based on the evidence from this thesis, that speech rhythm sensitivity contributed to reading by facilitating fluency and comprehension, or it could be, in line with this model, that the relationship between speech rhythm and reading might be mediated by morphology (the dotted lines). In summary, morphology needs to be assessed along with all other



reading-related components noted above in a comprehensive path analysis: such a project would be timely.

Three other avenues of research will now be considered more briefly. Firstly, while there is a growing literature investigating the relationship between speech rhythm sensitivity and reading in children, few studies have investigated whether this relationship persists into adulthood. Secondly, given the discrepancies of different languages, based on the rhythmic properties of that language (e.g. whether they are stress-timed or syllable-timed), it might be useful to investigate whether speech rhythm sensitivity is related to reading in other stress-timed languages, and whether the relationship is absent in syllable-timed languages. Interestingly, Muneaux et al. (2004) found beat detection deficits in French dyslexics, which is a syllable-language, so it seems that sensitivity to rise-time at least may be universal. Thirdly, it would be interesting to investigate the relationship between speech rhythm sensitivity and reading using different paradigms. Some researchers (e.g. Ashby & Clifton Jr, 2005) have assessed prosody using eye movements. To enhance construct (convergent) validity, it would be important to demonstrate speech rhythm sensitivity deficits using a variety of assessment from different paradigms.

### **6.3. General Conclusions**

Overall, the findings from the three core studies in this thesis suggest that speech rhythm sensitivity plays an important, and potentially, a unique role in children's reading development. Using concurrent, longitudinal, and cross-sectional data, speech rhythm sensitivity has been consistently associated with reading development (in its

variety of forms). It is linked theoretically to phoneme awareness, rhyme awareness, and spoken word recognition during speech perception, and yet can predict unique variance beyond these skills. Moreover, typical readers seem to have suprasegmental phonology that maps onto their segmental phonology; this relationship is not found in poor readers. The overall conclusion is that speech rhythm sensitivity is an important, yet neglected aspect of English-speaking children's phonological representations, which should now be incorporated into theoretical accounts of reading development.

## Chapter 7 - References

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## Appendix 1

### The revised mispronunciations task administration and scoring details

#### ADMINISTRATION DETAILS

1. Using a quiet room away from disturbances, two chairs should be seated next to each other (for administrator and child) so that both can look directly at the mispronunciations task in front of them on the table.
2. Locate the first practice item at the beginning of the mispronunciations task and follow the following standardised set of instructions. For the normal condition say ‘you are going to hear a word and I want you to point to the picture which goes with that word, for instance if you hear the word “spider” (press play on the laptop from the appropriate file for this practice item) where would you point to’. For the reversed stress condition, say ‘you are going to hear a word but the word will not be said properly. I want you to point to the picture which goes with that word, for instance if you hear “sp’DER” (press play on the laptop from the appropriate file for this practice item) where would you point to’. For the following set of test items, simply say ‘where is the (and press play on the appropriate file for each item)’.
3. Whether the child gets the right answer or not, be pleasant and encouraging. Corrections are allowed by the administrator for the practice item only, but only tell them what the correct answer was, do not say why. Have the scoring sheet containing the word list to hand (*shown overleaf*) and begin the test items following the practice item.
4. Do not show the child the word list at any time and try to ensure that each word is only heard once (unless there is a severe disruption), thus make sure the atmosphere is quiet in order to reduce the likelihood that it will need to be repeated.
5. Allow children sufficient time to give a response, but encourage them to make a choice if they are taking as long as a minute for any one item.
6. Children may alter their choice, but this must be done before they move on to the next item.
7. Incidentally, children may answer by pointing or simply saying the number that corresponds to that item. If they do verbally express their answer you should point at that item to make sure it was the picture they were referring to.
8. Have the scoring sheet overleaf to hand and mark a correct response by putting a line through the box and an incorrect response by leaving the box blank as shown below.

Example: 3    sp’DER            (3)       3       [ / ]  
                   sp’DER            (3)       4       [   ]

Keep the marking sheet out of sight from the child. Once the child has completed all the items the test can finish. Give the child a total score by adding up the number of correct answers i.e. those boxes that have a cross through them. This will be out of 18 (excluding the single practice item).

SCORING SHEET

Practice item	Normal		MSS	
	spider	(3)____[]	sp'DER	(3)____[]
Item 1	baker	(1)____[]	b'KER	(1)____[]
Item 2	barrel	(4)____[]	b'REL	(4)____[]
Item 3	builder	(2)____[]	b'LDER	(2)____[]
Item 4	butcher	(4)____[]	b'CHER	(4)____[]
Item 5	butter	(3)____[]	b'TER	(3)____[]
Item 6	carrot	(4)____[]	c'ROT	(4)____[]
Item 7	cleaner	(1)____[]	cl'NER	(1)____[]
Item 8	cooker	(4)____[]	c'KER	(4)____[]
Item 9	jumper	(3)____[]	jm'PER	(3)____[]
Item 10	mirror	(2)____[]	m'ROR	(2)____[]
Item 11	painter	(1)____[]	pn'TER	(1)____[]
Item 12	parrot	(3)____[]	p'ROT	(3)____[]
Item 13	plaster	(2)____[]	pl'STER	(2)____[]
Item 14	rubber	(4)____[]	r'BER	(4)____[]
Item 15	ruler	(2)____[]	r'LER	(2)____[]
Item 16	sailor	(1)____[]	s'LOR	(1)____[]
Item 17	singer	(2)____[]	sn'GER	(2)____[]
Item 18	tiger	(3)____[]	t'GER	(3)____[]
<b>TOTAL SCORE</b>	<b>Normal</b>	<b>[   ]</b>	<b>Reversed</b>	<b>[   ]</b>



## Appendix 2

### The phoneme deletion task: stimuli and administration details

**BEGINNING:** I am going to say a word. See if you can say the word back without saying the first sound. For instance, say “told”...wait response...now say “told” without the “t” sound. How would you say...(run through practice items and correct mistakes)

TOLD – OLD            CASE – ACE            SLEEP – LEAP            ATTIC – TIC

Good. OK then let’s have a go at some other words. How would you say...

CAR – ARE  
WALL – ALL  
BEAR – AIR  
FOUR – OR  
BREAK – RAKE  
PLAY – LAY  
SCHOOL – COOL  
STILL – TILL  
AGAIN – GAIN  
AWAY – WAY  
MANY – ANY  
IGLOO – GLUE

**LAST:** I am going to say a word. See if you can say the word back without saying the last sound. For instance, say “made”...wait response...now say “made” without the “d” sound. How would you say...(run through practice items and correct mistakes)

MADE – MAY            LIKE – LIE            POPPY – POP            PINT – PINE

Good. OK then let’s have a go at some other words. How would you say...

TIME – TIE  
HOUSE – HOW  
WENT – WHEN  
LADDER – LAD  
PLEASE – PLEA  
PARTY – PART  
STORY – STORE  
WINDOW – WIND  
TOLD – TOLL  
BUILD – BILL  
PAINT – PAIN  
FIND – FINE

## Appendix 3

### Reading fluency: stimuli, administration, and scoring details

#### Multidimensional Fluency Scale

This scale is based upon research published as:

Zutell, J. & Rasinski, T.V. (1991). Training teachers to attend to their students' oral reading fluency. *Theory Into Practice*, 30 (3), 211-217.

#### Directions:

1. Select a passage well within the reader's instructional range of reading.
2. Have the individual student read the passage aloud, while being recorded on an audiocassette recorder.
3. As the teacher later assesses the oral reading, give each pupil a score (from one to four as indicated by the following scale) for phrasing, smoothness, and pace of reading. Record the numerical rating for each dimension.

#### Multidimensional Fluency Scale

Use the following scales to rate reader fluency on the three dimensions of phrasing, smoothness, and pace.

#### A. Phrasing

1. Monotonic with little sense of phrase boundaries. frequent word-by-word reading.
2. Frequent two and three word phrases giving the impression of choppy reading; improper stress and intonation that fails to mark ends of sentences and clauses.

3. Mixture of run-ons, mid-sentence pauses for breath, and possibly some choppiness; reasonable stress/intonation.
4. Generally well phrased, mostly in clause and sentence units, with adequate attention to expression.

#### B. Smoothness

1. Frequent extended pauses, hesitations, false starts, sound-outs, repetitions, and/or multiple attempts.
2. Several “rough spots” in text where extended pauses, hesitations, etc., are more frequent and disruptive.
3. Occasional breaks in smoothness caused by difficulties with specific words and/or structures.
4. Generally smooth with some breaks, but word and structure difficulties are resolved quickly, usually through self-correction.

#### C. Pace

1. Slow and laborious
2. Moderately slow
3. Uneven mixture of fast and slow reading
4. Consistently conversational

## **Appendix 4**

### **Programming manual and detailed description of the non-speech rhythm tasks (Rhythm Matching Task and Rhythm Copying Task)**

## **Rhythms**

A computer-based procedure to assess children's ability to copy and discriminate between rhythms.

### **1. Introduction**

### **2. Rhythm Matching**

- Control
- Setting up
- Scoring
- Logging

### **3. Rhythm Copying**

- Control
- Setting up
- Scoring
- Logging

## Introduction

Rhythms is a computer-based procedure designed to assess children's ability to copy and discriminate between rhythms. It is supposed that this ability is an indicator of early reading ability.

Each child to be tested will be seated at a laptop computer (details in Chapter Two) along with an investigator who will describe the task, and provide any assistance that might be required.

The rhythms are presented via headphones to minimise the interference from outside sources of noise. When the child is ready to proceed, seven pre-set rhythms will be presented in order. The child is then required to either copy the rhythm (Rhythm Copying Task) or to say whether or not a second rhythm is the same as the first (Rhythm Matching Task). The investigator will not be able to hear the rhythms and so will not be in a position to verify the child's responses. The computer procedure, however, will monitor the progress of the child, logging the results in a file that the investigator will be able to access and analyse later.

The procedures use the same rhythms for Matching and Copying: they are simple rhythms composed of up to seven notes. Two notes are used- a Full note and a Half note (these might be considered as Quavers and Semiquavers). But, the procedure departs from musical method in that both Full notes and Half notes contain the same 600 cycles-per-second tone for 200ms, followed by a period of silence. The silence for a full note is 400ms giving a total note duration of 600ms. A half note's silent period is 100ms, giving a total note duration of 300ms. A third construction is used to provide the equivalent of a musical rest. This is 600ms of silence.

In addition, for all notes, there is an additional amount of silence that has not been quantified. This is the computer processing time required to control the rhythm. For any particular computer, this will be a fixed amount. The actual amount will vary with the processing power of the computer, but it will always be negligible being, at most, in the order of a few microseconds per note played.

Because it was not clear at the outset what the tempo of the rhythms ought to be, it has been made variable. The tone length is always 200ms. This is because a recording has been used rather than having the computer generate a tone internally. This means that the tone is always the same in frequency and duration, no matter what the note or tempo. The variability comes from the additional silence mentioned above. By default, this is 400ms, but the experimenter can alter this in the range 200ms to 600 ms.

<b>Pulse rate</b>	<b>Note</b>	<b>Tone</b>	<b>Silence</b>	<b>Total</b>
300ms	Full note	200ms	300ms	500ms
	Half note	200ms	50ms	250ms
<b>400ms</b>	<b>Full note</b>	<b>200ms</b>	<b>300ms</b>	<b>500ms</b>
	<b>Half note</b>	<b>200ms</b>	<b>50ms</b>	<b>250ms</b>
500ms	Full note	200ms	500ms	700ms
	Half note	200ms	150ms	350ms

The rhythms used in the procedure are as follows:

1:	Full Full Full Full	(4 beats)	Ta Ta Ta Ta
2:	Full Full	(2 beats)	Ta Ta
3:	Full Rest Full Full	(3 beats)	Ta-a Ta Ta
4:	Full Full Half Half	(4 beats)	Ta Ta TaTe
5:	Full Half Half Full Full	(5 beats)	Ta TaTe Ta Ta
6:	Half Half Half Half Full Full	(6 beats)	TaTe TaTe Ta Ta
7:	Full Full Full Half Half Full Full	(7 beats)	Ta Ta Ta TaTe Ta Ta

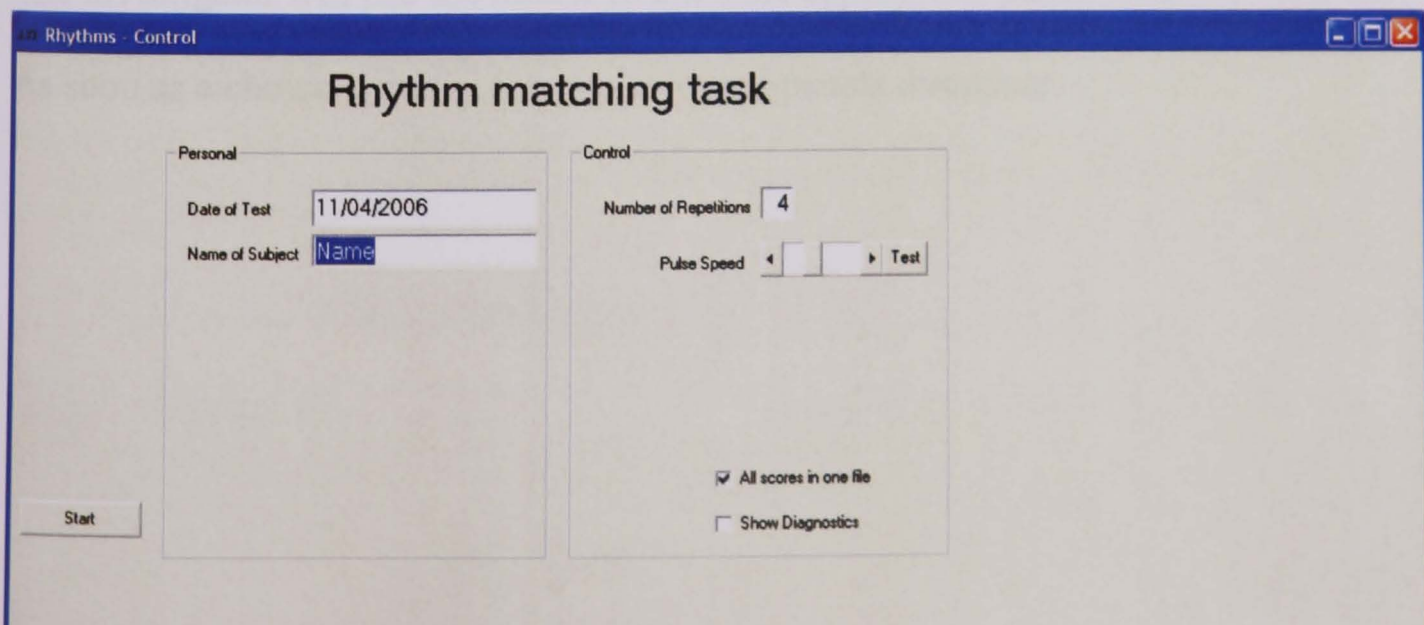
## Rhythm Matching Task

### Control

When the procedure is started up, it will present a screen for the investigator's use (see below). The screen contains two main areas. One of these is for personal information and the other for the control of the procedure itself. The date of the test will be inserted automatically, and the procedure will expect the investigator to enter the child's name. This name may be presented in any convenient form e.g. "Jim", "Mary Smith", "42". But it is important that the name is unique in the group of children being tested. The procedure will use this information to identify the logged responses from the child. The Control area allows the investigator to tune the testing. "Number of Repetitions" governs the number of times that the rhythms are presented to the child. The default is two, but the investigator may change this to any number between 1 and 9. "Pulse Speed" determines the tempo of the rhythm. As set, it is a little slower than two beats per second. The investigator may move the control to the left to speed the pulse rate up, or move it to the right to slow it down. A "Test" button is provided to check the pulse rate. Also in the Control area are the options that determine the type of testing that will be performed. At present, only "Match Rhythms" is operable.

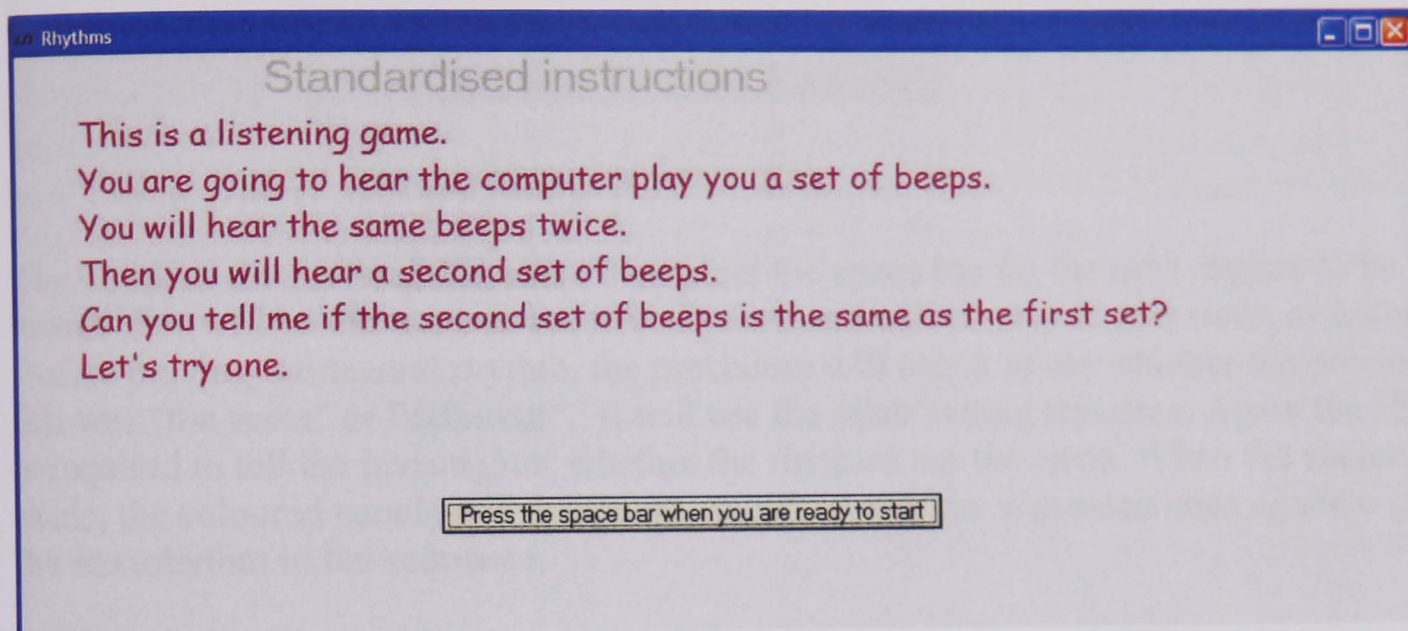
The "All scores in one file" option allows the investigator to accumulate all the scores during a session in a single file. There will be one line per child per test. It is most likely that the investigator will want the scores saved in this way. Consequently, this is the default setting. However, if required, the scores may be kept separate, with each child's scores being stored in their own file. The "Show Diagnostics" feature displays the sequence number during testing, and whether or not the rhythms are the same during Rhythm Matching. Obviously, this feature is useful during development of the tool, and perhaps may be of benefit also to the investigator. It will normally be switched off by default, so that the child doesn't see it.

When the investigator has set the testing up, he/she clicks the "Start" button.



## Setting up

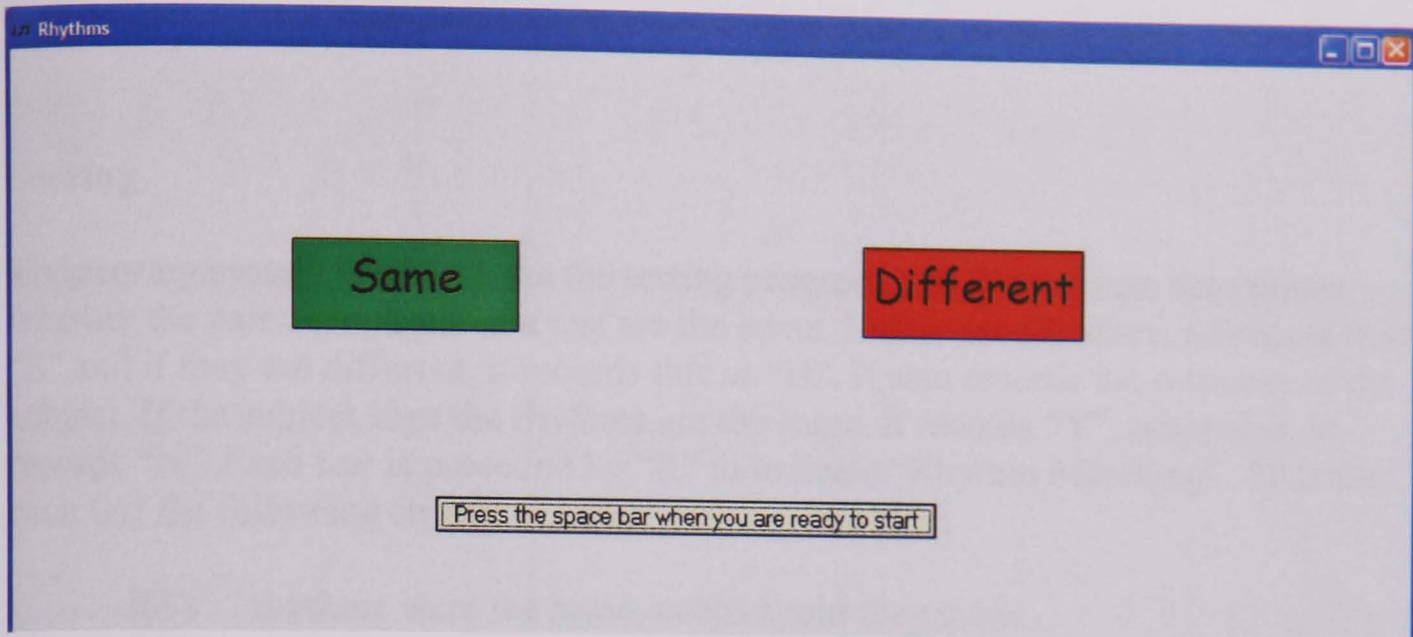
Before letting the children undergo any testing, the investigator must be satisfied that the audio level is adequate. This can be done from the Control panel described above. When satisfied, the investigator will click the "Start" button. The following screen will then be displayed (see below). The child may be unable to read the text (based on reading ability), so the investigator should read it aloud to the child to provide a briefing of what to expect.



When the child is ready to proceed, he/she presses the space bar. The box with the text will disappear, and a practice rhythm will be played. It is introduced by a recorded voice saying, "Rhythm One". The rhythm is then played. Between repetitions of the rhythm, the recorded voice says, "..again..". After two repetitions, the recorded voice says, "Rhythm Two". A second rhythm is then played. At random, this will be the same rhythm, or a different, but deliberately similar rhythm.

Two coloured panels are then displayed on the screen (see below). The child is required to say out loud whether the two rhythms were perceived to be the same, or different. The investigator will use the mouse to click the appropriate panel. Alternatively, the investigator may use the keyboard for this where "A" = the same and "L" = different. As soon as a choice is made, the two coloured panels disappear.

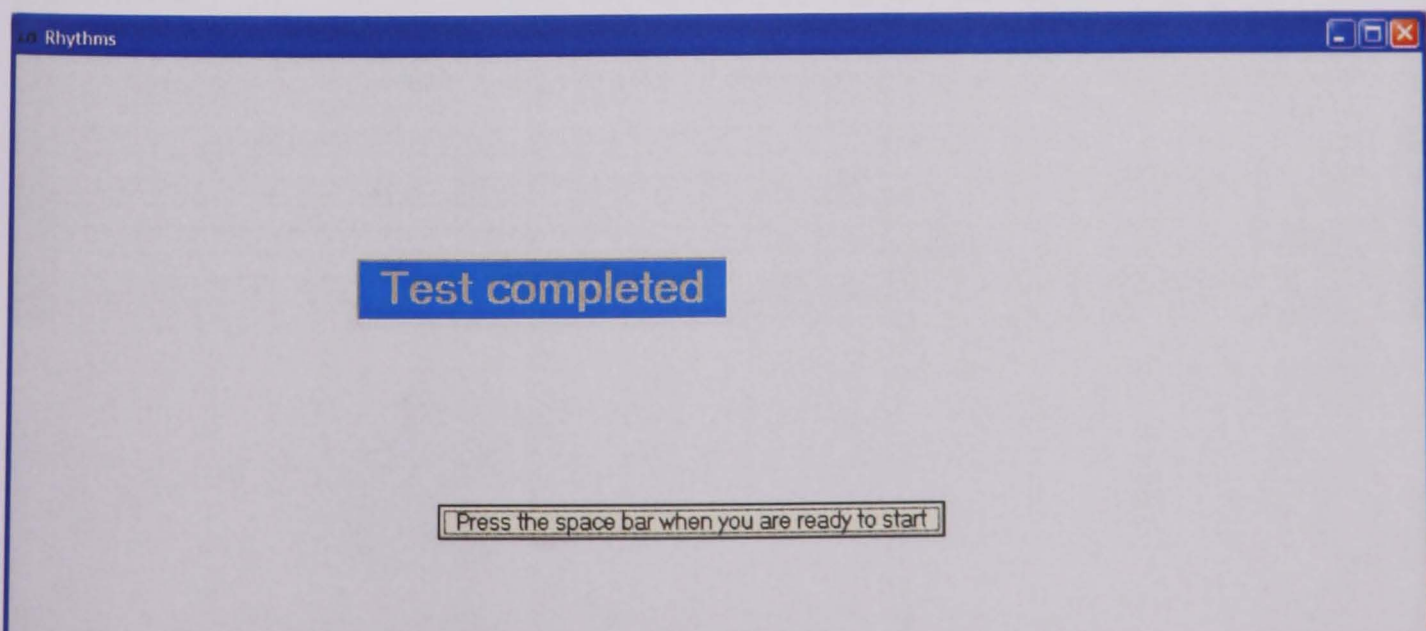




The child, or the investigator, must then press the space bar for the next rhythm to be heard. This will be the same as the first rhythm, and will be played four times as before. Before playing the second rhythm, the procedure will check to see whether the previous test was "the same" or "different". It will use the other setting this time. Again the child is required to tell the investigator whether the rhythms are the same. When the choice is made, the coloured panels will disappear, and the space bar is pressed once again to get the next rhythm in the sequence.

In a complete series of tests the child will be presented with seven different rhythms, the first is a practice rhythm. In the practice, the second rhythm will be the same as the first. The computer will monitor the child's response. If the child correctly chose "Same", then it will proceed to the next part of the process. If, however, the child chose "Different", the computer will play the practice rhythm again. Regardless of the child's second response after this time, the computer will then proceed to the next rhythm.

The following rhythms are all played twice, each presented with a rhythm (played once) that matches it, and another one (played once) that does not match it. When the entire sequence has been played, a "Test completed" message is displayed to indicate this. The procedure will then not permit any further action.



When the procedure window is closed, the logging data will be created.

## Scoring

The scoring system is simple. As the testing progresses, the procedure determines whether the pair of rhythms of a test are the same. If they are the same, it records this as "S" and if they are different, it records this as "D". It also records the response of the subject. If the subject says the rhythms are the same, it records "Y", otherwise, it records "N". Each test is preceded by "R" to indicate "Rhythm Matching". Thus for each test the following strings of letters may be recorded:

- RSY rhythms were the same, subject said they were
- RSN rhythms were the same, subject said they were not
- RDY rhythms were different, subject said they were
- RDN rhythms were different, subject said they were not

## Logging

All the recorded results for a test session are written to a file when the session is closed (see below). The file's name is derived from the "Name" supplied in the Control screen, and can be loaded directly into Microsoft Excel for inspection. There will be a different file for each person, but if more than one test session is conducted for the same individual, then there will be a separate line in the logging file for each session. The investigator can then consult this Excel document to obtain a total score for each child out of 12, and also see where the errors were made (if necessary).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Date	Name	Score	Test1	Test2	Test2a	Test3	Test3a	Test4	Test4a	Test5	Test5a	Test6	Test6a	Test7	Test7a				
2	04/04/2006	Alan	8	RSY	RDY	RDN	RSN	RSY	RDY	RSY	RDY	RSY	RDY	RSN	RDN					
3	05/04/2006	Alan	9	RSY	RDY	RSY	RDY	RDY	RSY	RSN	RDY	RSN	RDY	RSY	RDN					
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				

## Rhythm Copying

### Control

When the procedure is started up, it will present a screen for the investigator's use (see below). The screen contains two main areas. One of these is for personal information and the other for the control of the procedure itself. The date of the test will be inserted automatically, and the procedure will expect the investigator to enter the child's name. This name may be presented in any convenient form e.g. "Jim", "Mary Smith", "42". But it is important that the name is unique in the group of children being tested. The procedure will use this information to identify the logged responses from the child. The Control area allows the investigator to tune the testing. "Number of Repetitions" governs the number of times that the rhythms are presented to the child. The default is two, but the investigator may change this to any number between 1 and 9. "Pulse Speed" determines the tempo of the rhythm. As set, it is a little slower than two beats per second. The investigator may move the control to the left to speed the pulse rate up, or move it to the right to slow it down. A "Test" button is provided to check the pulse rate. "Tolerance" is used in determining the accuracy of a child's copy. It is inevitable that the copied rhythm will be different from the computer-generated one. But if the child's intervals between beats is within a certain percentage of the "real" intervals then it is counted as the same and is scored correctly. The Tolerance field allows the investigator to specify that percentage. It is preset to 20%, but may be varied between 10% and 30%. The "Show Diagnostics" feature displays the sequence number during testing. Obviously, this feature is useful during development of the tool, and perhaps may be of benefit also to the investigator. It will normally be switched off by default, so that the child doesn't see it.

When the investigator has set the testing up, he/she clicks the "Start" button.

The screenshot shows a software window titled "Rhythms - Control". The main heading is "Rhythms". The interface is split into two columns: "Personal" and "Control".

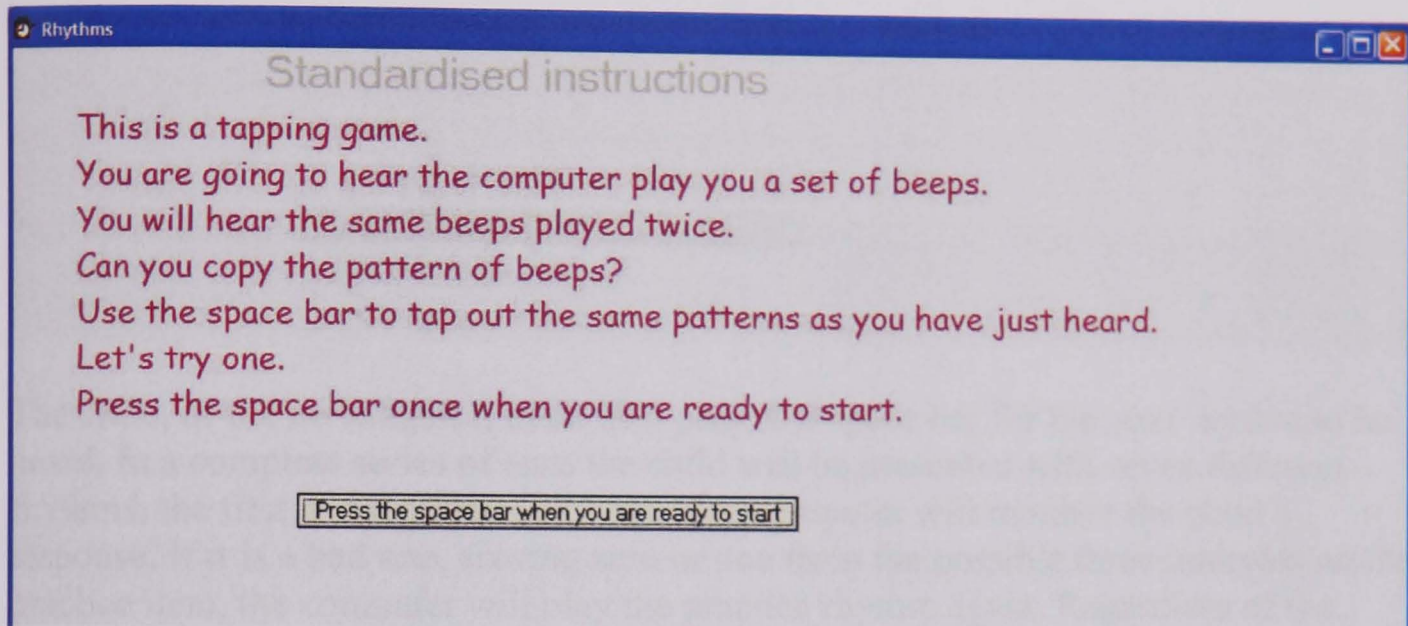
- Personal:**
  - Date of Test: 18/05/2006
  - Name of Subject: Name
- Control:**
  - Number of Repetitions: 2
  - Pulse Speed: A slider control with left and right arrows and a "Test" button.
  - Tolerance: 20 (dropdown menu)

At the bottom left is a "Start" button. At the bottom right is a checkbox labeled "Show Diagnostics", which is currently unchecked.

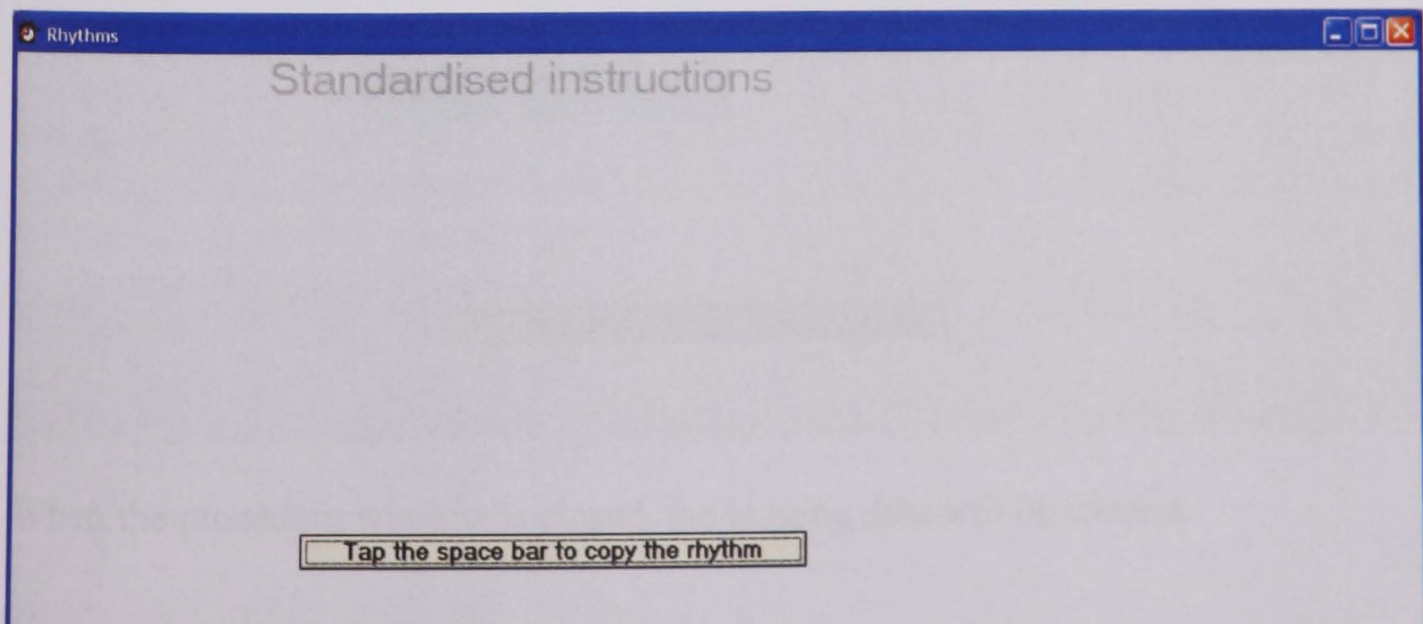
When the child has tapped out the rhythm, the computer will check it with the C.T.B. This will signify to the computer that the child has finished the rhythm. After this

## Setting up

Before letting the children undergo any testing, the investigator must be satisfied that the audio level is adequate. This can be done using the “Test” button from the Control panel described above. When satisfied, the investigator will click the “Start” button. The following screen will then be displayed (see below). The child may be unable to read the text (depending on reading ability), so the investigator should read it aloud to the child to provide a briefing of what to expect.

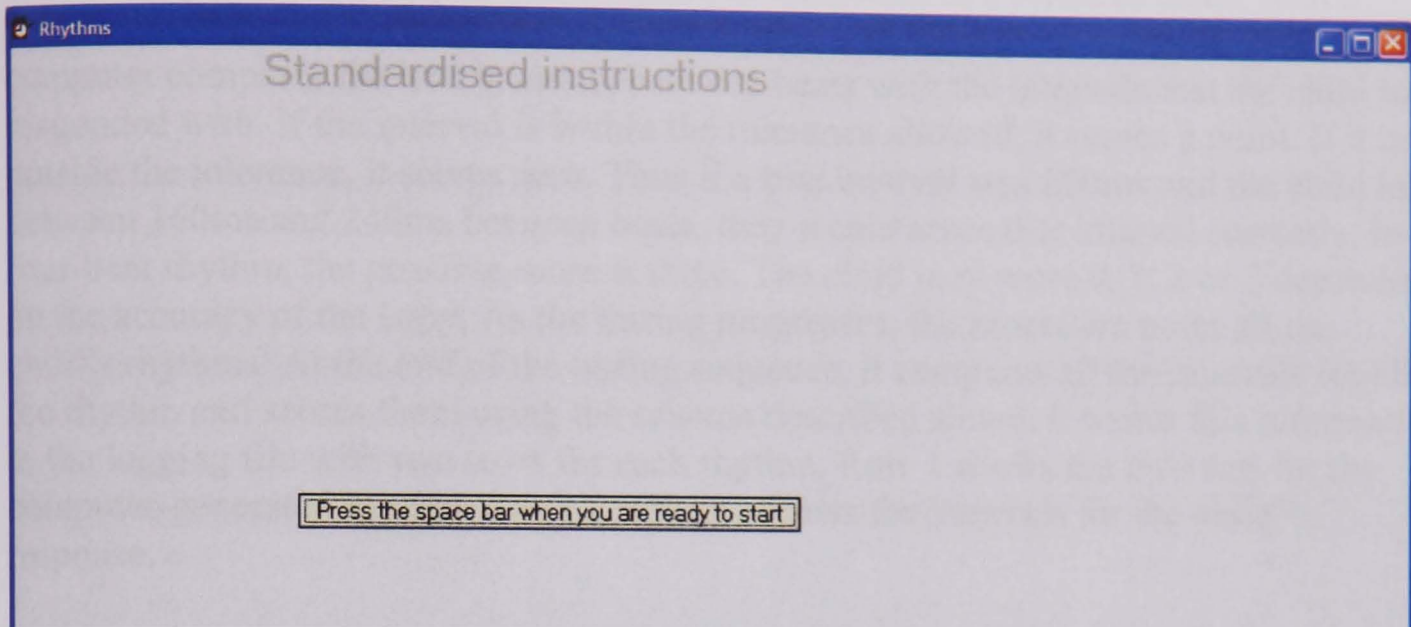


When the child is ready to proceed, he/she presses the space bar. The box with the text will disappear, and a practice rhythm will be played. It is introduced by a recorded voice saying, “Rhythm One”. The rhythm is then played. Between repetitions of the rhythm, the recorded voice says, “..again..”. After two repetitions, the recorded voice says, “Now it’s your turn”. The child is now expected to mimic the rhythm, using the space bar to tap it out. The screen changes to that below (see below) and the computer waits for the child to press the space bar. As soon as he does so, a timer is enabled in the program which measures the time intervals between successive space key strokes.



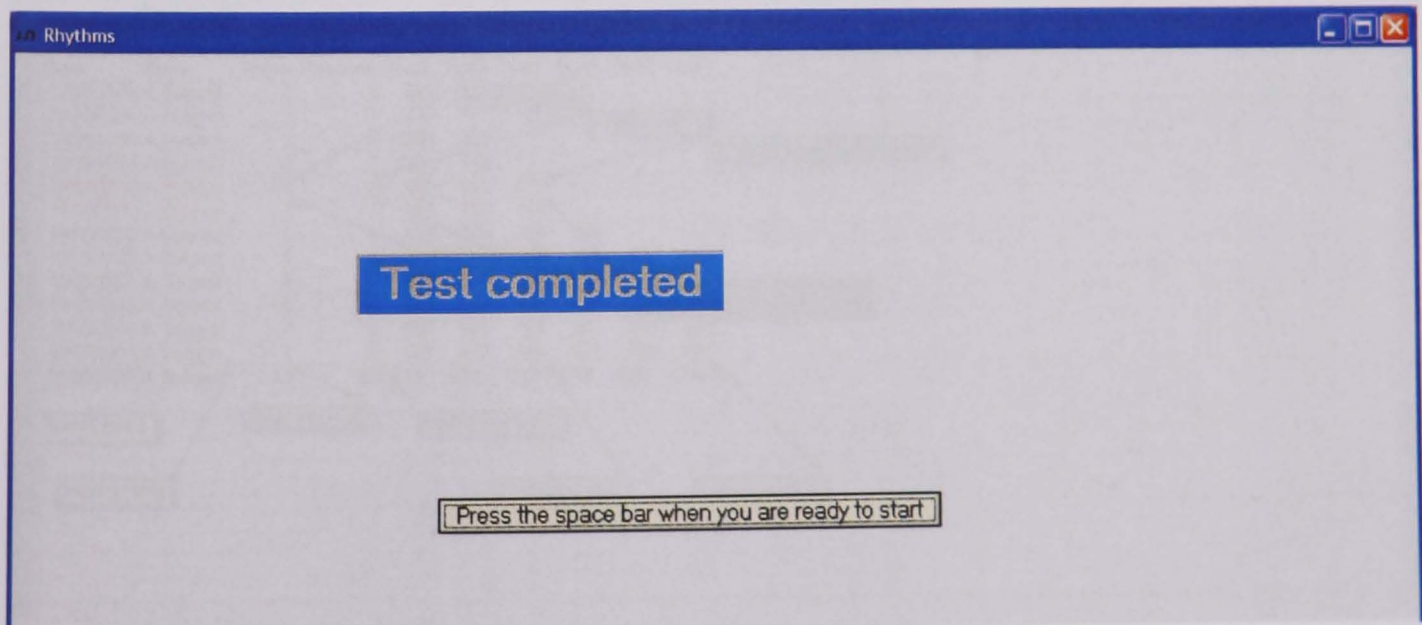
When the child has tapped out the rhythm, he/she may follow it with the CTRL key. This will signify to the computer that the child has finished the rhythm. Alternatively,

he/she may do nothing. The computer will wait for a few seconds and then store the tapped-out rhythm. The screen will then change (as below).



The child, or the investigator, must then press the space bar for the next rhythm to be heard. In a complete series of tests the child will be presented with seven different rhythms, the first is the practice rhythm. The computer will monitor the child's response. If it is a bad one, scoring zero or one from the possible three intervals on the practice item, the computer will play the practice rhythm again. Regardless of the child's second response, the computer will then proceed to the next rhythm. The next rhythms are all played twice.

When the entire sequence has been played, a "Test completed" message is displayed to indicate this. The procedure will then not permit any further action.



When the procedure window is closed, the logging data will be created.

Date	Date of the test
Name	Subject's name
Score	Subject's total score for the session
Possible	The possible total score for the session

### Scoring

The scoring system is simple. Each rhythm is composed of a series of beats, with a certain time interval between. A four-beat rhythm will have three intervals. The computer compares the true intervals between beats with the intervals that the child has responded with. If the interval is within the tolerance allowed, it scores a point. If it is outside the tolerance, it scores zero. Thus if a true interval was 200ms and the child left between 160ms and 240ms between beats, they would score that interval correctly. In a four-beat rhythm, the possible score is three. The child may score 0, 1, 2 or 3 depending on the accuracy of the copy. As the testing progresses, the procedure notes all the child's rhythms. At the end of the testing sequence, it compares all the intervals for all the rhythm and scores them using the scheme described above. It writes this information to the logging file with two rows for each rhythm. Row 1 shows the intervals for the computer-generated rhythm. The second row shows the intervals for the child's response.

### Logging

All the recorded results for a test session are written to a file, RhythmCopyScores.csv when the session is ended. Thirteen lines are written to the file for each subject: two for each of six tests performed, and a summary line. The summary line is the one most likely to be referred to as it represents the total score (it is line 14 in the snapshot below).

1	Date	Name	Score	Possible	Test2	Test3	Test4	Test5	Test6	Test7
2	18/05/2006	A Subject	2	1	600					
3	18/05/2006	A Subject	2	1	657					
4	18/05/2006	A Subject	3	2	1200	600				
5	18/05/2006	A Subject	3	2	1167	640				
6	18/05/2006	A Subject	4	3	600	600	300			
7	18/05/2006	A Subject	4	3	687	703	344			
8	18/05/2006	A Subject	5	4	600	300	300	600		
9	18/05/2006	A Subject	5	1			735			
10	18/05/2006	A Subject	6	5	300	300	30	300		
11	18/05/2006	A Subject	6	3	359	360	328	328		
12	18/05/2006	A Subject	7	6	600	600	600	300	300	600
13	18/05/2006	A Subject	7	5	687	672	656	313	390	703
14	18/05/2006	A Subject	15	21	C11	C22	C33	C14	C35	C56
15										
16	Date of testing		Actual total score	Possible total score						
17										
18	Subject's name									
19							Copied 3 out of 3		Copied 5 out of 6	
20										
21										
22										
23										
24										

It contains the following fields:

- Date                      Date of the test
- Name                     Subject's name
- Score                     Subject's total score for the session
- Possible                 The possible total score for the session

Test2	The score for test 2
Test3	The score for test 3
Test4	The score for test 4
Test5	The score for test 5
Test6	The score for test 6
Test7	The score for test 7

The other twelve lines contain details of the timings and scores for each of the individual tests in the session. They might have some use in detailed analysis of a subject's performance. For instance, the summary can tell a subject's score for a test, whilst the detail lines can indicate which of the beats of the rhythms were recorded accurately. If the same subject is to be tested twice on a single day, the scores will be accumulated in the order that the tests were conducted. However, if the data were to be sorted during analysis, this sequence would be lost. The file can be loaded directly into Microsoft Excel for inspection.

## Appendix 5

### Stimuli and phonetic transcription for the mispronunciations task

Baseline Word	Phonetic Transcription	Stress Reversal Condition
Money (practice)	'mʌni	mə'ni:
Sofa	'səʊfə	sə'fɑ:
Paper	'peɪpə	pə'pɑ:
Teddy	'tedi	tə'di:
Carpet	'kɑ:pɪt	kə'pet
Parrot	'pærət	pə'rɒt
Garden	'gɑ:dən	gə'den
Shopping	'ʃɒpɪŋ	ʃə'pɪŋ
Jumper	'dʒʌmpə	dʒəm'pɜ:
Table	'teɪbəl	tə'bɔ:l
Camera	'kæmrə	kəm'ra:
Mirror	'mɪrə	mə'rɔ:
Candle	'kændəl	kən'dɔ:l
Cushion	'kʊʃən	kə'ʃʊn
Flower	'flaʊə	flə'wa:
Blanket	'blæŋkɪt	blən'ket
Trumpet	'trʌmpɪt	trəm'pet

*Notes: Jumper was the only additional item to the original task used by Wood (2006a)*



## Appendix 6

### Stimuli for the DEEdee task

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#### Practice trials

1. Humpty Dumpty	DEEdee DEEdee Humpty Dumpty	dee DEEdee DEE The Lion King
2. Bob the Builder	DEE dee DEEdee Bob the Builder	deeDEEdeeDEE Pinocchio

#### Trials

1. Snow White	DEE DEE Snow White	DEEdee Bambi
2. Aladdin	dee DEE DEE The Frog Prince	deeDEEdee Aladdin
3. Pokemon	Dee DEE DEE The Snow Dogs	DEEdeeDEE Pokemon
4. Old King Cole	DEE DEE DEE Old King Cole	DEE dee DEE Jack and Jill
5. The Simpsons	DEEdee DEE Peter Pan	dee DEEdee The Simpsons
6. Cinderella	DEEdeeDEEdee Cinderella	DEEdee dee DEE Winnie the Pooh
7. Old Mother Goose	DEE DEEdee DEE Old Mother Goose	deeDEEdeeDEE Pinocchio
8. Sesame Street	DEEdeedee DEE Sesame Street	Bob the Builder DEE dee DEEdee
9. Thumbelina	deeDEEdeeDEE Pinocchio	DEEdeeDEEdee Thumbelina
10. Sleeping Beauty	DEEdee DEEdee Sleeping Beauty	dee DEEdee DEE The Saddle Club
11. The Jungle Book	dee DEEdee DEE The Jungle Book	DEEdee DEEdee Mary Poppins
12. Pocahontas	dee DEEdee DEE The Lion King	DEEdeeDEEdee Pocahontas
13. Stuart Little	DEEdee DEEdee Stuart Little	DEEdee DEE DEE Little Boy Blue
14. The Gingerbread Man	dee DEEdeedee DEE The Gingerbread Man	dee DEEdee DEEdee The Ugly Duckling
15. The Little Mermaid	dee DEEdee DEEdee The Little Mermaid	DEEdee deeDEEdee Hairy Mclary
16. Hansel and Gretel	dee deeDEEdeeDEE The Aristocrats	DEEdee dee DEEdee Hansel and Gretel
17. The Fox and the Hound	dee DEE dee dee DEE The Fox and The Hound	DEE DEEdee DEEdee Hey Diddle Diddle
18. Lady and the Tramp	DEEdee dee dee DEE Lady and the Tramp	DEEdee DEE DEEdee Little Miss Muffet

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## Appendix 7

### Stimuli for the compound nouns task

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Stimuli

1. chocolate, cake and honey
  2. twenty-one and six
  3. foot, ball and socks
  4. paper-bag and string
  5. bow-tie and shoes
  6. fruit, salad and milk
  7. bean, bag and flowers
  8. sunlight and trees
  9. bread-stick and eggs
  10. paint, brush and water
  11. fruit-salad and milk
  12. paper, bag and string
  13. bean-bag and flowers
  14. chocolate-cake and honey
  15. bow, tie and shoes
  16. football and socks
  17. sun, light and trees
  18. bread, stick and eggs
  19. paint-brush and water
  20. twenty, one and six
-

## Appendix 8

### Stimuli for the aural suffix judgement task

Practice trials		
1. froşureful	<b>FRO</b> sureful	fro <b>SURE</b> ful
2. bistinity	BI <b>St</b> inity	bi <b>STIN</b> ity
Trials		
1. primpiful	<b>PRIM</b> piful	prim <b>PI</b> ful
2. nocticity	NO <b>CT</b> icity	no <b>CTIC</b> ity
3. measerless	<b>MEAS</b> erless	mea <b>SER</b> less
4. griffably	<b>GRIFF</b> ably	griff <b>AB</b> ly
5. itopetic	IT <b>OP</b> etic	it <b>OPET</b> ic
6. yiremmaful	yire <b>MA</b> ful	yi <b>REMMA</b> ful
7. otamenic	o <b>TAMEN</b> ic	o <b>TAMEN</b> ic
8. clumatic	CL <b>UMAT</b> ic	clu <b>MAT</b> ic
9. bodrittiness	bo <b>DRITTE</b> ness	BO <b>DRITTE</b> ness
10. vilasplonic	vil <b>ASPLON</b> ic	vi <b>LASPLON</b> ic
11. thicrakely	TH <b>ICRAKEL</b> y	thi <b>CRAKEL</b> y
12. wirooper	WI <b>ROOPER</b>	wi <b>ROOPER</b>
13. prethurity	PRE <b>THURIT</b> y	pre <b>THURIT</b> y
14. fuptality	fup <b>TALIT</b> y	FUP <b>TALIT</b> y
15. ickatter	ick <b>ATTER</b>	ICK <b>ATTER</b>

## Appendix 9

### Stimuli for the stress assignment task

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Practice					
1. below	be	<b>low</b>			
2. magazine	ma	ga	<b>zine</b>		
Test items					
1. analysis	a	<b>na</b>	ly	sis	
2. literature	<b>lit</b>	er	a	ture	
3. democratic	de	mo	<b>cra</b>	tic	
4. remember	re	<b>mem</b>	ber		
5. decision	de	<b>ci</b>	sion		
6. direct	di	<b>rect</b>			
7. approach	ap	<b>roach</b>			
8. appear	ap	<b>pear</b>			
9. international	in	ter	<b>na</b>	tion	al
10. equipment	e	<b>quip</b>	ment		
11. understand	un	der	<b>stand</b>		
12. activity	ac	<b>ti</b>	vi	ty	
13. answer	<b>an</b>	swer			
14. opportunity	op	por	<b>tu</b>	ni	ty
15. beautiful	<b>beau</b>	ti	ful		

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## Appendix 10

### Investigating poor internal reliability of the rhythm matching task

It was interesting to investigate why the rhythm matching task involving beeps along the same-different paradigm had such poor internal reliability ( $\alpha = 0.193$ ) that it had to be excluded from the main analyses. Perhaps the instructions themselves (language) made the test too difficult? Using Pearson's Product Moment a significant relationship was found between children's BPVS scores and their rhythm copying scores,  $r = 0.316$ ,  $n = 102$ ,  $p < 0.001$ . It was then investigated whether there was a memory link? Using Pearson's Product Moment a significant relationship was found between children's digit span scores and their rhythm copying scores,  $r = 0.386$ ,  $n = 102$ ,  $p < 0.001$ . Related to this age should be related if this is a developmental skills and it was,  $r = 0.222$ ,  $n = 102$ ,  $p = 0.025$ . It seems plausible that there may be a cut off point where the task becomes too difficult for younger children. This may reduce the internal reliability of the data. The mean age in months was 78.86, therefore the sample was split into two groups: younger children (78 months and below) and older children 79 months and above. An unrelated t-test found a significant difference between the two age groups with respect to their rhythm matching score,  $t(1) = -2.453$ ,  $p = 0.016$ . To investigate the previous hypothesis, it was then considered whether the task would become more internally reliable with the older children. For 'younger children' only, the internal reliability was  $\alpha = 0.016$ , which was extremely low. For the 'older children' only, the internal reliability was  $\alpha = 0.274$ , which was higher, but still rather low. However, this does suggest that the task is more internally reliable for the older age group. Another way of approaching this is to consider whether the internal reliability of the test would improve if the more difficult items (containing more beeps) were deleted. As noted, the internal

reliability for the task was  $\alpha = 0.193$  and this contained beeps ranging from two beeps to seven beeps. When the seven-beep items were deleted, leaving a total of 10 items rather than 12, the internal reliability increased to  $\alpha = 0.254$ . Using the same procedure, when the six-beep items were deleted, leaving a total of 8 items, the internal reliability increased further to  $\alpha = 0.289$ . However, we could not increase the internal reliability beyond this and reluctantly had to accept this as evidence of a bad test.

## Appendix 11

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of word reading**

Parameter	Unstandardised	SE	<i>p</i>	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Word.	0.932	0.432	0.031	0.197
Age → Word.	0.029	0.18	0.873	0.014
Vocabulary → Word.	-0.193	0.143	0.176	-0.108
Phoneme → Word.	1.041	0.232	***	0.462
Rhyme → Word.	0.878	0.32	0.006	0.304
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.353
Vocabulary	100.496	16.983	***	0.299
Phoneme	44.822	7.47	***	0.014
Rhyme	25.273	4.145	***	0.21
Word.	101.06	17.332	***	0.689

Notes: The st. indirect effect of stress on word reading was 0.427, and the st. total effect was 0.624.

\*\*\**p*<.001

Model	CMIN	df	<i>p</i>	NFI	CFI	RMSEA	Low	High	Hoelter ( <i>p</i> < 0.01)
Default	53.126	6	0	0.738	0.749	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958

## Appendix 12

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of spelling**

Parameter	Unstandardised	SE	<i>p</i>	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Spelling	0.537	0.279	0.054	0.184
Age → Spelling	0.097	0.116	0.403	0.074
Vocabulary → Spelling	-0.143	0.092	0.121	-0.129
Phoneme → Spelling	0.506	0.15	***	0.362
Rhyme → Spelling	0.657	0.207	0.001	0.368
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.353
Vocabulary	100.496	16.983	***	0.299
Phoneme	44.822	7.47	***	0.014
Rhyme	25.273	4.145	***	0.21
Spelling	42.186	7.235	***	0.662

Notes: The st. indirect effect of stress on spelling was 0.436, and the st. total effect was 0.619.

Model	CMIN	df	<i>p</i>	NFI	CFI	RMSEA	Low	High	Hoelter ( <i>p</i> < 0.01)
Default	53.126	6	0	0.731	0.741	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958



## Appendix 13

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of reading comprehension**

Parameter	Unstandardised	SE	<i>p</i>	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Comp.	0.311	0.149	0.037	0.214
Age → Comp.	0.062	0.062	0.314	0.096
Vocabulary → Comp.	0.087	0.049	0.077	0.158
Phoneme → Comp.	0.234	0.08	0.003	0.338
Rhyme → Comp.	0.218	0.11	0.048	0.246
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.353
Vocabulary	100.496	16.983	***	0.299
Phoneme	44.822	7.47	***	0.014
Rhyme	25.273	4.145	***	0.21
Comp.	11.966	2.052	***	0.611

Notes: The st. indirect effect of stress on comprehension was 0.394, and the st. total effect was 0.608.

\*\*\* $p < .001$

Model	CMIN	df	<i>p</i>	NFI	CFI	RMSEA	Low	High	Hoelter ( $p < 0.01$ )
Default	53.126	6	0	0.718	0.728	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958

## Appendix 14

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of non-word reading**

Parameter	Unstandardised	SE	<i>p</i>	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Non-word	0.229	0.16	0.153	0.15
Age → Non-word	-0.02	0.067	0.768	-0.029
Vocabulary → Non-word	-0.052	0.053	0.328	-0.09
Phoneme → Non-word	0.312	0.086	***	0.428
Rhyme → Non-word	0.31	0.119	0.009	0.332
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.353
Vocabulary	100.496	16.983	***	0.299
Phoneme	44.822	7.47	***	0.014
Rhyme	25.273	4.145	***	0.21
Non-word	13.981	2.398	***	0.59

Notes: The st. indirect effect of stress on non-word reading was 0.408, and the st. total effect was 0.558.

\*\*\* $p < .001$

Model	CMIN	df	<i>p</i>	NFI	CFI	RMSEA	Low	High	Hoelter ( $p < 0.01$ )
Default	53.126	6	0	0.712	0.722	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958

## Appendix 15

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of reading accuracy**

Parameter	Unstandardised	SE	$p$	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Accuracy	0.738	0.488	0.131	0.151
Age → Accuracy	0.274	0.203	0.177	0.125
Vocabulary → Accuracy	0.02	0.161	0.9	0.011
Phoneme → Accuracy	0.937	0.262	***	0.401
Rhyme → Accuracy	0.838	0.362	0.021	0.28
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.21
Vocabulary	100.496	16.983	***	0.014
Phoneme	44.822	7.47	***	0.299
Rhyme	25.273	4.145	***	0.353
Accuracy	129.024	22.127	***	0.632

Notes: The st. indirect effect of stress on accuracy was 0.444, and the st. total effect was 0.595.

\*\*\* $p < .001$

Model	CMIN	df	$p$	NFI	CFI	RMSEA	Low	High	Hoelter ( $p < 0.01$ )
Default	53.126	6	0	0.723	0.733	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958

## Appendix 16

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of phrasing**

Parameter	Unstandardised	SE	<i>p</i>	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Phrasing	0.079	0.034	0.02	0.331
Age → Phrasing	-0.008	0.014	0.562	-0.077
Vocabulary → Phrasing	0.001	0.011	0.929	0.011
Phoneme → Phrasing	0.024	0.018	0.186	0.212
Rhyme → Phrasing	0.009	0.025	0.725	0.061
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.353
Vocabulary	100.496	16.983	***	0.299
Phoneme	44.822	7.47	***	0.014
Rhyme	25.273	4.145	***	0.21
Phrasing	0.623	0.107	***	0.242

Notes: The st. indirect effect of stress on phrasing was 0.118, and the st. total effect was 0.449.

\*\*\**p*<.001

Model	CMIN	df	<i>p</i>	NFI	CFI	RMSEA	Low	High	Hoelter ( <i>p</i> < 0.01)
Default	53.126	6	0	0.629	0.632	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958

## Appendix 17

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of smoothness**

Parameter	Unstandardised	SE	<i>p</i>	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Smooth.	0.026	0.031	0.406	0.116
Age → Smooth.	0.006	0.013	0.659	0.057
Vocabulary → Smooth.	-0.009	0.01	0.379	-0.107
Phoneme → Smooth.	0.034	0.017	0.041	0.32
Rhyme → Smooth.	0.018	0.023	0.429	0.134
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.353
Vocabulary	100.496	16.983	***	0.299
Phoneme	44.822	7.47	***	0.014
Rhyme	25.273	4.145	***	0.21
Smooth.	0.518	0.089	***	0.277

Notes: The st. indirect effect of stress on smoothness was 0.268, and the st. total effect was 0.384.

\*\*\**p*<.001

Model	CMIN	df	<i>p</i>	NFI	CFI	RMSEA	Low	High	Hoelter ( <i>p</i> < 0.01)
Default	53.126	6	0	0.635	0.639	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958

## Appendix 18

**Table showing the maximum likelihood parameter estimates for a path analysis (Model 2) of pace**

Parameter	Unstandardised	SE	<i>p</i>	Standardised
<u>Direct effects</u>				
Stress → Age	1.025	0.241	***	0.459
Stress → Vocabulary	0.314	0.318	0.323	0.119
Stress → Phoneme	1.146	0.213	***	0.547
Stress → Rhyme	0.973	0.16	***	0.594
Stress → Pace	0.055	0.031	0.077	0.249
Age → Pace	-0.004	0.013	0.743	-0.043
Vocabulary → Pace	0	0.01	0.962	-0.006
Phoneme → Pace	0.034	0.017	0.045	0.316
Rhyme → Pace	0.007	0.023	0.31	0.053
<u>Variances and covariances</u>				
Stress sensitivity	14.597	2.503	***	
Age	57.549	9.776	***	0.353
Vocabulary	100.496	16.983	***	0.299
Phoneme	44.822	7.47	***	0.014
Rhyme	25.273	4.145	***	0.21
Pace	0.532	0.091	***	0.265

Notes: The st. indirect effect of stress on pace was 0.184, and the st. total effect was 0.433.

\*\*\**p*<.001

Model	CMIN	df	<i>p</i>	NFI	CFI	RMSEA	Low	High	Hoelter ( <i>p</i> < 0.01)
Default	53.126	6	0	0.634	0.637	0.34	0.259	0.427	22
2	0.32	2	0.852	0.998	1	0	0	0.131	1958