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Assessment of a new speech rhythm sensitivity measure and its relation with children's reading skill development

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„...Geh Wege, die noch niemand ging,

damit du Spuren hinterlässt..." (Antoine de Saint Exupéry)

Abstract

This thesis evaluated a new speech rhythm measure, the Lexical Judgement Task (LJT), by conducting a series of cross-sectional studies. It was examined whether the LJT could be used with children from different age groups, whether associations between speech rhythm sensitivity, phonological awareness and reading skills could be observed and whether speech rhythm sensitivity could predict reading skills cross-sectionally and longitudinally. Study 1 piloted the LJT with 5- to 9-year-old children and assessed the relationship between poor and good readers' speech rhythm sensitivity and their reading skills. Analyses showed that poor readers performed lower on the task compared to good readers, indicating that reduced stress sensitivity was related to lower reading proficiency. Examination of the task indicated potential fatigue effects, thus the task was shortened, which resulted in a 12-item tasks that was used through the remainder of the studies. Children between 4- and 11-years old were assessed in three following studies and results showed differential associations between stress sensitivity and reading (related) skills; indicating an involvement of maturation in stress sensitivity's development but also highlighting that stress sensitivity is involved in reading skills differently across varying ages. The final study in this thesis examined the longitudinal effect of stress sensitivity on reading skills and it was found that stress sensitivity was not able to account for growth in reading skills, independently from vocabulary or phonological processing skills; although concurrently unique variance in reading skills was accountable to stress sensitivity. Overall, this thesis highlights the importance of stress sensitivity in children's reading development, offers supporting evidence for previously found associations between this skills and reading abilities and demonstrates the need to incorporate speech rhythm sensitivity in theoretical reading development models.

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Chapter 1 – Theoretical Overview

A consensus has been reached that phonological awareness (PA), the ability to identify and manipulate sound segments in words (Share 1995), is a skill directly linked to reading (e.g. Snowling 2000) and is also strongly predictive of reading development (e.g. Bradley & Bryant 1983; Castles and Coltheart 2004). PA, however, is not the only skill necessary for, and predictive of, reading development and cannot alone account for all the variance in reading acquisition and reading difficulties (e.g. Adams 1990; Scarborough 2005). This chapter will critically review reading theories and the importance of phonological awareness within reading, as well as basic speech production and speech perception mechanisms (including aspects of speech segmentation and word recognition), in order to identify which skills may be linked to reading development, and be important for the reading of multisyllabic words in particular. It is argued that the reading of multisyllabic words is not well understood, and that the focus on segmental phonological awareness in theories of reading may have contributed to this, as other aspects of phonology need to be accounted for in multisyllabic word reading, such as the processing of lexical stress. The chapter will then conclude with a review of recent literature and new reading models, which discuss the phonological skills necessary for reading development which go beyond those included in current reading models, such as prosody (speech rhythm), and stress sensitivity in particular.

It will be argued that prosody is another vital component in reading development which requires further empirical study before being integrated into reading theories. One major aim of this thesis was therefore to explore gaps in our current knowledge and understanding of speech rhythm sensitivity and to review critically existing assessments of it. It is argued that there is need for a new measure of speech rhythm sensitivity, which can be used with children across different ages, in order to theorise systematically about its development and contribution to reading skills. Such a new measure was developed as part of this doctoral research, which allowed the systematic assessment of children's sensitivity to stress at different ages. A further aim of this thesis was to test whether stress sensitivity is linked to children's phonological awareness and reading skills when assessed with this new measure. It is proposed that the assessment of children with one speech rhythm measure over time (cross-sectionally and longitudinally) is essential in order to further understand the underlying associations of children's reading development in line with their sensitivity to stress.

1.1 Theories of Reading Development

Some children acquire skilled reading more successfully than others. In order to understand and subsequently address reading difficulties, one must understand the typical progression in reading acquisition first, then identify the aspects that may inhibit reading development. Several theorists and researchers have attempted to conceptualise the processes and skills needed for the development of 'normal' word reading, and these are reviewed briefly below.

1.1.1 Phases and Stages of Reading Development

For a child to become a skilled reader, he or she must initially code the spoken word (and its pronunciation) in to its written form and its meaning and store this information in his or her mental lexicon (Ehri 1995). In alphabetic languages, these connections are based on grapheme (letter) and phoneme (sound) correspondences (GPCs), which link the spelling of the word to its pronunciation and facilitate the storage of a sight word lexicon. The development of sight word learning according to Ehri (1995) changes over the course of a child's reading development in a phase like fashion; it begins with non-alphabetic processes, including the association of words with visual cues and the storage of these selected cues in memory (*pre-alphabetic phase*). This is followed by the ability to form partial connections between the most salient letters and sounds, when children gain some knowledge about the alphabetic writing system (*partial alphabetic phase*). The next phase occurs once children have acquired full knowledge of the alphabetic system (*full alphabetic phase*) and once they are able to map these graphemes to phonemes successfully and their sight vocabulary expands, children are able to restructure these memorised words according to reoccurring letter patterns, and thus represent larger phonological blends as multi-letter strings in memory (*consolidated alphabetic phase*).

This phase framework is closely based upon Frith's (1985) original stage theory of reading development, which was conceptualised as a three-stage model, including *logographic*, *alphabetic* and *orthographic stages*. However, Ehri (1995) felt the terms of the first and third stages were misleading, since the term 'logographic reader' could imply that the child was able to read logographs, such as those found in Chinese orthography, whereas the children in this phase are merely able to mimic reading by association of whole visual symbols to words. Also, 'orthographic' was deemed too ambiguous, so was re-named the consolidated alphabetic phase. The partial- and pre-alphabetic phases correspond to Frith's alphabetic stage, but differentiate between small changes in the child's reading development.

In terms of Frith's model, in order to enter the logographic stage, children must first master knowledge of words and sentences, which they acquire very early on, but which will vary from child to child (e.g. Francis 1982). In this stage, the identification of words does not occur based on letter-to-sound (grapheme-to-phoneme) connections but is based on visual features and connections to semantics. Children in this stage are able to "read" words based on their contextual cues by using the letters as visual cues rather than symbols for sounds (Gough, Juel and Griffith 1992; for example remembering "the two eyes" in the middle of the word *look*).

Support for the pre-alphabetic phase (and the logographic stage) has been shown in studies with pre-school children who were able to "read" logos like *McDonalds* but who did not notice individual changes in letters in words, and still read the original word (e.g. changing *Pepsi* to *Xepsi*; (Masonheimer, Drum and Ehri 1984). This showed that the children had not yet stored connections between the individual letters and sounds in memory. Treiman and Broderick (1998) also showed that children were able to write their own name and read it; however they were not able to identify the letters in isolation, indicating that the memorisation of letters was not based on their symbolisation of sounds but based on the letters' visual shapes. Byrne (1992) highlighted that children can attend to the print-meaning correspondence but are unable to make letter-sound connections in this early phase, and the ability to instantly recognise familiar words, aided by visual cues, requires a large memory capacity that allows a considerable sight vocabulary to develop.

After some letter knowledge is acquired, children move into the partial alphabetic phase in which partial connections between letters in words and their corresponding sounds can now be made (Ehri 1995). Although the children still lack full decoding skills, they are able to form some connections between letters and sounds and apply this knowledge to novel words and display some phonemic awareness skills. First and last letters are most salient and the relevant letter-sound correspondences of these are memorised, when the letter names contain the equivalent sounds (Treiman 1993). Not all grapheme-phoneme connections are yet learned and children are not yet fully aware of the spelling system, thus segmentation of speech into phonemic units and its corresponding graphemic units is not always successful.

Ehri and Wilce (1985) showed that children in the pre-alphabetic phase were able to remember words based on their visual form whereas children in the partial alphabetic phase found it easier to remember words when they contained letters easily linked to their corresponding sounds. This provides support for the distinction between these two phases and the progression into a more alphabetic understanding of letters within words. In order to achieve this teaching of sounds in words, the segmentation of initial sound pronunciations and the recognition of letters symbolizing sounds in words is essential (Byrne and Fielding-Barnsley 1990).

Teaching children letter-sound correspondences enables beginning readers to successfully decode words (Bradley & Bryant 1983); thus when children acquire decoding skills and use grapho-phonemic knowledge to connect spellings to pronunciations in memory, the full alphabetic phase occurs. Phonological awareness and letter-sound knowledge are important to further reading acquisition and the ability to form connections between all graphemes and phonemes aids word recall (Stuart and Coltheart 1988).

Further studies showed that spelling words aids the memorisation of letter-sound correspondences and pronunciation of words and thus furthers successful reading, indicating that spelling new words is an important process in learning to read words (Ehri 1989). The writing of words with invented spellings prompts children to pay attention to the sounds of letters, and according to Frith (1985) enables the shift from the alphabetic to the orthographic stage of reading. Children instructed to invent phonetic spellings of words were better able to read new words through decoding or sight reading than children not instructed to do this (Clarke 1988).

To highlight the importance of spelling and reading development, Frith (1985) incorporated spelling into her stage model, showing the interplay between reading and spelling development in a progression through six steps, instead of three. At different times in overall literacy development spelling and reading each act as a pacemaker for the other skill (see Figure 1.1).

Figure 1.1 The six step model of reading and writing acquisition, adopted from Frith (1985)

Writing is first symbolic, and reading develops within the logographic phase first (Step 1a). The logographic knowledge then increases and promotes writing (logographic$_2$, Step 1b). Based on the small array of letters known by children now, it is easier to learn to write, consequently writing first reaches the alphabetic stage in Step 2a, becomes more advanced in step 2b (alphabetic$_2$) and leads into the transition of logographic reading (logographic$_3$, Step 2a) into alphabetic reading (Step 2b, alphabetic$_2$). Following this, reading takes over again and at Step 3a, although weak but dominant, orthographical knowledge (orthographic$_1$) changes gradually into more orthographic knowledge (Step 3b, orthographic$_2$) for reading, which promotes writing from alphabetic (Step 3a, alphabetic$_3$) into orthographic writing (Step 3b, orthographic$_2$).

In support of this writing and spelling discrepancy, Bradley and Bryant (1979) showed that some beginning readers were able to read a few words, even highly irregular ones (such as *school* or *light*), for which they not yet had alphabetic understanding. Additionally, those children were able to apply alphabetic strategies to some words and spell those correctly, using simple phoneme-grapheme conversions (such as *bun* or *mat*).

Additionally, Wimmer, Landerl, Linortner and Hummer (1991) have demonstrated that early spelling abilities were strongly correlated with phonological awareness rather than reading, supporting the initial pacemaker properties of spelling for reading development, guided by phonological awareness.

When children progress to the final, orthographic stage, they are able to identify words based on orthographic units without having to analyse these as individual phonemes. It was suggested that orthographic units coincide with morphemes and are represented as letter-strings, enabling many different combinations of unlimited numbers of words to form (Frith 1985). In terms of Ehri's phase model, the final phase is the consolidated alphabetic phase, which is reached once children are able to further their knowledge of letter sequences, which represent grapho-phonemic units and which also include morphemes and enables readers to read multisyllabic words. For example, connections between reoccurring letter patterns enable consolidated readers to form fewer connections for those letter patterns compared to beginning readers; when the connection -*EST* has been made by a consolidated reader, they become able to read new, unfamiliar words (like *chest*) by forming two separate connections (*CH* and *EST*, linked to /tʃ / and /ɛ st/) whereas a reader in the alphabetic phase would form four separate connections (*CH*, *E*, *S*, *T*), linking these to the phonemes /tʃ /, /ɛ /, /s/, /t/, respectively. These morphographic connections (most commonly -*ED*, -*ING*, -*ER*, and -*EST*) are predominant in consolidated readers compared to full alphabetic readers, however children begin to learn these morphemic suffixes in the full alphabetic phase (Ehri 2005).

Frith (1985) stated that the knowledge of spelling patterns within words and their relationship to orthography, morphology and phonology occurs following the mastering of grapheme-to-phoneme correspondence rules. However research has demonstrated that children can recognise sequences of letter strings earlier in their development (e.g.

Goswami and Bryant 1990) prior to knowing the relationship of phonology and morphology, which indicates that GPC does not have to be fully mastered prior to orthographic knowledge (e.g. Lehtonen and Bryant 2005). This offers criticism to Frith's (and Ehri's) sequential progression through the stages/phases of reading development, since not all children would progress through learning of the same skills at the same time in order to be successful readers.

In summary, both models highlight the importance of grapheme-to-phoneme correspondences as essential for reading acquisition and important for facilitation of sight word memory development. Additionally, both models fail to draw attention to the sub-syllabic units of onset and rime however, which have been found to be important aspects of children's reading development (e.g. Goswami 2002). These theories also do not explain how children progress from monosyllabic reading to multisyllabic word reading. It can be assumed that the consolidated or orthographic readers are able to read multisyllabic words with ease (using their sight word vocabulary) however this is not mentioned directly (Ehri 2005; Frith 1985). Further, the irregularities of many words and their potential difficulty for children during early decoding stages, when the GPC does not enable simple decoding, need to be examined in more depth.

Two further theoretical viewpoints will now be discussed briefly, as they address some of these limitations; (1) the dual route cascade model (including irregular GPC) and (2) the psycholinguistic grain size theory (including onset-rime importance in early reading acquisition).

1.1.2 Dual-Route-Model and Grain Size Development of Reading

One limitation that was highlighted in Ehri's and Frith's models of reading development concerns the aspect of how children can read words that cannot be easily decoded using grapheme-to-phoneme correspondence rules. Coltheart, Curtis, Atkins and Haller (1993) proposed a Dual-Route Cascade (DRC) model, which proposes two routes to reading aloud, one being a lexical route and the other a non-lexical route (see Figure 1.2). When being presented with a written word (e.g. *colonel* [kɜ rnl]) the visual input is used to construct letter representations of the word. The lexical route (dashed lines) accesses the memory store of representations of previously seen words, whereas the non-lexical route (dotted lines) is used to convert the visual input of graphemes into phonemes, thus no previous exposure to the word is required.

Figure 1.2 Dual-Route-Model, adopted from Castles *et al*. (2006)

Both routes create a phonological output which then enables word production. Taking the example of *colonel*, this word can only be read aloud after being processed via the lexical route; this may be facilitated through previous exposure to the word or a semantic context, to aid recognition of the word. The non-lexical route would decode this input into its graphemes and "regularises" the word based on letter-sound rules (Castles, Bates, Coltheart, Luciano and Martin 2006) thus producing an incorrect pronunciation. Nonwords on the other hand, like *gop*, cannot be read via the lexical route since no orthographic representation of this would be stored in the mental lexicon, thus it requires the application of letter-sound rules. This model highlights the importance of phonological awareness, since young children would have limited vocabulary and orthographic lexica when they begin to read and would need to rely more upon letter-to-sound conversions prior to learning words by sight (over the lexical route). However, this model does not account for aspects of multisyllabic word reading or prosody, which are important features to be considered when evaluating how word reading develops.

The second issue raised earlier concerns the neglect of onset-rime in the phase/stage models. A monosyllabic word consists of an *onset*, the initial consonant or consonant cluster followed by the *rime*, the vowel and any following consonant(s). For example, the word *run* consists of the onset */r/* and the rime */un/*. Ziegler and Goswami (2005) proposed the *psycholinguistic grain size theory of reading development*, which emphasises the importance of onset-rime knowledge and further highlights that this knowledge is present in young children prior to phonemic awareness. This was not only found in English speaking children but also in children with other language backgrounds, such as Dutch, German and Chinese (e.g. de Jong and van der Leij 2003; Ho and Bryant 1997; Wimmer, Landerl and Schneider 1994).

Ziegler and Goswami (2005) expand on the earlier theories by stating that children need to find shared grain sizes in orthography and phonology in order to process words phonologically and then to successfully recode them. However, when children are presented with new words and try reading those, they are faced with three problems: *availability*, *granularity* and *consistency*. Consequently, these three problems need to be mastered in order to read successfully.

Availability summarises the issue of accessibility of phonological units. Not all phonological units that can be mapped onto orthographic units are fully developed in pre-readers, therefore further cognitive development has to occur in order for children to explicitly access these units and subsequently read them fluently. The most accessible units for beginning readers are words, syllables, onsets and rimes. The emergence of phonological awareness follows the pattern of shallow sensitivity to larger units (i.e. words and syllables) and moves towards a deeper awareness of small phonological units (i.e. phonemes; e.g. Anthony and Lonigan 2004). Thus, to acquire phoneme awareness, formal tuition (schooling) is needed in reading and writing, although some studies have demonstrated that tuition is not always required (e.g. Wood and Terrell 1998a).

Consistency refers to the issue relating to sound-to-letter regularity, which is not transparent for all phoneme/grapheme conversions in English. The main problem of letter-to-sound consistency is presented through the multiple pronunciations of letters and letter clusters in some languages (e.g. English) whereas in other languages (such as Greek) the same letters always receive the same pronunciations. Secondly, phonemes can also have multiple spellings (e.g. in French) but are almost always spelt the same in other languages (e.g. Italian). This causes problems for the development of reading and can slow the reading process down; likewise problems for spelling can occur and this can be seen as the explanation for why spelling lags behind reading in some languages (e.g. Geva, Wade-Woolley and Shany 1993).

The final issue which may arise for children when learning to read is the one of *granularity*. The theory summarises that larger units are most accessible for pre-readers (such as whole-words, syllables, onsets and rimes) and that learning to read occurs through the knowledge of words, then syllables, onset-rimes and then phonemes. However, there are more words than syllables and more syllables than rimes and so forth; hence many more orthographic units need to be learnt. Furthermore, more fine-grained information is learnt when vocabulary knowledge grows, and based on sound similarities some incidental phoneme knowledge may emerge in very phonologically sensitive individuals (e.g. Saffran *et al.* 1997). Lexical reconstructions occur based on these newly learnt words, resulting in more segmental representations (e.g. Perfetti 1992). Once reading and spelling abilities start to emerge through tuition, the phonological representations change more and orthography itself influences this further. Additionally, the grapheme-to-phoneme recoding skills seem to take longer to develop in inconsistent languages and also children appear to be using different strategies in less transparent languages, which would explain why their recoding accuracies may be lower compared to other children across orthographies. The strategies applied by children are based on different, larger, grain sizes.

In addition to Ehri and Frith’s reading models, Ziegler and Goswami’s (2005) theory does account for sub-syllabic units, which have been found to aid the reading acquisition process. However, similar to the previous theories, the psycholinguistic grain size theory does not come without criticism. One major issue with the proposal is in fact the strong emphasis on onset-rime knowledge and the claim that this precedes phonemic awareness (which was stated to develop only as a result of literacy tuition). Although support for the theory has been provided (e.g. Bryant 2002; Goswami and Bryant 1990;

Morais 1991) others have argued against it (e.g. Caravolas 2006; Hulme *et al.* 2002; Wood and Terrell 1998b) especially highlighting that children across European languages display phonemic awareness prior to any formal literacy tuition.

The theories reviewed so far have focused on monosyllabic words and the progression to multisyllabic word reading has been neglected. Although most assessments used with young children are based on monosyllabic words, they will quickly be exposed to multisyllabic words and need to have strategies in place to successfully read them. An additional phonological feature of multisyllabic words is lexical stress, which is also not incorporated into or accounted for by the previously discussed theories.

However, Rastle and Coltheart (2000) did attempt to extend the dual-route theory of reading to account for polysyllabic word reading and highlighted that the reading of such words generally requires the assignment of lexical stress and vowel reduction. Lexical stress is placed on different syllables within words, for example *hotel* is stressed on the second syllable (hoTEL) rather than on the first syllable (HOtel). Vowel reduction occurs in unstressed syllables, and these vowels have reduced intensity and are less pronounced, such as in *carrot*, where the lexical stress is placed on the first syllable and the vowel in the second syllable is reduced, in this instance to a schwa. In terms of the lexical route, this should not pose a problem, since the orthographic representations of particular multisyllabic words could be stored in the mental lexicon, ready for phonological (speech) output. However, in terms of the non-lexical route, these words would pose a problem, as this rule-based route would need to explain how exactly the stress should be assigned and which rules are being applied to reduce vowels. In English, not all words follow a specific stress assignment rule, although 83% of disyllabic words have first syllable stress (CELEX, in Rastle and Coltheart 2000). Thus, the remaining 17%

of words (the “stress-irregular words”) cannot be produced via the non-lexical route with a “first syllable stressed” rule.

In sum, Rastle and Coltheart (2000) hypothesised that the placement of stress and vowel reduction can be, in part, completed by sets of rules in their model, but these however depend on information from all parts of the letter string, thus, the non-lexical route in the DRC is not entirely able to compute these rules, since it operates in a serial way. This account may not fully explain how children come to read multisyllabic words, other than by accessing their mental lexicon for stored representations of these words, but it does however highlight that other factors apart from grapheme-phoneme correspondence may need to be accounted for when attempting to explain multisyllabic word reading.

More recently, Perry, Ziegler and Zorzi (2010) developed a new version of the connectionist dual process model (Perry, Ziegler and Zorzi 2007) which was adapted to simulate the reading aloud of mono- as well as disyllabic words (and nonwords) with correct stress assignment. A lexical as well as sub-lexical route is presented, with the sub-lexical route also including sub-lexical stress nodes for stress assignment of nonwords. Prior to speech output, information (about either real words or nonwords) moves into stress output nodes and phoneme output nodes to generate the words, with accurate pronunciation. The model therefore learns to assign stress in the same way that it learns to associate graphemes with phonemes, and overall it is successful in replicating skilled reading aloud. The issues that still remain are that the model does not account for individual differences and errors, which are frequently found in children’s early reading. Powell, Plaut and Funnel (2006) have addressed this issue in another computational model of reading (the Plaut, McClelland, Seidenberg and Patterson model – PMSP, Plaut *et al*. 1996) and demonstrated that incremental training combined with training on GPCs and inclusion of a training corpus (which reflects children’s reading materials) are essential to improve a model's capacity to generalise to novel letter strings encountered by children. However, discrepancies between the errors produced by the model and by children remain and are still to be resolved.

Thinking back to Ziegler and Goswami's (2005) psycholinguistic theory, they emphasised the importance of onset-rime knowledge in children and that early rhyming skills are linked to later reading ability (e.g. MacLean, Bryant and Bradley 1987). With growing vocabularies, children are able to form categories of words that rhyme (e.g. *cat* – *mat*). When they begin to encounter spellings of these words they come across common spelling patterns in words and may use analogies to read these. Duncan, Seymour and Bolik (2007) highlighted the fact that sensitivity to rime units is heavily based on monosyllabic words and they were interested in exploring whether sensitivity to rime expands to multisyllabic words. Dividing a disyllabic word has been proposed to occur either by dividing the word into individual syllables, each having an onset and a rime (e.g. Treiman 1992), or by dividing the word into an onset and a remainder, called *superrime* (Berg 1989, see Figure 1.3), where the superrime is further divided into a rime and syllable (and this being separated further into onset and rime units).

As the diagrams show, the structure of the multisyllabic word is more complex, especially when including a superrime division, than monosyllabic words are. Further, the onset of stressed syllables has been found to be especially prominent in the interaction between syllable structure and stress pattern (Treiman, *et al*. 1995). In a series of experiments with children and adults, Duncan *et al.* (2007) examined the rhyme productions of their participants and found that the nature of the rhyme (in lexical or non-lexical stimuli) changed depending on the stress pattern of the word.

(a) (b)

Figure 1.3 Disyllabic hierarchical division based on (a) Treiman (1992) and (b) Berg (1989), adapted from Duncan *et al.* (2007)

In disyllabic words with initial stress, a preference for rhymes based on superrimes was found, whereas disyllabic words with final stress yielded a range of rhymes based on superrime, final syllable or final rime unit. The rhymes based on superrime division in stress initial words were in line with Berg's (1989) theoretical hierarchy for disyllabic divisions; however the results obtained with final stress disyllables did not fit neatly into this model. One explanation for the variability of rhymes in final stress disyllables was based on the notion that stressed syllables provide cues for word boundaries, since they are dominantly positioned at beginnings of syllables (Cutler and Butterfield 1992); thus even in isolation, segmentation may be triggered in final stress syllable words at the string syllable boundary, interfering with information integration across syllables (Cutler and Norris 1988).

The orthographic lexicon of English monosyllabic words has been shown to develop in an onset-rime organisational fashion and that early rhyming skills promote this organization further (Goswami and Bryant 1990; Treiman, Goswami and Bruck 1990). Linking the findings from Duncan *et al.*'s (2007) studies to children's representations of multisyllabic words in their lexicon, it has been suggested that this is based on "phonological structures composed of onset plus superrime for disyllabic words with initial stress. This suggests that if children derive the common spelling patterns for rhyming categories of disyllabic words, it is orthographic units at the level of the superrime that will be represented" (Duncan *et al.* 2007*:* 214). However, the observed variability in final stress words in relation to rhyme may indicate that an orthographic structure related to multisyllabic words is less likely and that phonological skills may not be the driving force behind the organization of the orthographic lexicon. In other words, features of the English language itself that indicate the pronunciation of multisyllabic words may gradually increase as reading skills develop.

In conclusion, these theories of reading development (Ehri 1995; Frith 1985; Ziegler and Goswami 2005) have provided an overview of how typical reading develops and offered an insight into the potential problems that may occur along the path to becoming a skilled reader. All three theories indicate to some extent that grapheme-phoneme mapping is salient in the reading acquisition process, and children who experience problems with this process may demonstrate problems with their reading. Additionally, it was highlighted that the way children acquire multisyllabic word reading is still less well understood and that investigations may need to expand upon phonological aspects to understand how the orthographic representations for those words are formed.

Before exploring this avenue further, however, the importance of phonological awareness needs to be briefly highlighted first.

1.2 Phonological Awareness and Literacy

Overall, research has shown that aspects of phonological awareness can develop at different times and subsequently influence the process of reading acquisition in different ways (Treiman and Zukowski 1996). It does not matter whether onset-rime or phonemic awareness develops first (Muter *et al.* 1998; Bryant 1998; Hulme, Muter and Snowling 1998 for the debate) as research generally has shown that phonological awareness overall is essential to literacy acquisition (e.g. Goswami and Bryant 1990) and "it appears to be children's general sensitivity to the sound structure of language that is important for learning to read and write in an alphabetic system" (Anthony *et al.* 2002: 87).

Over 30 years of research has now shown that phonological awareness is strongly associated with reading development (e.g. Boyer and Ehri 2011; Bradley & Bryant 1978; Goswami and Bryant 1990; Muter *et al.* 1998; Stanovich 1988) but despite specific tuition of phonological skills and letter-to-sound correspondences and interventions, some children still struggle to acquire good phonological awareness (Torgesen 2000). Therefore the question remains regarding which other phonological representations or skills are impaired in these children. Snowling (2000) suggested that some children with reading difficulties also demonstrate inhibited phonological short-term memory and reduced rate of access to phonological information in long-term memory (Vellutino *et al.* 2004). Verbal information is stored as speech codes in memory, and children with reading difficulties appear to be less able to access this information. This has been demonstrated through the use of rapid automatised naming tasks, and studies have shown that children with reading difficulties take longer to retrieve information from memory whilst completing these tasks (e.g. Katz, Curtiss and Tallal 2004). Furthermore, those underspecified phonological representations of words can reduce the ability to successfully acquire phonological processing skills, alphabetic and orthographic awareness and decoding in children with dyslexia (Vellutino and Fletcher 2005).

According to Stanovich's (1988) *phonological-core variable-difference model*, dyslexic children have a cognitive deficit in various aspects of phonological processing. This is apparent through difficulties with various phonological tasks, such as phoneme segmentation, slower rapid naming and inefficient access to phonological codes from short-term memory (e.g. Liberman and Shankweiler 1985). This model however does not provide an explanation for why some children have underspecified phonological representations. Although this core phonological deficit hypothesis has been widely accepted, research needs to investigate further where these core phonological deficits stem from. Additionally, Ramus and Ahissar (2012) have recently provided an overview of the empirical evidence to date and suggested that the evidence is not sufficient to explain reading difficulties in some individuals based on access deficits of phonological representations (Ramus and Szenkovits 2008). It was suggested that the deficits in some individuals may be based on broader perceptual deficits rather than purely in the phonological domain.

However, in order to assess where core phonological deficits stem from and how they relate to reading difficulties (if they are present), those skills preceding the development of phonological awareness need to be investigated. As phonological awareness is based on being able to segment the speech stream into ever smaller units (e.g. words, syllables, onset-rimes and phonemes), children's speech perception and speech production need to be examined more closely, highlighting word recognition abilities and emphasising prosodic sensitivity.

As noted earlier, the theories reviewed in Section 1.1 do not incorporate reading prosody into their conceptualisation of the reading process, and it has been argued that prosody in the form of lexical stress at least is an important feature of multisyllabic word reading. It is argued therefore that these models, and indeed the phonological deficit account of reading difficulties, do not account for all the phonological skills required for children's reading development. In the next section, research is reviewed which demonstrates that prosody is linked to both phonological awareness and a range of reading skills, and it is argued that the inclusion of this fundamental skill into reading models is essential.

1.3 Speech Production and Perception

To expand on the previous section, the following passages will focus on how speech is perceived and produced, and which linguistic features can be extracted from the speech signal. This will be followed by an overview of different theories examining spoken word recognition that combine the knowledge of how speech signals can be segmented into meaningful units and how deficits in speech perception can be linked to reading difficulties.

1.3.1 Segmental and Suprasegmental Phonology

Speech is a mixture of sounds, and this sound system of languages (phonology) can be separated into *segmental phonology* and *suprasegmental phonology*. The segmental elements of speech refer to individual sound segments; the vowels and consonants (phonemes) whereas the suprasegmental elements refer to phonological features which are realised across syllables, words and phrases, such as intonation, tone and metre.

In order to hear individual sounds in the speech signal, the physical signal needs to be interpreted, and one must know that certain sounds are mapped onto specific alphabetic units. Additionally, phonotactic and allophonic sensitivity has been demonstrated to be present in young infants; for example 2-month-old infants are able to discriminate between noncontrastive sounds (allophones), such as e.g. the /t/ in "night rate" versus "nitrate" (Hohne and Jusczyk 1994) and also 9-month-olds prefer word lists containing high frequency phonetic patterns common in their native language (Jusczyk, Luce and Charles-Luce 1994). These skills are important for word segmentation and are a result of initial sensitivity to suprasegmental features of phonology (see Section 1.3.3).

The suprasegmental features are embodied in the speech signal as fundamental frequency (F_0), amplitude and duration and can be perceived as relative pitch, loudness, rhythm and tempo in speech (Garman 1990). It needs to be emphasised that a clear, widely agreed upon, definition of prosody and its components (or features or units) has not been provided to date and consensus on the individual terminology has not yet been reached across disciplines (e.g. Fox 2000). Thus the terminology used in this thesis only draws from some psycholinguistic and psychological sources, and attempts to provide a working definition of terms.

Intonation relates to the variation of tone across sentences and phrases. Tone (a linguistic parameter) is linked to pitch, which is most closely associated with the fundamental frequency of sound waves (which is determined by the frequency of vocal fold vibrations; Denes and Pinson 1993). Sentences can have different intonations, which emphasise meaning; this provides information on whether an utterance is a question or a statement for example, or conveys emotions or can indicate whether a speaker is sincere or sarcastic. Rhythm relates to the perceived evenness or unevenness of speech, or may refer to beats in the acoustic signal, which are realised through changes in tempo and stress

(Shriberg and Kent 2003). Stress is associated with changes in vocal cord frequency (pitch), intensity (loudness) and changes in duration (Fry 1955, 1958; Morton and Jassem 1965).

In sum, phonology can be divided into segmental and suprasegmental phonology. Segmental phonology concerns individual sound segments and is closely related to phonological awareness skills. Suprasegmental phonology refers to prosodic features of speech. Prosody can be seen as the umbrella term referring to perceptual characteristics of acoustic features, which are pitch, loudness, intonation, rhythm, stress and duration. When discussing most, or all of these features, *prosody* or *prosodic sensitivity* will be referred to; the term *speech rhythm sensitivity* will also be used interchangeably with prosody. As already noted, one very important aspect of prosody is stress, which is realised both on the word-level (lexical), and across words, at the phrase- or sentence-level (metrical). The sensitivity to these stress features will be labelled as *stress sensitivity* throughout this thesis.

According to metrical stress theory (Liberman 1975, Liberman and Prince 1977) "stress is the linguistic manifestation of rhythmic structure" (cited in Hayes 1995: 30) but it should be noted that this does not imply that stress is entirely rhythmical in all languages. Hayes (1995: 31) highlights the importance of stress and also its complex components: "Functionally, there is good reason for stresses not to be produced with perfect rhythm. Stress serves multiple purposes: it creates phonemic contrasts, marks morphological and syntactic structure, signals the distribution of focus, and so on. The timing or duration of speech sounds is also multifunctional [...] Thus many factors compete with rhythm in determining the location and timing of stresses [...] rhythm plays an important role in stress placement, but it is by no means the only factor".

The literature further highlights how these segmental and suprasegmental features are linked and displayed in infants' language development. They learn about language and sounds very early on and master sound production. Dore (1973) suggested that during pre-linguistic, non-segmented vocalization, infants evidence some prosodic features of language, before their segmented phonemic system develops (cited in Beilin 1975: 339). Infants as young as two-months-old were found to make phonemic distinctions between /p/ and /b/ (Eimas *et al.* 1971) and by eight-months-old, different intonational patterns in their sound productions were observed (e.g. Kaplan 1969).

Interestingly, research has shown that foetuses already begin to learn and memorise auditory stimuli as early as in the third trimester of gestation (Hepper 1997; Shahidullah and Hepper 1994) and it was reported that prosodic features are well perceived by the foetus whereas phonetic aspects are distorted through the abdominal barrier (Benzaquen *et al.* 1990; DeCasper *et al.* 1994; Rosen and Iverson 2007). Additionally, research has demonstrated that emotions are perceived by young infants through the intonation contours in their mother's speech (Fernald and Simon 1984) and changes in pitch of infants' crying were observed, with higher pitch and sudden shifts being more common in cries of pain, compared to cries of hunger (Stark 1986). Thus it can be inferred that infants are making use of different prosodic features to demonstrate different emotive states. Accordingly, being exposed to prosodic cues during gestation enables foetuses not only to learn about these cues, but they also make use of these cues from birth. Studies with one-month-old children have shown that neonates prefer their mother's voice to that of a stranger (e.g. DeCasper and Fifer 1980; Mehler *et al.* 1978), which appears to be based on the prenatal exposure to the mother's voice and native language per se, and which enables the infants to learn prosodic features (Mehler *et al.* 1988; Moon, Cooper and Fifer 1993).

Once infants begin to babble, the sound segments increase in duration and intensity. Following the reduplicated babbling (e.g. na na or da da) children produce non-reduplicated babbling (variegated babbling), in which the consonants as well as vowels may differ across the produced syllables. Uses of different intonational patterns and varieties in stresses have also been observed in infants' babbling (Stark 1986). A more recent study also found that newborn French and German babies cry in melodies that are in line with the languages' melodic (prosodic) contour (Mampe *et al*. 2009). This further lends support to the notion that prosodic characteristics of language are important for language perception and production, since these are the cues that already foetuses are exposed to.

To summarise, neonates possess the ability to discriminate between languages based on different rhythmic properties, which also has been shown to occur in primates (Ramus *et al.* 2000; Tincoff *et. al.* 2005). Whether other abilities present in infants are shared with nonhumans requires further investigating, but it can be said that infants prefer speech to acoustically matched nonspeech and are able to discriminate lexical words from grammatical words (Shi *et al.* 1999). The later speech input from the environment is prepared through these competencies (Werker and Yeung 2005) and the refinement of this perceptual sensitivity helps infants to attend to speech, segment it into words and subsequently learn and remember words.

1.3.2 Spoken Word Recognition and Speech Perception Difficulties

Within the first year of a child's life the sensitivity to features of the native language increases, and a decline in discrimination of non-native features occurs by 6-12 months (Jusczyk 2002). Within this time, infants learn to discriminate between phonetic features, especially those prominent in the native language, and they are also able to make generalisations about other features, such as syllable structure, stress and phonotactic patterns (e.g. Chambers, Onishi and Fisher 2003; Gerken 2004; Thiessen and Saffran 2003). Social interactions as well as statistical learning when exposed to speech can also further infants' phonetic discrimination abilities (e.g. Kuhl, Tsao and Liu 2003). Prosodic cues guide parsing of speech into words and grammatical units (e.g. Echols, Crowhurst and Childers 1997) and are used in natural discourse to determine emotional states (e.g. Morton and Trehub 2001). Recent research also proposed that prosodic cues might be used by five- (and to a lesser extent) by four-year-olds in bootstrapping meaning to novel emotive or non-emotive words (Herold *et al.* 2011).

Thinking back to the issue proposed in Section 1.2, that some children experience deficits with phonological awareness (which are persistent to some degree despite interventions and treatments), we do not know which aspects of speech perception may be impaired that could lead to those persistent phonological issues, which have been found to be present in nearly all poor readers (Brady and Shankweiler 1991). Learning the printed letter-to-sound correspondences is important for beginning readers, but phonological deficits in dyslexics limit this ability (e.g. Wagner and Torgesen 1987). One reason for this difficulty in analysing phonemes in speech has been stated to arise from basic perceptual deficits which hinder the full mental representation of phonemes. Having problems perceiving the speech stream can lead to underspecified lexical representations (phonological problems), can weaken the verbal short-term memory and also cause issues with syntactic awareness and problems with the overall understanding in listening or reading (Studdert-Kennedy 2002).

The literature provides mixed findings regarding speech perception task performance in dyslexics. One viewpoint states that the phonological categories are more fragile and more easily disrupted in children with speech perception problems, which becomes apparent in phoneme manipulation tasks that require specific manipulation of phonemes rather than mere discrimination between two sounds (Werker and Tees 1987). The second viewpoint states that differences in speech perception are only found in phonological dyslexics who display errors in nonword reading and phonological errors in real word reading, compared to surface dyslexics who do not have severe problems with nonword reading but display problems with irregular spelling-sound correspondences (Manis *et al.* 1996). This indicates that surface dyslexics, albeit being poor readers, do not display phonological awareness impairments or difficulties in speech perception. However, differences in tasks used and in differing proportions of phonological versus surface dyslexics used in studies may be at the core of these varying findings regarding differing speech perception abilities.

Some evidence was put forward by Brady, Shankweiler and Mann (1983) indicating that speech perception deficits on the phoneme level could impair long-term memory representations of phonemes, which could lead to deficits in phoneme segmentation and manipulation and subsequently could impair learning of grapheme-phoneme mappings and thus result in reading difficulties. Consequently, speech perception appears to be an important skill required prior to reading development.

The association between phonological deficits in poor readers with deficits in speech perception has been debated in the literature, with a focus on two predominant theories: the *speech-specific hypothesis* and the *general-auditory hypothesis* (Brady *et al.* 1983). The speech-specific hypothesis attempts to explain phonological deficits in terms of impairment in the transformation of phonetic features from the speech signal into mental phonological representations; the deficit is regarded as purely linguistic and also closely related to verbal working memory deficits (e.g. Brady *et al.* 1983). The general-auditory-hypothesis links these phonological impairments to a deficit in perception of rapid acoustic changes, which result in impaired "rapid auditory temporal processing" (e.g. Tallal 1980). This impairment manifests itself as a deficit in perceiving rapid spectral changes (such as duration, sequence, timing and rhythm) in the auditory signal (either non-speech or speech-based).

Additionally, Goswami *et al.* (2002) have provided further supporting evidence for an auditory rhythmic deficit in dyslexic children. They assessed dyslexic children (mean age 9 years), chronological age-matched controls (CA) and reading-age matched controls (mean age 7 years 11 months) on measures of phonological processing, IQ, nonword reading and three auditory processing tasks. They adopted a rapid-frequency discrimination (RFD) task and used a temporal order-judgment (TOJ) task; additionally they created a beat perception task, which required the children to differentiate between sounds that followed the same modulation envelop (with a fixed fall time at 350 ms) but have varying rise times (ranging from 15ms to 300ms). The shorter rise time in amplitude modulation (AM) signals produces one clear beat in rhythmical occurrences in a continuous sound, whereas the 300 ms stimuli results in a continuous sound that varies in loudness.

It was found that the dyslexic children produced less change in AM-related experiences of beat perception compared to the control groups, which was evident through flatter slopes across the different rise times. Further, the beat detection task also yielded correlations with phonological processing skills, reading, spelling and nonword reading. After controlling for age, nonverbal IQ and vocabulary, the beat detection measure was still able to account for an additional 25% of unique variance in reading and spelling, across all participants. In a second study, Goswami *et al*. assessed precocious readers (mean age 11 years 4 months) on the beat detection task, compared to CA. The precocious readers showed greater sensitivity to AM and the sensitivity to rise time changes was also significantly associated with reading comprehension.

Similar findings were demonstrated by Richardson, Thomson, Scott, and Goswami (2004) who compared dyslexic children with chronological-age matched controls and reading-level matched controls on auditory processing tasks, phonological processing tasks and psychometric tests. The amplitude processing tasks included rise time tasks, intensity and pitch discrimination tasks and a TOJ task. Dyslexic children were found to be significantly poorer at the rise time detection tasks and required longer rise times compared to the CA controls to detect changes in the beats. Comparable to the previous study, the two measures of rise time processing used in this study also accounted for unique variance in reading and nonword reading (8-13%) after age, nonverbal IQ and vocabulary were accounted for.

These studies provide support for the auditory processing deficit, and also link it to reading difficulties observed in dyslexic children. However, contradictory evidence has also been presented in the literature stating that these observed differences may only appear when tested at specific ages (Halliday, Baldeweg and Bishop, 2008), or that dyslexics may not differ significantly on auditory processing measures from controls (e.g. Georgiou *et al.* 2010, for data from Greek samples).

1.3.3 Prosody and Speech Segmentation

For children to be able to use language they must be equipped with a strategy to segment the continuous speech stream into meaningful units. Theories have suggested that children build on semantic abilities to develop syntactic competencies (Pinker 1984) or vice versa, they use syntactic abilities to develop semantic abilities (Gleitman 1990).

However in order to use these abilities the segmentation of the speech stream into individual words needs to occur first. When presented with an utterance, it needs to be matched to knowledge stored in memory but given that there are so many different utterances it is unfeasible that every utterance can be stored as a whole. Thus the speech stream must be segmented into smaller units, which correspond to lexically stored units.

Investigations in different languages have shown that these units differ across languages. Mehler, Dommergues, Frauenfelder and Segui (1981) found that French listeners use syllables as segmentation units, whereas Japanese listeners use the mora (a sub-syllabic unit) when segmenting speech (Otake, Hatano, Cutler and Mehler 1993). In English it was proposed that segmentation occurs at strong syllables in the speech stream. Large prosodic units help young infants to learn about the sound structure of their language, as they are attentive to these features from a very young age (Christophe, Mehler and Sebastián-Gallés 2001).

Taking these findings together, the differences between languages' segmentation strategies can be unified in terms of linguistic rhythm. In French, the linguistic rhythm is syllable based, in Japanese, mora based, and in English rhythm is stress based. Thus, when a child is born they need to build a vocabulary that can be used for communication, and in order to do so the speech signal needs to be segmented first, applying language specific segmentation strategies. The ability to "tune into" the rhythmic properties of one's native language (the *periodicity bias*) provides one such strategy as it allows for the segmentation of the speech stream into meaningful units (Cutler and Mehler 1993).

As previously mentioned, foetuses are able to extract the rhythmic pattern of the language they are exposed to (Mampe *et al*. 2009; Rosen and Iverson 2007), thus using the rhythm of a language as a template to map meaning onto these prosodic structures in order to build a lexicon appears to be very plausible. A recent study by Curtin (2011) found support for the inclusion of lexical stress access in infants' word learning and mental representation development. She taught one-year-old infants a single nonword pairing and then presented them with this correct pairing followed by two incorrect pairings (switch trials). One switch trial included the novel word being paired with another new nonword, differing in segments (but retaining the same stress, e.g. BEdoka – TIpegu) whereas the second switch trial included a novel form with the same segments but different stress pattern (e.g. BEdoka – beDOka). It was found that infants were encoding information not only about which syllable was stressed, but they were learning the new words-object pairings along with all phonological information. This includes the lexical stress patterns, and it appeared that the unstressed and stressed syllables were stored, even if the segments within the words were the same. Thus, lexical representations in young infants are formed with prosodically-rich information when the learning of new words occurs. This was also found in studies with adults (Lindfield, Wingfield and Goodglass 1999a and b), who demonstrated that word recognition was aided by prosody and that prosody was important in the retrieval of words from the mental lexicon.

Additionally, there is evidence in support of this, as infants prefer listening to their own native language rather than a foreign one (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini and Amiel-Tison 1988) and prefer child-directed speech to adult-directed speech (Fernald 1985). Jusczyk, Cutler and Redanz (1993) further demonstrated the preference for the predominant stress pattern in English words through a series of experiments with young infants. By nine months the infants showed a preference for words with strong-weak syllable patterns as opposed to weak-strong syllable patterns, which was not apparent in six-month-old infants. This has been explained with the increased familiarity of the older infants with their native language, as they had more exposure to the language and its rhythmic properties. The salient feature of the English stress pattern of words was further investigated by using low-band pass filtered stimuli. Adopting this approach retains prosodic (stress pattern) information of words but removes most of the phonemic content (Jusczyk *et al.* 1993). The nine-month-old infants again listened longer to those low-pass filtered words which had a strong-weak pattern, thus they were distinguishing between frequently and less frequently occurring stress patterns in their own language.

The preference shown by infants for their own native languages compared to other languages and the ability to distinguish between their own native language and another one after speech has been low-pass filtered also indicates an ability to distinguish between languages based on their prosodic pattern (Mehler *et al.* 1988), which is apparent in infants as young as two-months-old. Jusczyk, Friederici *et al.* (1993) compared the preference for English words compared to Norwegian words (which have different word stress) in six-month-old American infants, and found that they listened longer to the English words, even after the words had been low-pass filtered. In comparison, Dutch words follow the same strong-weak syllable pattern as English words and have similar pitch, amplitude and duration characteristics (Rietveld, Koopmans-van Beinum 1987). Research has shown no preferential difference in listening times to English or Dutch words in English six-month-old infants (Jusczyk, Friederici *et al.* 1993) but more recent studies (e.g. Nazzi, Jusczyk and Johnson 2000) have shown that by five months, infants are able to differentiate their own language (e.g. American English) from a language with the same rhythmic patterns (e.g. Dutch or British English) but were unable to differentiate between two languages from a different rhythmic pattern than their native one (e.g. Spanish and Italian). According to Nazzi, Jusczyk and Johnson (2000) this ability to perceive different rhythms is based on their growing sensitivity to linguistic rhythm, which is refined further through repeated exposure to the native language and allows for representations being created for different language rhythm classes. This has also been demonstrated more recently by a study with five-month-old children from a British English background, who were able to differentiate between their local accent and that of an unfamiliar Welsh accent (Butler, Floccia and Goslin 2011).

Several experiments were conducted by Cutler and Norris (1988) to test the hypothesis that strong syllables trigger segmentation of the speech stream, whereas weak syllables do not trigger this segmentation. They measured whether adult participants were able to identify a real word (e.g. *mint*), in nonsense strings, which had either a strong suffix (e.g. – *ayve*) or a weak one (e.g. – *esh*). It was hypothesised that strong (nonsense) syllables would interfere with the detection of the real word, because the target word (*mint*) would belong partly to both syllables, triggering a segmentation at – *tayve* (instead of – *ayve*). In contrast, when the second syllable was weak (as in *mintesh*) no segmentation should occur, thus enabling *mint* to be detected faster in *mintesh* compared to *mintayve.* The results supported this hypothesis, and it was argued that this strong syllable segmentation occurs due to the need for the most efficient segmentation of the speech stream at a location, which would be most efficient to initiate lexical access for word recognition, which appears to be at a strong syllable location.

Cutler and Butterfield (1992) supported this strong syllable segmentation strategy with their findings from experiments examining missegmentations of continuous speech. They found that boundaries were inserted incorrectly prior to strong syllables whilst deleted before weak syllables. Also, those boundaries inserted before strong syllables produced lexical words compared to the inserted boundaries before weak syllables, which produced grammatical words. This is in line with findings from a corpus analysis by Cutler and Carter (1997) who identified that most grammatical words (such as *the* and *of*) are weak syllables, whereas most lexical words are strong syllables; in fact 73% of monosyllables and polysyllables analysed (from a computer based English dictionary containing 33000 entries) had strong initial syllables (Cutler and Butterfield 1992). These findings with adults as well as infants further support the notion that segmentation based on prosodic cues (namely strong-weak syllable rhythm in English) is a salient cue for word segmentation from fluent speech.

In summary, before infants are able to produce their first words they are accumulating information and strategies to segment the speech stream into meaningful units and by the age of around nine months, they appear to have developed these skills which allow them to build a mental lexicon in their native language (Jusczyk, Cutler & Redanz 1993). Overall, the attainment of language has been proposed to occur in a periodic structure, from large chunks to small ones; initially infants pay attention to the rhythmic properties of language, then the metrical units (such as syllables) and lastly to phonemes, with vowel identification occurring prior to consonant identification. Support for this comes from several studies with infants of varying ages. At four-and-a-half months, infants listened to passages with pauses inserted at clausal boundaries significantly longer compared to pauses inserted within clauses (Jusczyk 1989). By six months infants are able to use sensitivity to acoustic cues in line with clause boundaries (Nazzi, Kemler Nelson, Jusczyk & Jusczyk 2000), which is followed by sensitivity to prosodic markers in phrases around nine months (Jusczyk *et al.* 1992). Thus the ability to extract clauses from speech appears to precede the ability to extract phrases (Soderstrom *et al.* 2003).

Further, Jusczyk, Friederici *et al*. (1993) demonstrated that nine-month-old English learning infants listened longer to utterances in their native language compared to Dutch infants. No significant differences in listening times or preferences were found in six-month-olds, or when the utterances where low-pass filtered. This suggests that phonotactic information of their own language begins to be also important to infants older than six months, and not only prosodic information. Infants learn how sounds form patterns in words in their language (Kuhl *et al.* 1992) and that some phonotactic constraints are present (phonemes appear sequentially in specific orders, which are specific to their native language, e.g. English words do not begin with consonant sequences like /zw/ whereas Dutch words do). Jusczyk, Friederici *et al.* demonstrated this in experiments with infants, where they showed that six-month-old children do not differentiate between permissible or impermissible sequences, whereas nine-month-olds prefered the permissible sound sequences.

Overall, between the ages of 6- and 9-months infants appear to develop an increased sensitivity to prosodic and phonetic, regularly occurring, patterns in words. Consequently, it appears appropriate that use of both strategies is useful in identifying sequences of sounds, which further enables the development of a lexicon. The early ability to utilise prosodic information to segment the speech stream into interpretable units could therefore be exploited by children later on when they are learning to read, as sensitivity to speech rhythm underpins segmental phonology, which is associated with reading skills.

In conclusion, these studies have demonstrated early language understanding and acquisition in line with the hypothesis put forward by Cutler and Norris (1988), that segmentation of the speech stream occurs at strong initial syllables, however, since English has many words that do not correspond with this pattern it is feasible that nonprosodic information as well may help to locate word boundaries. Initially, the speech signal needs to be segmented into trochaic foot-based segments (which are units consistent with the predominant strong-weak stress pattern in English), which then help make these nonprosodic, phonotactic and allophonic, constraints more accessible. Being sensitive to prosodic as well as nonprosodic cues in fluent speech enables young children to develop successful strategies to segment more and more words. However, sensitivity to stress appears to precede phonotactic and allophonic cues, since it is necessary to first chunk the speech signal into word-sized units to then learn about these nonprosodic cues.

This section has provided information about the link between prosody and speech segmentation and word recognition abilities in young infants. The chapter so far has demonstrated the current theoretical views regarding children's reading development, highlighted the importance of phonological awareness for reading acquisition and expanded upon speech perception and production in young infants. The overview regarding prosodic sensitivity in relation to language perception has highlighted that these skills are essential for speech segmentation. It has also been suggested that prosody may play an important underlying role in reading development because it precedes and underpins the development of segmental phonology.

Next, this knowledge needs to be directly applied to children's early reading abilities and reading development issues. Given that prosodic skills precede phonotactic skills, one could assume that difficulties with prosodic information result in phonological deficits. The next section will further explore deficits with phonological awareness and reading difficulties in children, but will incorporate prosodic skills, in an attempt to explain the underlying links between phonological awareness, reading (difficulties) and prosody further.

1.4 Prosody and Literacy

The literature reviewed in Section 1.3.2 showed that auditory deficits may impair the perception of (speech) signals, which could impair phonological representations (or impair the access of these representations) and thus cause reading development to be problematic. In Ramus' (2001) review of phonological processing in dyslexics he suggested many areas which require further investigation, in order to confidently affirm the underlying causes for deficits in phonological representations in dyslexics. If the development of phonology is impaired in children at risk of dyslexia, then this hypothesis requires further assessment, which until recently has not been the case. In short, it was proposed that segmental phonology (such as phonemic awareness) is not the only aspect that could be impaired, but that research must incorporate aspects of suprasegmental phonology in the quest to establish the nature of the underlying deficits at the root of impaired (or difficult to access; Ramus and Ahissar 2012) phonological representations.

Given the evidence presented thus far, that prosodic sensitivity to one's native language is important in language development, then the assessment of prosody, and stress in particular, should receive more attention. Knowing that dyslexic children display phonological impairments (Snowling 2000), the hypothesis remains that deficits in prosodic development may delay or impair the development of phonological skills (Wood *et al*. 2009).

This chapter will continue with a review of reading theories which have incorporated prosody. These will be supported by recent research studies that are further highlighting the important role that stress sensitivity plays in the development of reading skills.

1.4.1 Prosody, Fluent Reading and Comprehension

In 2003, Kuhn and Stahl reviewed fluency development theories and remedial practices which highlighted the growing need to incorporate *prosodic features of language* in the assessment of and instructions for fluent reading. They argued that in order to become a fluent reader, one must progress from the word-by-word assessment of written material to a "rapid, accurate, and expressive rendering of text" (Kuhn and Stahl 2003: 3).

LaBerge and Samuels' (1974) automaticity theory suggests that automatic and accurate reading enables a reader to engage with other processing needed for fluent reading, which can only occur once decoding skills have been mastered. They did not include aspects of prosody in their theory however, which is a key component of fluent reading (e.g. Dowhower 1991). Kuhn and Stahl (2003) further suggested that comprehension is aided by prosody because prosody helps the segmentation of text in accordance to syntactic-semantic elements, which improves comprehension (e.g. Cromer 1970). Furthermore, it was proposed that prosody may be a mediator between decoding skills and comprehension (e.g. Schwanenflugel *et al.* 2006). Moreover, fluency ratings were found to be related to comprehension skills, showing that more fluent children demonstrated better comprehension, parsing and decoding skills compared to children with lower fluency ratings (e.g. Young and Bowers 1995). When fluency has not been achieved, children's rendering of text can be performed in a word-by-word manner or by grouping words together in a way that does not imitate spoken language's rhythm, and studies have shown that appropriate use of prosody (phrasing, intonation, stress placement) is indicative of fluent reading (e.g. Chomsky 1978; Rasinski 1990).

The National Reading Panel (2000) also highlighted that fluent reading not only comprises accurate and fast decoding but also involves prosody. This includes pitch changes, stress placement and pausing. Additionally, it may include chunking of words into groups or meaningful units in line with the syntactic structure of the text. Consequently, reading with expression and adequate intonation is considered to be part of fluent reading, however, as Dowhower (1991) stated, the inclusion of prosody in fluency assessments is not always the case. Poor readers display slow and inconsistent reading rates, which are indicative of poor fluency, however, fast and accurate decoding does not ultimately mean fluent, expressive rendering of text. To make reading sound like speech, appropriate phrasing and pausing, stress and general expressiveness is needed.

Kuhn and Stahl (2003) further stated that repeated and assisted reading interventions enhance children's reading accuracy and automaticity (and therefore improve fluency), however these reading skills alone were not found to improve children's reading comprehension (e.g. Spring, Blunden and Gatheral 1981). Consequently, other skills must be involved in children's reading comprehension development. As Cromer (1970) has highlighted, slow but accurate readers benefit from texts being presented to them in segmented (phrase) form, which enhanced comprehension. In line with this, Schreiber (1980, 1987) argued that segmented texts may offer similar cues to written phrase structures as prosody offers to oral language. Additionally, Frazier, Carlson and Clifton (2006) highlighted that prosody is also used as a function to hold auditory sequences in working memory, which can enable semantic analyses of the text and therefore enhances comprehension (Koriat, Greenberg and Kreiner 2002).

Combining this information, it therefore can be said that simple word reading accuracy and automaticity are not enough to promote reading comprehension and given that prosody is important for oral language understanding it would not be surprising that prosody also plays an intricate role in written language understanding. Furthermore, fluent reading also requires "expressiveness" which cannot be achieved without making use of prosodic features. This suggests that prosody not only plays a part in reading fluency but also in reading comprehension. Exactly how and when these reading skills are shaped or influenced by prosody requires additional empirical research however.

Research studies concerning fluent reading which incorporate prosody have emerged in recent years but one study by Dowhower (1987) provided an interesting starting point. She audiotaped students' reading and assessed how repeated reading out loud affected prosodic rendering of text. Although showing good word decoding skills, the children read slowly and in a word-by-word manner and also included inappropriate pausing. Following repeated reading of a text it was found that the children made fewer pauses (which were not indicated by the sentence structure) and included more sentence-final vowel lengthening. Although this indicates that improvement in reading skills are linked to expressive oral reading, it still does not further the understanding of how exactly prosody could enhance reading skills.

To further understand the role that prosody plays in children's decoding and comprehension skills, Schwanenflugel *et al.* (2004) conducted a study which aimed to characterize the development of prosodic reading and explored two potential models of prosodies' involvement in reading. The first model predicts that prosody is a partial mediator, as it assists fluency and consequently aids reading comprehension. The second model proposes that reading comprehension can predict reading prosody, because better comprehension skills may serve as feedback of meaning, which enables the reader to enhance their prosodic reading. To assess this, Schwanenflugel *et al.* assessed 120 children (mean age 8 years 6 months; SD = 7 months) and additionally 34 adults (as controls for fluent reading performance). The children were tested on speeded decoding measures and on a passage reading comprehension assessment. In order to test prosodic reading fluency, the children were asked to read a passage as quickly and accurately as they could. This was recorded for later analysis of intersentential pause lengths and variations, intrasentential pause lengths, child-adult fundamental frequency (F_0 – pitch) match and sentence final declination of F_0.

It was found that children with good decoding skills read with fewer and shorter intrasenential pauses, marked sentence boundaries clearly, used more falling pitch and mirrored the adults' sentence contour better than children with lower (or poor) decoding skills. These children demonstrated slower reading overall with longer pauses, including pauses in the middle of sentences and produced a less prosodic contour. To assess which prediction model incorporates prosody's role in reading skills best, structural equation modeling was used. The first model (*prosody as partial mediator model*) showed that children with faster decoding speed were more likely to also read more prosodically and this supports the view that automatic decoding skills are linked to prosodic reading. It also showed that prosody only plays a small role in reading comprehension and that decoding is the major factor that enhances comprehension. The second model (*reading comprehension as predictor of reading prosody model*) assessed whether prosody is a reflection of children's ability to comprehend text. It was found that decoding speed only accounted for two prosody variables and overall this model was seen as a worse fit in terms of where prosody "sits" in the reading skills development process.

Schwanenflugel *et al*. (2004) concluded from their data that fluent word decoding skills do free up attentional resources which are then available for prosodic reading and that prosody appears to be a result of fluent word decoding skills, since better decoders also demonstrate reading with fewer pauses and more adult-like prosodic contours. This study did not provide supporting evidence for a link between better comprehension skills and more prosodic reading however. Similar findings were obtained by a comparable study conducted by Schwanenflugel *et al*. (2006) with first, second and third Grade children (overall age range 5 years 7 months to 10 years 4 months). Their data did again suggest a more *simple reading fluency model*, which indicates that word-reading skills are used to aid comprehension of text, in line with the *automaticity view* (LaBerge and Samuels 1974) and Schwanenflugel *et al*.'s earlier study (2004). It was also noted that the children in the study may have been able to use their freed-up resources (from fluent reading) to comprehend text, but that the comprehension text used may not have been demanding enough to require these additional resources, therefore no direct contribution of fluency to reading comprehension was found. Further, more syntactically complex texts may activate children's prosodic resources more, which would then be related to reading comprehension. It is however difficult to provide passages that are easily decodable, but also more complex and difficult in terms of comprehension. Miller and Schwanenflugel (2006) therefore conducted a study to address this issue, which may enable the identification of prosody's role in the overall reading process further.

Eighty 8- to 10-year-olds were examined (mean age 9 years and 3 months), as well as 29 adults (as controls for fluent rendering of texts). Based on Chafe (1988) and Cooper and Paccia-Cooper's (1980) suggestions about the importance of the inclusion of more complex and complete grammatical features in texts, a passage was created. It included basic declaratives, basic quotatives, *wh* questions, yes–no questions, complex adjectival phrases, and phrase-final commas as these sentences types were said to enable children's ability to mark punctuations prosodically. First identifying which syntactic features are marked prosodically by children aged 8 to 10 years, would allow for the clear examination of whether prosody is linked to comprehension of texts (at least in these age groups). Adults' rendering of text was used to establish which sentence types elicit prosodic reading and it was found that *wh* questions were produced with large variations in pitch changes and thus these sentences were not included in the children's reading analyses.

Additionally to fluent reading of this newly generated passage, word reading efficiency and phonemic decoding efficiency were measured alongside the Gray Oral Reading Tests (as an independent measure of children's skills to read connected texts). Lastly, comprehension was also measured. The children were grouped depending on their mean reading scores (composite of word reading efficiency and fluent reading) into low,

low middle, high middle, and high, and regression analyses were conducted to establish which reading skills were associated with each prosodic feature. Overall, it was found that the more skilled children made shorter pauses during text reading and differences in voice pitch for basic declarative pitch declination, and yes-no question pitch rise were found (other F_0 changes were generally meaningless as an overall flat prosodic contour was evident across reading skill groups). To further analyse how prosody related to reading (speed and accuracy) and comprehension, the prosodic features that were significantly related to reading skills were further assessed. The ‘pause’ factor comprised basic quotative pause, basic declarative pause, phrase final comma pause, and yes-no question pause; the ‘pitch’ factor consisted of basic declarative pitch and yes-no question F_0. Reading comprehension was predicted significantly by reading skills (when entered in Step 1) but also by prosody (entered in Step 2). It was found that the pitch change variable accounted for this additional variance however, not pause.

Taken together, these findings suggest that comprehension is assisted by certain aspects of prosody and that accurate word reading promotes prosodic rendering of texts. Inclusions of long pauses appear to indicate difficulties in decoding skills whereas changes in pitch (at the end of sentences where adults also include pitch changes) may be indicative of good comprehension skills. In line with others (e.g. Cromer 1970; Kuhn and Stahl 2003), prosodic reading (and specifically pitch changes) appears to provide syntactic and semantic information to the readers, which enhances their comprehension skills. These findings are insightful and offer support for the proposed importance of prosody in the learning to read process and it is essential to further establish how different aspects of prosody may relate to decoding, comprehension and fluency at different points in the reading development.

To make inferences about the development of prosody in relation to reading it is important to examine this longitudinally; such studies are however lacking. One of the few that has directly included prosody was conducted by Miller and Schwanenflugel (2008) and assessed 92 children over three school years (first assessments were conducted in first Grade, follow-up assessments were also completed in Grade 2 and 3). The development of prosodic text reading was examined from Grade 1 to Grade 2, and in Grade 3 the relationships between reading prosody and general fluency and comprehension were examined. As a means of comparing prosodic reading, recordings of adult oral reading from Schwanenflugel *et al.* (2004) were used. Six different prosodic features were examined specifically in a sub-sample of the tested children to assess which features demonstrated reliable changes between first and second grades across children. Based on Chafe (1988), Cooper and Paccia-Cooper (1980) and Miller and Schwanenflugel (2006) and Schwanenflugel *et al.* (2004; 2006) intersentential pause duration, phrase-final comma pause duration, pausal intrusion duration, number of pausal intrusions, sentence-final pitch declination and intonation contour were examined. Analyses showed that the largest effects were observed on the number of pausal intrusions and fundamental frequency match (between adult-child intonation contours), thus these two prosodic features were used as indicators of prosodic reading skills.

Overall, the longitudinal analyses revealed that those children who included fewer pauses in Grade 1 where those children who showed more adult-like intonation in second Grade. Additionally, as reading became more fluent, children demonstrated more speech-like rendering and their pausing was substantially linked to word reading skills. The amount of these pauses was also predictive of the children’s later intonation contour production skills. The development of reading fluency between the first two Grades was then used to predict comprehension skills and fluent reading in Grade 3. This showed that early word reading was predictive of later fluency, and early adult-like intonation contour was additionally able to predict fluency over and above word reading skills. Pausal intrusions in Grades 1 and 2 however were not found to be predictive of fluency achievements in Grade 3. It was consequently suggested that use of appropriate intonations is a “true” indicator of prosodic text reading (e.g. Cowie, Douglas-Cowie and Wichmann 2002) and able to predict future reading fluency. When reading comprehension skills in Grade 3 were examined longitudinally, it was found that early ability to produce adult-like intonations was also predictive of later comprehension skills; it was also found that the amount of pauses used was related to later comprehension skills, which was not found for fluency. This may suggest that children who have acquired good word decoding skills and fluency insert these pausal intrusions as a way to check their understanding of the text.

These longitudinal findings provide support for previous studies (e.g. Miller and Schwanenflugel 2006; Schwanenflugel *et al.* 2004, 2006), but also add to those previous findings. Unlike Schwanenflugel *et al*. (2004; 2006), the longitudinal investigation showed that fewer pausal intrusions were associated with comprehension, which indicates that some effects prosody has on reading skills may only be detectable over time. However it was also suggested that other prosodic aspects, such as stress, may be important to be investigated further and more specifically over longer time periods. Whalley and Hansen (2006) stated that sensitivity to speech rhythm may show relationships to different reading skills at different time points. Additionally, it has been reported that reading fluency continues to develop beyond the primary school years and the lack of reading fluency was evidently affecting comprehension negatively (e.g. Rasinski *et al.* 2005). Further, Rasinski, Rikli and Johnston (2009) stated that prosodic aspects of fluent reading have still not been examined extensively enough, as focus is mostly placed on reading rate (automaticity of word recognition); although more studies are now emerging demonstrating links between prosodic fluent reading and comprehension (e.g. Miller and Schwanenflugel 2006; Whalley and Hansen 2006).

Benjamin and Schwanenflugel (2010) further highlighted the importance of text difficulty when assessing the link between prosody and comprehension (which may be very important for the detectability of this link). Stronger associations between reading comprehension and fluent (prosodic) reading have been found when more difficult comprehension texts have been used, indicating that prosody is important for reading, especially in (older) readers who are exposed to more complex and syntactically challenging reading materials. Additionally, more expressive readers are those who can read fast and accurately and comprehend more, however, children who are less automatic with their decoding have also been found to attempt to use prosodic skills to aid their processing of difficult texts (Benjamin and Schwanenflugel 2010).

In conclusion, these studies showed that the link between reading fluency and comprehension can be described as having been established; the differing findings appear to be due to the specific reading and prosody assessments used (and also the specific samples assessed). Nevertheless, it is not clear yet where in the reading development process prosody “sits”. The fluency studies examined here included prosody as a feature of fluent text reading, whereas others (e.g. Wood and Terrell 1998b, Holliman *et al.* 2008) have measured prosodic skills separately from fluency (see next section). This highlights some issues faced by researchers when attempting to integrate research findings into one conceptualised model of reading development; drawing clear conclusions and links based on an array of different measures of prosody may obscure the actual role that speech rhythm plays in literacy attainment. However, the next section will examine a reading theory model that has incorporated speech rhythm sensitivity, and empirical data will be reviewed to evaluate the model.

1.4.2 The Role of Prosody in Reading Development

Wood, Wade-Woolley and Holliman (2009) reviewed empirical studies to further the understanding of speech rhythm's role in literacy development and proposed four possible ways in which speech rhythm sensitivity could contribute to reading. The model centres on the notion of the periodicity bias (Cutler and Mehler 1993), which enables speech rhythm sensitivity, which then facilitates spoken word recognition. According to the first pathway, this in turn facilitates vocabulary growth, which has been suggested to contribute to phonological awareness development (e.g. Metsala and Walley 1998), which then furthers reading and spelling abilities.

The second pathway suggests that speech rhythm sensitivity impacts upon rhyme awareness directly through the enhancement of sensitivity to vowel occurrences that facilitate onset-rime boundary detection (Goswami 2003; Wood and Terrell 1998b). Rhyme awareness then promotes phonemic awareness and also impacts upon reading and spelling directly. The third pathway suggests that speech rhythm sensitivity impacts upon phonemic identification, which then promotes phonemic awareness. Since it was reported that the identification of phonemes in stressed syllables is easier opposed to unstressed syllables (Wood and Terrell 1998b) it is reasonable to suggest that children who are sensitive to stress are also more skilled at identifying and manipulating phonemes, which then promotes reading and spelling attainment.

The fourth pathway proposed in Wood *et al.*'s (2009) model incorporates several potential routes over which speech rhythm sensitivity could impact upon literacy development (see Figure 1.4). Not only could it enhance literacy through its involvement in vocabulary and phoneme and rhyme awareness but also through its association with morphological awareness. Given that polysyllabic words contain varying stress patterns and stress changes in some words occur when suffixes are added to a word (as in *AC*tive and ac*TIV*ity), it is possible that speech rhythm sensitivity promotes grammatical knowledge about words, which can enhance reading performance.

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Figure 1.4 Reading model depicting speech rhythm's contribution to reading via morphological awareness; adopted from Wood *et al.* (2009)

Empirical research will now be reviewed to evaluate this proposed model and to ascertain whether the proposed model provides the most comprehensive and contemporary views.

One study that investigated the relationship between speech rhythm and reading in children was conducted by Wood and Terrell (1998b). They set out to investigate whether poor readers performed worse on phonological awareness and speech perception (rhythmic awareness) tasks, compared to children with normal reading abilities. The underlying rationale was that phonemic awareness skills have been found to be associated with reading skills. Speech perception tasks may promote phonemic awareness development, thus phonological skills should be found to be worse in poor readers and subsequently the rhythmic awareness in these poor readers should also be reduced. They assessed 90 children, with a mean age of 8 years and 2 months on word reading, spelling, vocabulary, phonological awareness and speech perception tasks. The children were divided into three experimental groups: poor readers, age-matched controls and reading age-matched controls in order to compare the performances on these tasks.

The rapid speech perception task used involved the measurement of children's ability to perceive words from sentences that had been digitally speeded up. The children's responses were recorded and analysed for errors; these could be phonemic (*cat* instead of *pat*) or word boundary related (e.g. *a loud* instead of *allowed*). The second speech perception task measured children's sensitivity to the stress patterns of utterances. Applying low-band pass filtering, the phonemic information of some utterances was removed, so that only the prosodic contour remained (e.g. alterations of strong-weak stressed words; SWWSSS). A filtered utterance was played to the children, followed by the experimenter reading two utterances out loud, with one sentence having the same metrical stress pattern as the filtered one, and another differing by one syllable (SWWSWS). Matching the correct sentence to the filtered version would indicate sensitivity to the underlying metrical stress pattern, which was the only cue provided by the filtered sentence. The phonological tasks included letter-sound knowledge, phoneme deletion, rhyme detection and syllable segmentations.

The poor readers performed worst on the rapid speech perception task but these differences were not significant when vocabulary scores were controlled. Thus, it appears that speech perception is dependent on vocabulary knowledge and that the children did not differ in speech perception per se. The rhythmic sentence matching task was also performed badly by the poor readers, followed by the reading age-matched controls. When controlling for the children's vocabulary scores, a group difference on the sentence matching task was still found, with a significant difference between poor readers and their age-matched controls. In this instance, perception of rhythmic cues appears to be independent of vocabulary knowledge. Thus, the perception of actual words is related to a child's knowledge of vocabulary, whereas the perception of suprasegmental cues is not. Additionally, 10.9% of the variance in the rhythmic matching scores was accounted for by reading ability, indicating a relationship between reading skills and rhythm detection. The rhyme detection measure (phonological awareness task) showed differences between the poor readers and both control groups, and when vocabulary scores were controlled for, a significant main effect for rhyme detection was still obtained.

Since language development begins in an initial auditory domain, one can argue that speech perception and sensitivity to suprasegmental features may promote segmentation skills (e.g. Sawyer 1991), which in turn facilitate segmental awareness and thus enhances literacy skills (Cutler and Norris 1988). Wood and Terrell (1998b) showed that overall a relationship between prosody (stress sensitivity in particular) and phonological awareness thus appears to be implicated, but it is unclear whether speech rhythm contributes directly to literacy development or only indirectly through phonological awareness.

These findings oppose the proposed vocabulary pathway but do offer support for the involvement of speech rhythm in phonological awareness. Other researchers have however found supporting evidence for a contribution of speech rhythm to reading via vocabulary. Whalley and Hansen (2006) used two different rhythm measures, which assessed phrase-level stress sensitivity (*DEEdee task*; adapted from Kitzen 2001) and word-level stress sensitivity (*Compound Noun task*; based on Wells and Peppé 2003). The DEEdee task includes stimuli which are constructed by replacing syllables in words by reiterative 'dee' syllables, which are spoken in a way that retains the stress pattern of the words but removes phonemic information, e.g. *Snow White* would be DEEDEE, whereas *Bambi* would be DEEdee.

The second speech rhythm measure comprised two subtests. The first included compound nouns (such as *ice-cream*) and noun phrases (such as *ice, cream*). These stimuli differed in stress, pause and intonation. Children had to decide whether they heard two or three items. The second subtest followed the same format but included compound nouns (such as *highchair*) and compound phrases (such as *high chair*) which were presented in sentences (without contextual cues). Additionally to assessing the children on these measures, they were also assessed on a non-speech rhythm task which asked the children to listen to several stimuli containing two drumbeats and decide whether they were the same or different. Assessments of reading ability and phonological awareness were also completed.

It was found that the compound noun task was significantly correlated with word reading accuracy in isolation and in context, correlated with a word attack measure and with a phonological oddity task. The DEEdee task was also significantly correlated with both word accuracy measures and in addition with reading comprehension and the compound noun task. Non-speech rhythm also showed significant associations with both word accuracy measures, word attack, phonological oddity and with the DEEdee measure. To further assess whether word- or phrase-level stress sensitivity could account for unique variance in word reading and reading comprehension skills several hierarchical regression analyses were conducted.

The findings indicated that word-level stress was most closely associated with decoding whereas the DEEdee task showed stronger associations with reading comprehension. The predictive power of phrase-level stress was assessed further for reading comprehension, controlling for word identification, phonological oddity and non-speech rhythm (in Step 1) and the Compound Noun task (in Step 2) before entering the DEEdee task. Controlling for all four measures still left 5% of variance in reading comprehension to be accounted for by phrase-level stress sensitivity (p = .05). The results lead the authors to the conclusion that prosody may aid word identification skills by facilitating word retrieval from the mental lexicon (Lindfield, Wingfield and Goodglass 1999b), especially since the Compound Noun task was able to predict unique variance in word identification skills but not in word attack skills (which are more closely linked to phonological recoding). This thus indicates that prosody may aid reading not only by contributing to phonological awareness development but also by enhancing access to words in the lexicon. It was concluded that prosody influences reading comprehension indirectly through its close link to oral language skills. Using prosodic skills to master spoken language also enhances spoken language (listening) comprehension, which then can be used to aid the comprehension of written texts (Hoover and Gough 1990). This study offered not only support for the phonological pathways, but also partial support for the first, vocabulary, pathway proposed by Wood *et al.* (2009) and also indicated that different levels of speech rhythm sensitivity may be associated differently with word reading and reading comprehension skills.

Additionally, Goodman *et al.* (2010) examined younger children (mean age 5 years and 7 months) and only found evidence partially supporting speech rhythm's contribution to reading via vocabulary. They found that metrical stress sensitivity did not add significant unique variance to reading after controlling for verbal and nonverbal IQ, whereas lexical stress sensitivity added significant unique variance to the model (ΔR^2 = .15, $p < .05$). Thus, lexical stress may aid vocabulary and then reading skills in young children, however, after IQ and phonological awareness had been controlled for first, lexical stress sensitivity was no longer adding unique variance to the model. It was argued that lexical stress sensitivity may facilitate vocabulary and phonological awareness, which in turn enhance reading skills. Metrical stress sensitivity on the other hand was not able to predict phonological awareness after IQ and lexical stress sensitivity were accounted for; it may thus not play a unique, direct, role in the development of reading, at least not in young early readers. These findings provide stronger support for the second and third pathway proposed by Wood *et al.* (2009) but also highlight that differences between metrical and lexical stress may influence literacy related skills differently, at different ages.

Another aspect worth considering is the effect that speech rhythm sensitivity may have on children at risk of dyslexia. DeBree, Wijnen and Zooneveld (2006) wanted to explore whether Dutch children at-risk of dyslexia showed poorer word stress production compared to not at-risk children. They tested 49 children at risk of dyslexia (mean age 3 year 3 months) and 28 control children (mean age 3 years and 1 month). To assess word stress competency, the children were presented aurally with recordings of phonotactically legal nonwords (two to four syllables long), with differing syllable structures and stress positions, and were asked to repeat the heard word. Overall, the at-risk children performed poorer on irregular stress pattern items (40% correct) compared to the controls (57% correct), and the at-risk children adopted regular stress pattern placements more often than the controls in regular as well as irregular items. However, the pattern of stress placement were similar across groups thus it was stated that the basic regularities of the Dutch stress system appear to have been acquired by all children. The at-risk children had more difficulties with these tasks however and displayed more regularisation of stress patterns, thus it was concluded that a delay in stress placement abilities is already apparent in 3-year-old children at risk of reading difficulties.

This study further highlighted that a delay in stress sensitivity is apparent in very young children, prior to formal literacy tuition, which provides support for the importance of prosody in language development and its potential implication in later reading development. This may be offering support for the implication of speech rhythm sensitivity in line with the vocabulary pathway, further adding to the mixed empirical evidence that is present in support of Wood *et al.*'s model.

Although the assessed children came from a Dutch speaking background, the similarities between Dutch and English appear to be large enough to hypothesise a similar developmental delay may be present in young English speaking children at-risk of dyslexia. Furthermore, Goswami *et al*. (2002) observed reduced sensitivity to the "beats" in sounds in English speaking dyslexic children, which is potentially indicating a similar delay as has been observed in DeBree *et al.*'s study with young Dutch children. Further research studies also suggested that reading difficulties are linked to insensitivity to rhythm in a range of languages, for example in Greek (Protopapas *et al.* 2006), Spanish (Dupoux *et al.* 1997; Gutiérrez-Palma and Palma Reyes 2007), French (Dupoux *et al.* 1997; Goetry *et al.* 2006; Muneaux *et al.* 2004) and Dutch (e.g. Goetry *et al.* 2006; Poelmans *et al.* 2011), thus it appears that reading difficulties based on reduced stress sensitivity are a language-universal occurrence (Goswami *et al.* 2011). However, other studies in Finnish (e.g. Hämäläinen *et al.* 2009) or in Greek (e.g. Georgiou *et al.* 2010) did not find any differences in auditory perception tasks between dyslexics or controls. Therefore it seems that it cannot be determined yet whether speech rhythm is linked to reading abilities irrespective of one's language.

The evidence presented so far has focused on studies examining samples of children; however it is also important to examine studies which focused on adult data. Recall that research has found a relationship between metrical stress sensitivity, vocabulary and reading in older children (Whalley and Hansen 2006), it may be the case that metrical stress plays an even greater role in the reading of polysyllabic words and more complex texts, which adults are exposed to frequently.

For instance, Ashby (2006a) further investigated the use of prosody in skilled adult readers. Rather than measuring sensitivity to speech rhythm per se, the focus was placed on the activation of prosodic information whilst reading, which was assessed using eye-tracking equipment. It was argued that prosody not only enhances reading out loud but that it also plays a role in silent reading. When spoken language is produced it is full of prosodic information and this prosodic richness has been depicted in linguistic models through multi-layered phonological representations (e.g. Clements and Keyser 1983; Selkirk 1982), including the lexical stress pattern, the syllables, the (CV) segments and the melodic features (i.e. phonemes). Fodor (1998) suggested in an *implicit prosody hypothesis* that readers impose a prosodic contour to text they are reading, since the orthography does not provide this information; this would suggest that during (silent) reading a link between spoken language systems and reading systems is activated which enables the activation of speech-like representations that subsequently enable a speech-like rendering of text. Support for this comes from a study by Kentner (2012) who conducted an eye-tracking experiment with German speaking adults and also demonstrated that during silent reading mental representations of implicit lexical distinctions are constructed, which follow prosodic-phonological preferences (such as rhythmic alternations). These findings further add support to the notion that skilled readers access lexical stress during silent reading and also indicate that rhythm plays a role in text comprehension.

Furthermore, Ashby (2006b) generated a *phonological hub theory* of word recognition, which described possible processes between spoken language representations and reading. In short, word recognition, word production and memory processes cross over through a hub of phonological representation; these phonological representations enable skilled readers to access information parafoveally (outside the focus of attention), which aid word recognition and can be maintained in working memory once the words have been recognised. These phonological representations contain not only segmental information but also suprasegmental (prosodic) information, which are in effect activated simultaneously (Dell 1988). This indicates that speech rhythm is implicated in vocabulary knowledge (of skilled readers) and that prosodic skills impact upon vocabulary and phonological awareness and subsequently on reading skills. This provides further evidence for the vocabulary as well as the phonological pathways proposed by Wood *et al*. (2009) in adult readers.

Mundy and Carroll (2012) also investigated a sample of dyslexic adults (*n* = 32) and age/IQ matched controls (*n* = 48) on two prosodic measures and assessed the differences between implicit prosodic representations and explicit awareness of prosodic structures as well as investigated the relationship between these prosodic skills and phoneme awareness and decoding abilities. To measure prosodic awareness an adaptation of the DEEdee task was used (Kitzen 2001). To measure (implicit) prosodic representations in the mental lexicon, a *Cross Modal Fragment Priming task* (Cooper, Cutler and Wales 2002) was used.

The participants were presented with one of three types of spoken prime followed by a visual presentation of a target word. The three primes were either stress congruent to the target (consisting of the first two syllables of the target word, e.g. *ádmir/al* followed by ADMIRAL), stress incongruent (consisting of the first two syllable of the target word (sharing segmental phonology) but differing in stress assignment, e.g. *àdmir/átion* followed by ADMIRAL) or phonologically unrelated to the target (control stimuli), such as *mosquí/to* followed by ADMIRAL.

It was found that the control participants performed significantly faster and more accurately compared to the dyslexics on the DEEdee task. The controls also displayed significant correlations of DEEdee accuracy with nonword reading and phoneme awareness whereas the dyslexics' DEEdee accuracy correlated significantly with word reading, nonword reading, phoneme awareness and verbal short-term memory.

The priming effects were assessed by congruent/incongruent primes and reading groups (dyslexia and controls) and showed that significantly more priming occurred in the stress congruent conditions, but these priming effects were not significantly different across groups. The dyslexic participants were slower to respond than the controls but this did not influence the overall observed priming effect. A regression analysis further revealed that after age, verbal and nonverbal IQ, vocabulary, verbal short-term memory and phoneme awareness were controlled, the DEEdee task was still able to account for 6.4% of unique variance in nonword reading whereas the stress congruent and stress incongruent priming effects could not. These findings suggest that the conscious awareness of prosody may be impaired in dyslexic adults whereas the underlying implicit prosodic representations could remain intact and that speech rhythm sensitivity impacts upon (non) word reading independently from vocabulary and/or phonological awareness.

Since both tasks differ not only in the nature of prosodic skills measured but also in terms of verbal short-term memory and reading demands, another study was conducted controlling for these factors by using tasks more comparable on memory and reading demands. A *Fragment Identification task* (Mattys 2000) was used instead of the DEEdee task, in which the participants were presented with a spoken word fragment (e.g. *prósec*) followed by two visually presented words; they were instructed to choose the word that matched the heard stimuli. The response options were matched on segmental phonology and derived from a common root word but differed in lexical stress (e.g. *prosecutor* and *prosecution*). The cross modal fragment priming task followed the same procedure as in Experiment 1, but the stimuli used were the same words as were employed in the fragment identification task. The control stimuli were matched for length and frequency but unrelated to the other items.

Similarly to Experiment 1, it was found that the dyslexics were less accurate in identifying the correct matches in the fragment identification task. Additionally, a main effect of prime was found again for the stress congruent items in the cross modal fragment priming task. After controlling for the overall slower responses of the dyslexics on this task, no overall group differences on task performance were observed. Partial correlations (controlling for age and IQ) also showed significant associations between the fragment identification task and reading (r = 0.587, $p < .001$) and nonword reading (r = 0.688, $p < .001$); the stress congruent and incongruent prime responses were not significantly correlated with either reading measure.

The authors summarised that the findings taken together support different levels of prosodic impairments in adult dyslexics; tasks requiring conscious prosodic awareness appear to be more difficult for dyslexics compared to controls, whereas the non significant group differences in implicit prosody skills suggested intact prosodic representations. Additionally, these findings oppose the proposed pathways (Wood *et al.* 2009) as speech rhythm abilities were able to account for reading skills over and above vocabulary and phoneme awareness. Thomson *et al.* (2006) and Leong *et al.* (2011) for instance also found associations of rhythmic sensitivity with adult's reading skills, beyond its association with vocabulary or phonological awareness. Therefore, it can be concluded that studies examining stress sensitivity and its link to reading in adults are not all in support of the Wood *et al.* (2009) reading model, which suggests that speech rhythm's associations with reading does change over time. It also needs to be highlighted that these studies used different measures to assess stress sensitivity, which makes a comparison of these studies difficult and also makes it more difficult to come to clear conclusions linking the findings to theoretical models.

Focusing on studies with less skilled, early readers again, Wood and Terrell (1998b) and Wood (2006a) for instance found that speech rhythm sensitivity was associated with phonological awareness and with reading and spelling skills independently from vocabulary knowledge. Wood (2006a) re-analysed Wood and Terrell's (1998b) data and highlighted that rhythmic sensitivity was able to predict phoneme awareness, even after age and vocabulary had been controlled ($\Delta R^2 = .03$, $p < .05$), providing support against the vocabulary path proposed by Wood *et al*. (2009). In comparison, rhythmic sensitivity was able to account significantly for 8.2% of variance in rhyme awareness after age had been taken into account but was only marginally able to account for variance in rhyme awareness when both age and vocabulary where controlled first ($p = .056$). This may show that rhyme awareness is influenced by vocabulary knowledge, which is influenced by speech rhythm sensitivity. Similarly, rhythmic sensitivity was able to predict 4.3% of variance in reading and 4.4% of variance in spelling after age and vocabulary were controlled ($p < .001$ and $p = .003$ respectively), indicating that the link between speech rhythm and reading is not necessarily via vocabulary but rather influenced by phonological awareness.

Wood (2006b) further argued that stress sensitivity, although associated with phonological awareness (especially with rhyme awareness), also contributes something unique to literacy development, potentially by aiding spelling abilities and subsequently reading. As part of this study, 4- to 7-year-old children were assessed on the mispronunciations task (aural word recognition). This task includes four different conditions, which contain stimuli that had various aspects within words altered that result in changes of the stress pattern or vowel quality of these words, e.g. *carpet*, /kɑ □ pɪ t/, has first syllable stress and a schwa in the second syllable, which after the stress reversal changed to /kə□pɪ t/ (for details see Chapter 2.2).

In the first study 39 children were assessed on this mispronunciations task as well as on a receptive vocabulary assessment (BPVS II). Twenty-three children were pre-schoolers with a mean age of 4 years and 3 months and 16 were reception children with a mean age of 5 years and 2 months. No significant differences in performance between age groups in either condition were found. However, overall a significant main effect across the different conditions was observed; performance on the stress reversal condition was significantly worse compared to the other conditions (which for example involved changes of the first vowel's identity in the first syllable, but retained the reduced vowel in the second syllable, e.g. *table*, /□ teɪ bəl/, changed to /□ tʊ bəl/). The author concluded that, unlike PA, performance on this task does not appear to be boosted by school experience, although scope for improvement in ability to recognise variations in stress patterns was suggested by the data. Furthermore, maturation did not appear to play an important role in the development of this skill, nor did vocabulary explain the variations in performances. However, the age range was limited and no other control variables were included other than age and vocabulary, which may have obscured the findings. Additionally, mere amount of changes (how many factors were manipulated) in the different conditions did not seem to be at the root of the differences in observed performance; the nature of the change appeared to be the crucial factor. Since all children performed worse on the stress change condition another study was conducted, only using this condition.

The second study assessed 39 children cross-sectionally (aged 5-, 6- and 7-years-old). This enabled the assessment of differences in stress sensitivity across these age groups to further gauge whether maturation plays a role in this skill's development. Additionally, regression analyses were conducted to assess whether stress sensitivity could predict PA and/or literacy skills after age had been accounted for. The mispronunciations task consisted of a baseline condition and a stress reversal condition. In addition to this assessment, the children were also tested on receptive vocabulary (as in Study 1), word reading and spelling, phonological awareness (rhyme detection and nonword reading, phoneme deletion and letter sound knowledge).

Analyses revealed a significant main effect for task condition (stress reversal vs. baseline) and for year groups, indicating that the 7-year-olds significantly outperformed the 5-year-olds. Regression analyses showed that stress sensitivity could account for concurrent variance in word reading and spelling as well as in rhyme detection, letter sound knowledge and in nonword reading. After age had been taken into account, stress sensitivity was still able to account for independent variance in spelling ability and rhyme detection. Also, after controlling for PA, stress sensitivity could still account for variance in spelling abilities and after controlling for vocabulary, unique variance in spelling was also accountable to stress sensitivity.

Overall, a strong relationship between spelling and stress sensitivity was found, even after accounting for vocabulary scores. Being more sensitive to stress might boost spelling, through the link of knowledge of correct pronunciations facilitated by stress sensitivity. Further, early spelling ability and rhyme awareness were linked to stress sensitivity, both skills which were found to predict early reading development (e.g. Wood and Terrell 1998b), thus these findings may be indicating an underlying link between stress sensitivity and reading (through the link of stress to spelling and rhyme awareness), providing support for the rhyme awareness pathway proposed by Wood *et al.* (2009).

Furthermore, Holliman *et al.* (2008) also provided evidence for a direct link of speech rhythm to reading using speech-based stimuli. They assessed Reception and Year 1 children (mean age 6 years and 1 month) with the mispronunciations task (Wood 2006b). Age, vocabulary, phoneme deletion and rhyme awareness were controlled in their analysis, followed by stress sensitivity and they found that each variable was able to account for significant variance in reading attainment. Additionally, stress sensitivity was found to account for 3.8% of unique variance after the other variables were controlled for. These findings were partially in line with those obtained by Wood (2006b) but Holliman *et al.* suggested that suprasegmental phonology plays a role in reading beyond its association with PA, especially in the reading of multisyllabic words, perhaps through its involvement in morphology.

Further support for a direct link between reading ability and rhythmic sensitivity was presented by studies utilising tasks based on non-speech stimuli. Goswami and colleagues (2002) argued that assessments of non-speech rhythm also underpin speech-based processing (see Section 1.3.2) and they were able to demonstrate that poor readers (dyslexic) showed inferior rhythm abilities compared to controls, which were linked to poorer phonological processing skills. They used an *amplitude modulation (AM) task* (or *beat detection task*), which presents participants with sound sequences (at 500 Hz) which have changing amplitudes (with fixed fall times of 350ms but varying rise times from 15 to 300ms). These sounds were presented with either two toys swinging on a double swing (Tigger and Eeyore) or as one toy (Winnie the Pooh) sliding down a plastic spiral straw. The slower rise time stimuli (> 250ms) should be perceived as one sound varying in loudness (matched to Winnie the Pooh), whereas the faster rise time stimuli (e.g. < 120 ms) should be perceived as a continuous sound with rhythmically occurring beats (at the same rate as the modulation; matched to Tigger and Eeyore). The children were asked in subsequent trials to match the sounds heard to the corresponding toys (process of categorisation).

Additionally, two rapid temporal-processing tasks were used, a rapid frequency discrimination (RFD) task and a temporal order-judgement (TOJ) task (based on Tallal and Piercy 1973 and Tallal 1980). The RFD required the participants to decide whether two tone stimuli sounded the same or different. The TOJ task included sounds of a dog barking and a car horn, which were manipulated and changed so that the sounds either appeared like the bark was followed by the car horn or like a car horn followed by the dog bark. Participants were presented with these varying sounds and asked to indicate which sound they heard first.

Goswami *et al.* (2002) tested 24 dyslexic children (mean age 9 years), 25 chronological age matched controls (mean age 9 years) and 24 reading-level matched controls (mean age 7 year 11 months) on these three auditory processing tasks as well as on phonological processing tasks (oddity task, phonological short-term memory and RAN), IQ, spelling and reading. It was found that the dyslexic children had reduced sensitivity to rhythm compared to controls and the performance on the AM task (across the whole sample) was found to be significantly correlated with all measures, even after age and IQ were controlled for. The RFD and TOJ tasks were also correlated with the oddity task, reading and spelling, but not as strongly as the beat detection task.

Additionally, sensitivity to rhythm (beat detection) was able to predict reading over and above age, nonverbal IQ, vocabulary and phonological awareness, indicating a potential developmental progression and a direct contribution of speech rhythm to literacy (contrary to Wood *et al.*'s proposed model).

Further, Holliman *et al.* (2010a) also examined children (mean age 6 years and 7 months) with a non-speech rhythm task as well as with the mispronunciations task and a revised version of this measure. They further tested phonological awareness and reading measures to establish whether speech and non-speech rhythm are significantly related, and whether either of these skills could predict reading after phonological awareness and either rhythm skill were accounted for.

The revised mispronunciations task was simpler and included more distracter items that started with the same letter-sound and phoneme. The words were recorded and spoken normally in the baseline condition but were mispronounced (i.e. had their stress reversed) in the experimental condition. To measure non-speech rhythm a rhythm copying task was employed (based on Overy *et al.* 2003) in which the children had to reproduce a heard rhythm as accurately as they could; a second non-speech rhythm task involved the judging of two rhythms as either being “the same” or “different”.

They found the speech rhythm tasks and non-speech rhythm tasks were significantly correlated with reading and phonological awareness. However, the non-speech rhythm tasks’ association to reading and PA was weaker compared to the association of speech rhythm to these skills. Further, the revised mispronunciations task was significantly correlated with the receptive non-speech rhythm measure (same-different judgement) but not with the productive rhythm measure (rhythm copying). Regression analyses were conducted to investigate whether speech rhythm could predict word reading, after PA (Step 1) and both non-speech rhythm tasks (Step 2 and 3) were controlled. When entered into the fourth step, the revised mispronunciations task was still able to account for 3.2% of unique variance in reading attainment. Further regressions showed that receptive non-speech rhythm sensitivity was only marginally a non significant predictor of reading after controlling for PA and speech rhythm sensitivity. Productive non-speech rhythm was not contributing unique variance to the model (p = .49).

Lastly, a more stringent regression analysis was conducted controlling for age, vocabulary, PA, short-term memory and productive non-speech rhythm before entering receptive non-speech and speech rhythm (either in Step 6 or 7) into the model. Both, speech and non-speech rhythm, were able to account for significant unique variance (when entered either in Step 6 or 7 of the model) in reading attainment after the control variables had been accounted for. Although non-speech and speech rhythm sensitivity are related skills, they do contribute uniquely to reading and also beyond their associations with phonological awareness. Thus offering some support for the phonological pathway (Wood *et al*. 2009) but also indicating a direct contribution of rhythm sensitivity to reading.

Leong *et al.* (2011) have recently conducted a study that attempted to directly assess the relationship between basic auditory processing of rise time and stressed syllable perception in dyslexics. So far most studies have assessed aspects of rhythmic sensitivity in many different ways, and the combination of auditory processing and syllabic stress perception tasks in one study are few (e.g. Goswami, Gerson and Astruc 2009). As already presented, differences in sensitivity to stress have been observed in samples of children (e.g. Holliman *et al*. 2008, 2010a; Whalley and Hansen 2006; Wood 2006b) and adults (e.g. Mundy and Carroll 2012) and according to the rise time theory (Goswami *et al.* 2002) perception of stressed syllables should be impaired in dyslexics, and the severity of this impairment should be predictable by individual differences in rise time perception.

Leong *et al.* (2011) assessed 20 dyslexic adults (mean age 25 years and 3 months) and 20 non-dyslexic controls (mean age 26 years and 3 months). They created a novel task to measure stress perception (using a same-different task paradigm) which used four-syllable long words with two different stress patterns; either words with the primary stress on the first syllable (e.g. *DIfficulty*) or words with a primary stress placement on the second syllable (e.g. *maTERnity*). These were recorded with correct stress placement and incorrect stress placement (e.g. *MAternity*) and then paired as tokens in four different ways (SWWW – SWWW; WSWW – WSWW; SWWW – WSWW; WSWW – SWWW).

Participants were then asked to decide whether the presented stimuli had the "same" or "different" stress placement. Two experiments were conducted, the first included word pairs that had the same stress placement and were also the same words (e.g. *maternity – maternity*) and in the second experiment the words differed but had the same stress placement (e.g. *maternity – ridiculous*). Participants were also assessed on IQ, reading and spelling tasks as well as on phonological processing tasks (Spoonerisms and RAN). The psychoacoustic measures used were a frequency and intensity discrimination task and the rise time task previously employed by Richardson *et al*. (2004), which was a more child friendly adaptation of the rise time task used by Goswami *et al*. (2002) that used dinosaur characters which excluded the procedure of categorical distinctions (matching of sounds to specific toys; created by D. Bishop, Oxford University 2001).

It was found that the dyslexic adults were significantly less sensitive to the rise time and frequency measures compared to controls. In terms of the *first word stress task* (using same words for same stress pattern, but pronounced differently), significant differences between groups were found (p = .010). The groups did not differ however based on which stress patterns were used (SWWW or WSWW). Regression analysis further revealed that when group was entered at Step 1 and rise time was entered at Step 2, the rise time task was able to account for 24% of unique variance in the syllable stress task, indicating that accurate perception of syllable stress is related to basic auditory perception of rise time. Since the same words were used in the stress task it could have resulted in the task being rather easy, therefore the second experiment was conducted using the word pairs in the stress task that contained different words (but retained the same stress pattern). This would increase the cognitive load and also require more abstract stress templates to be accessed and segmental information would also need to be ignored.

Findings were the same as in Experiment 1; overall group differences were found, but no significant effects of stress pattern or interaction between groups and stress pattern were obtained. Regression analyses showed that rise time was nearly significantly able to contribute 5% of variance to this syllable stress task (p = .07); frequency and intensity did not add unique variance. As sensitivity to stress across both experiments was correlated, they were both combined to create an average sensitivity score (*d'*); rise time was then significantly contributing 10% of variance to this, even after controlling for the group factor.

Further correlations showed that stress sensitivity, when measured by both experimental tasks individually, and when combined, was significantly associated with all literacy and literacy related skills. Regression analyses also revealed that stress sensitivity and reading skills were predictive of group membership (either dyslexic or control). These findings indicate that stress perception is a better indicator of dyslexics' difficulties than auditory perception or phonological awareness in these adult dyslexics. Additionally, it was suggested that prosodic sensitivity may be a stronger marker of difficulties in adults than in children (were auditory and phonological difficulties indicate dyslexia).

The authors highlighted that relationships between stress sensitivity and reading acquisition are only beginning to be demonstrated; which is a warranted comment, however they did not acknowledge many studies other than those concerning rise time measures. Considering the literature presented in section 1.4.2, which demonstrated that several studies were conducted in the last decade, which found relations between prosody, phonological awareness and reading, it is not a novel finding. However, the findings depicted by Leong *et al.* (2011) showed associations between a rise time measure and a stress perception task, which until now have not been demonstrated and this now offers some support for the notion that stress sensitivity and rise time perception are in fact assessing similar aspects; or that stress sensitivity derives from basic auditory processing skills.

A general auditory processing-based account of reading difficulties was recently proposed by Goswami (2011) in her *temporal sampling framework (TSF) of developmental dyslexia* model, but this does not examine speech rhythm per se and, as has been demonstrated by Holliman *et al.* (2010a), independent contributions of speech and non-speech rhythm have been found. Since the focus of this thesis is placed upon speech rhythm, non-speech rhythm based studies were not further included in this review.

To expand upon Holliman *et al.*'s (2010a) study, Holliman *et al.* (2010b) conducted a follow-up investigation and tested 69 of the previously assessed children one year later. Their age ranged from 5 year and 11 months to 8 years and 8 months and the children were in Years 1 to 3 at the time of re-testing. Assessments included rhyme and phoneme deletion, word reading and reading fluency, which were also assessed at Time 1. Further to these measures reading comprehension was also tested at Time 2. It was of interest to investigate whether speech rhythm sensitivity was related to phonological awareness (at both times) and vocabulary and whether speech rhythm sensitivity (measured at Time 1) was able to predict word reading, reading comprehension and/or reading fluency at Time 2.

Significant correlations were found between speech rhythm and all measured variables. To further assess the relationship between speech rhythm and the reading variables several multiple regression analyses were conducted, controlling for age, vocabulary, phoneme and rhyme awareness at Time 1 prior to including the speech rhythm measure. For word reading, speech rhythm sensitivity was able to account for 2.2% of variance after the other variables were controlled. The contribution of speech rhythm to reading comprehension approached significance. Fluency was assessed with the

Multidimensional Fluency Scale (Zutell and Rasinski 1991), which yields scores for phrasing, smoothness and pace (also for accuracy but this was not included in this study). Thus three separate multiple hierarchical regression analyses were conducted to assess speech rhythm's predictability of each of these fluency aspects. It was found that phrasing was the only aspects that speech rhythm sensitivity could predict after age, vocabulary and phonological awareness were accounted for. Bearing in mind that phrasing is assessed on the basis of correct use of prosody and emphasis on words, this relationship may not be surprising.

The observed associations between prosody, phonological awareness and word reading were also in line with previous studies (e.g. Goswami *et al.* 2002; Holliman *et al.* 2008, 2010a; Wood 2006a) and indicated a direct contribution of speech rhythm sensitivity to reading skills, thus expanding upon the proposed model by Wood *et al.* (2009). Rhythm's contribution to reading comprehension appeared to be via vocabulary and/or phonological awareness thus indicating that reading skills may be influenced differently.

The final pathway proposed by Wood *et al.* (2009) incorporates morphological awareness, which was not assessed in the previously presented studies, and may explain the observed, direct contribution of speech rhythm to reading skills, at least in the older samples. Morphological awareness has been linked to reading abilities in English (e.g. Carlisle 2000; Carlisle and Stone 2005) and also in Hebrew, for example. Ravid and Mashraki (2007) have found that fourth-graders' morphological knowledge moderated the relationship between prosody and reading comprehension, which could also be the route in which prosody is linked to reading comprehension in English speaking children.

Since the stress pattern in some English words changes when suffixes are added, it appears important to be sensitive to these changes in order to read multisyllabic words correctly and to enhance semantic processing. It has been observed (Jarmulowicz 2002) that 7- to 9-year-old children are able to place correct stress on syllables in words which require stress-shifts due to addition of certain suffixes (such as – *ity*, and – *al*). This however appears to be an ability that increases with age, as older children were more accurate than younger children, indicating a skill developing over time.

The implication of speech rhythm sensitivity to reading skills via morphological awareness has been further assessed by Clin, Wade-Woolley and Heggie (2009). They examined 9- to 13-year-old children and found that prosodic sensitivity could significantly predict morphological awareness, even after controlling for vocabulary, nonverbal IQ, memory and phonemic awareness, and prosodic sensitivity also displayed significant associations with reading skills. Interestingly, and in line with the proposed model, after controlling for these variables and morphological awareness, speech rhythm sensitivity was no longer able to account for significant unique variance in reading skills, indicating that morphological awareness was mediating the relationship. However, more research is required to fully test this claim.

In sum, it can be said that the model proposed by Wood, Wade-Woolley and Holliman (2009) does provide good indications of the relationship of speech rhythm in reading development however the empirical evidence is rather mixed as to how exactly speech rhythm impacts upon reading skills. The studies overall indicate that the pathways associated with speech rhythm and its contribution to reading development vary, potentially according to age, but also depending on the speech rhythm measures used. Although it was stated that maturation does not appear to be implicated in speech rhythm's development (Wood 2006b) the varying findings of different samples of children across studies may be indicating otherwise. Different aspects of sensitivity to rhythm (speech and non-speech based as well as lexical or metrical stress sensitivity and perhaps a change from implicit sensitivity to stress to explicit awareness of stress) could be associated with varying literacy-related skills at different times in the child's reading development, thus making it more difficult to provide one theoretical model which captures this accurately. Furthermore, the use of diverse (non) speech rhythm measures across these studies further presents an obstacle, which makes it difficult to ascertain the true, underlying link of (non) speech rhythm to each of the literacy and literacy related skills that have been tested. A more systematic approach is required to disentangle how, and when, speech rhythm impacts upon reading attainment.

1.4.3 Speech Perception Based Account of Prosody in Reading

The implications of speech rhythm sensitivity as well as auditory processing have been demonstrated and Zang and McBride-Chang (2010) highlighted that auditory sensitivity and speech perception may both be causally associated with reading difficulties and that either of these domains (or both combined) could be at the root of phonological deficits. The importance of auditory sensitivity and speech perception abilities have been conceptualised into a new model, which demonstrates how these two skills relate to one another and how they can influence reading development.

It has been debated whether reading difficulties are based upon speech-specific or phonological deficits (e.g. Manis and Keating 2005; Mody, Studdert-Kennedy and Brady 1997; Ramus 2003) or stemming from deficits in auditory perception (e.g. Molfese 2000; Tallal 1980; Witton *et al.* 2002). According to Kuhl (2004) infants are born with different auditory sensitivities which develop further through the specific and frequently occurring acoustic features that children are exposed to in their native language; some children may experience delayed auditory sensitivities which could impair (or delay) speech perception (and subsequently reading). Therefore Zang and McBride-Change (2010: 331) concluded that "the apparent speech deficit may originate from early auditory insensitivity". Further, most studies investigating differences in speech-specific or auditory processing deficits have focused on auditory temporal processing, and it has been argued that acoustic rhythmic sensitivity also plays an important role in auditory processing. These two types of auditory processing may be related differently to reading problems and might be fundamentally different in nature (e.g. Hämäläinen *et al.* 2008).

Drawing on contemporary research, the proposed four stage model by Zang and McBride-Chang (2010) begins with temporal processing and rhythmic sensitivity, which are skills present early on in life (and determined to some extent by genes and individual differences). In the proposed model (see Figure 1.5) rhythmic sensitivity is directly impacting upon suprasegmental speech perception (or *speech prosody*; e.g. Goswami *et al.* 2009), whereas temporal processing influences segmental (phonemic) aspects of speech perception (based on the temporal processing hypothesis, e.g. Tallal 1980).

Speech prosody could also influence segmental speech perception, and this has been argued to occur through facilitation of spoken word recognition and vocabulary through stress (rhythm) sensitivity, which then enhances phoneme perception (based on the lexical restructuring hypothesis, Metsala and Walley 1998; Wood *et al.* 2009). Although temporal sensitivity and rhythmic sensitivity are both part of general auditory processing, research has also shown that poor readers could be impaired in one area but not the other (Amitay, Ahissar and Nelken 2002; Muneaux *et al*. 2004) and thus these constructs should be treated as separate entities.

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Figure 1.5 Model of Auditory sensitivity's role on reading, adopted from Zang and McBride-Chang (2010)

Following this, reading could be influenced by segmental sensitivity through several pathways; via phonological awareness, lexical access (rapid automatised naming) and verbal short-term memory (e.g. McBride-Chang 1996). Suprasegmental sensitivity on the other hand could impact upon reading via these three mentioned pathways but additionally also via morphological awareness; in line with the fourth proposed model by Wood *et al.* (2009). Given that some words' stress patterns change when suffixes or prefixes are added or when a word or morpheme becomes a compound noun, these stress changes could provide important cues for reading (based on morphological and grammatical cues; Clin *et al.* 2009).

In support for this model, research has shown that speech prosody correlates with phonological awareness (e.g. Holliman *et al.* 2008; McBride-Chang *et al.* 2008a; Wood and Terrell 1998b) but that it can also explain reading independently of PA (e.g. Goswami *et al.* 2002; Holliman *et al.* 2010; McBride-Chang *et al.* 2008b). In addition to this, suprasegmental speech sensitivity has been documented to occur prior to segmental speech sensitivity (e.g. Jusczyk 1992) and thus may aid and facilitate the understanding of phonemic information (e.g. Wood *et al.* 2009). Drawing upon these collective findings enables researchers to further the understanding of reading development and explore the underlying reasons for phonological deficits observed in children with reading difficulties. These could occur at various different points in the development of a child's auditory processing and/or development of speech perception, and then subsequently impact upon the child's ability to read.

1.5 Summary and Outstanding Questions

This literature overview has highlighted current views on reading development, with special emphasis on the role that prosody plays in this process. From this review it can be seen that typically developing readers appear to differ from poor readers (and dyslexics) on several reading related skills:

- Segmental phonological awareness
- Phonological possessing speed (RAN)
- Vocabulary (in some cases, such as SLI/Dyslexia)
- Suprasegmental sensitivity

To summarise, we can say that speech rhythm does appear to play a role in children's language development (e.g. Cutler and Norris 1988) and plenty of evidence has also emerged to link prosodic sensitivity to reading ability. The current view is that prosody could be a precursor for phonological awareness development; by aiding phoneme awareness and rhyme awareness, as well as the retrieval of phonological representations from memory (e.g. Frazier *et al.* 2006; Goswami 2003; Wood 2006b), which then indirectly affects reading. Speech rhythm could also be more strongly related to reading in older samples, via vocabulary for example (Williams and Wood 2012). Although other studies have shown deficits in speech rhythm to persist into adulthood, those associations were weaker compared to those with children (e.g. Pasquini, Corriveau and Goswami 2007) and the effects of vocabulary have not always been explored (Corriveau *et al*. 2010); however the impact of age and IQ were controlled for in most studies when speech rhythms' predictability of phonological awareness or reading was assessed. Moreover, age has not been found to play a direct role in speech rhythm sensitivity's relation to reading; however this sensitivity appears to change with age and clearly reading skills also vary with age thus some degree of association must be present. Whether speech rhythm sensitivity increases in line with reading exposure is doubtful (Wood 2006b) however the importance of this skill may vary depending on the literacy skills that are being developed further at any given time. We still do not know how speech rhythm sensitivity changes over time because there are such few longitudinal studies to date; they are underway however and may offer better insight to this matter in the future (Gowasmi *et al.* 2010; Huss *et al.* 2011).

Additionally, prosody could be seen as an intricate feature of reading fluency, which is mastered once accurate and fast word reading has been achieved, which then aids reading comprehension (Miller and Schwanenflugel 2006). Although this also depends on the comprehension measure being used (Benjamin and Schwanenflugel 2010). Further, word reading has also been linked to prosody (Holliman *et al.* 2008, 2010a) and researchers have demonstrated that metrical and lexical stress sensitivity may correlate differently with reading skills (Whalley and Hansen 2006). However, consensus has not been reached about the exact properties being described when referring to metrical and lexical stress sensitivity (Goodman, Libenson and Wade-Woolley 2010); issues with regards to prosodic "awareness" or "sensitivity" are also still present (e.g. Mundy and Carroll 2012).

Moreover, suprasegmental phonology features are also termed differently across studies; some are:

- *Prosodic sensitivity/Prosodic awareness*
- *Speech rhythm sensitivity*
- *Amplitude envelope onset sensitivity*
- *Rise time sensitivity*
- *Sensitivity to beats*
- *Stress sensitivity*
- *Lexical/Metrical stress sensitivity*
- *Suprasegmental sensitivity*

This further presents a challenge, as it cannot always be ascertained whether researchers are in fact investigating the same construct, therefore drawing conclusions from such a vast literature cannot be completed without caution. Additionally, most studies used different measures and it is not clear whether all measured exactly the same skills. It can be said that all measured some aspects of suprasegmental sensitivity; perhaps to different degrees however.

In view of these findings and limitation this thesis consequently sets out to investigate:

1. Whether a newly developed stress sensitivity task is able to measure stress sensitivity better, and more reliably, than an existing task.

It is important to create a specific task, with clearly established parameters of what it is measuring, so that direct comparisons across studies can be completed, with one task, to further assess the relationship of speech rhythm with reading development more systematically. Therefore assessing speech rhythm should be conducted in a more practical and child-friendly way.

2. If stress sensitivity (as measured by this new task) is related to children's reading performance and phonological awareness across age groups.

Another important aspect is the systematic assessment of children across different age groups, using the same speech rhythm measure. The literature to date is mixed and clear conclusions cannot yet be drawn in terms of how speech rhythm sensitivity affects or influences reading skills. Using the same measure with a range of different children may aid this and could enable a clearer conclusion as to how speech rhythm is associated with reading-related skills and subsequently with the development of reading skills.

3. Whether stress sensitivity is predictive of children's reading development over time.

Clearly, the need for more longitudinal studies is present in order to provide more understanding of speech rhythms' relationship to reading skills, which may change over time, or may only be detectable over time (Miller and Schwanenflugel 2008). Thus it is important to investigate speech rhythm longitudinally to further ascertain this. Additionally, assessing children cross-sectionally with the same measure may also offer insight into underlying relationships between stress sensitivity and children's reading skills at one given time. In doing so, it may provide further insights which could promote the development of clearer reading models, which specify different associations of rhythmic sensitivity across ages and time, to map the developmental trajectory of reading skills.

Overall, plenty of areas still require additional research support but this thesis will focus on the measurement and age-related aspects of speech rhythm sensitivity to aid the research and theory in this area. It is important to employ more systematic research methods in this field, conducting clear cross-sectional assessments and longitudinal studies that use the same measures, in the way that Goswami and colleagues have done with their rise time paradigm for investigating general auditory processing of non-speech rhythm. However, although Goswami and colleagues use the rise time paradigm across all their research studies, they also appear to vary the rise times across studies slightly, thus it is difficult to appreciate the measure fully and to be able to replicate their findings systematically. Furthermore, it may be helpful to use more unselected samples rather than strictly comparing dyslexics and typically developing readers, as not all dyslexics consistently demonstrate speech rhythm sensitivity deficits, and typical readers may also demonstrate some reduced sensitivity in some cases, but may demonstrate normal phonological awareness skills (Goswami *et al.* 2010; Ramus and Ahissar 2012).

The following chapter will provide an overview of speech rhythm measures used to date, followed by the demonstration of a newly developed task. This will be followed by an overview of the research studies that were conducted as part of this doctoral thesis.

Chapter 2 – Methodology

2.1 Introduction

This chapter will provide an overview of several prosody measures which have been used to assess sensitivity to speech rhythm in the literature to date. This will be followed by an in-depth explanation of the development of a new measure, the Lexical Judgement Task, which was piloted and validated as part of this doctoral thesis. Following this overview, the measurements and tests used in each study conducted will be outlined. As the same measures were used in several studies included in this thesis it was regarded as most efficient to present all assessments in detail below to avoid repetition. The assessments used in each study (see Chapters 3 to 7) will be mentioned briefly in each corresponding chapter, and this chapter will be referred to for a detailed overview.

Most of the tests used (apart from the speech rhythm assessments) are standardised tests previously used with children, and were administered according to standardised instructions. The measures were selected because they are commonly used in reading research and their administration here would allow for a comparison with the literature. Where available, the Cronbach's alpha as reported in the test manuals was included following each assessment overview. In addition, the alpha values for each test with each sample in this thesis are presented in the corresponding study chapters.

2.2 Speech rhythm assessments

As has been outlined in Chapter 1, several research studies have found evidence that prosody plays an important role in children's reading attainment and development. It is important to understand which methodologies have been used to measure speech rhythm and which reading skills were found to be linked to this ability. The key components of speech rhythm that have been assessed will be evaluated in line with the methodologies used to provide an overview of important aspects needed within a task to measure children's sensitivity to speech rhythm.

Prosody or speech rhythm has been described as including intonation, stress and duration of speech (e.g. Kuhn and Stahl 2003). When measuring children's sensitivity to speech rhythm one or more of these components have been assessed in previous studies. Therefore, an important question in terms of speech rhythm assessments would be which component(s) to focus on. In this thesis, the decision was made to focus on the assessment of sensitivity to lexical stress. The rationale for this decision is explained below.

The perception of words from the speech stream has been highlighted to be aided by strong (stressed) syllables (e.g. Cutler and Mehler 1993) and being sensitive to perceptual centres in acoustic signals (onset of peaks of beats in sound signals) has also been suggested to be associated with the onset of vowels and thus facilitates vowel identification (e.g. Goswami *et al*. 2002). This stress sensitivity may also aid onset-rime boundary detection and enable better rhyme awareness, which subsequently aids reading attainment (Wood and Terrell 1998b). Therefore, it seems that being sensitive to stress plays an important role in children's speech rhythm sensitivity and is related to reading skills, and so warrants to be assessed further. Table 2.1 provides an overview of a range of studies which have assessed sensitivity to speech rhythm either directly or indirectly, summarising the speech rhythm assessments used and details about the age and abilities of the participants that were tested. It is apparent that a range of different age groups have been assessed on a range of various speech rhythm measures.

Table 2.1 Overview of some speech rhythm measures used across studies with different samples

Speech rhythm studies (in order of publication)	Description of speech rhythm measure, stimuli used and presentation of task	Sample details
Wood & Terrell (1998b)	Low-pass filtered sentences presented over a computer and external speakers; required to match filtered sentences to normal spoken sentences (correct match based on stress and overall rhythm).	90 children; mean age of 8;2 years (*SD* = 23.9). Included 30 poor readers, 30 age-matched and 30 reading-level matched controls
Kitzen (2001)	Phrases spoken by researcher followed by tape-recorded phrases in DEEdee language (heard through external speakers). Required to match spoken phrases to Deedee phrase which follows same rhythmic pattern as the target. Also, Compound Noun Task; required matching of phrases to pictures of heard items based on intonation, stress and pauses.	60 adults; 30 with history of reading difficulties (mean age of 20.97 years, *SD* = 4.68) and 30 without history of reading difficulties (mean age 22.2 years, *SD* = 6.17).
Goswami *et al.* (2002)	Sound sequences, with manipulated amplitude rise times were presented over a computer and headphones; required to match a rhythm to either 'Winnie the Pooh' or 'Tigger and Eyeore' based on two different beats (rise time) and rhythms.	101 children; 24 dyslexics and 24 age-matched controls ((mean age 9 years, *SD* = 11 and 8 months) as well as 25 reading-level matched controls (mean age 7;11 years, *SD* = 4 months).
Schwanenflugel *et al.* (2004)	Children's passage reading was recorded and subsequently scored for intersentential pause length means and variance, intrasentential pause length means, child–adult F0 sentence match and sentence-final declination of pitch.	123 children; mean age 8;6 years (ranging from 7;4 to 10;4 years) Additionally, 24 adults as comparison for prosodic reading.
Wood (2006b)	Mispronunciations Task; presentation of pre-recorded words from a minidisc over external speakers. Required identification of objects from a line drawing of a house after hearing words with manipulated or reversed stress.	Study 1: 39 children; 23 pre-schoolers and 16 reception class children (mean age 4;3 and 5;2 years, respectively). Study 2: 31 5-, 6- and 7-year-olds (mean age 5;4, 6;3 and 7;2 years, respectively).
Whalley & Hansen (2006)	DEEdee task adaptation; Spoken English phrases followed by recorded DEEdee phrases presented over speakers. Required matching of spoken phrases to DEEdee phrases based on rhythm. Also Compound Noun Task; required matching of phrases to pictures of heard items based on intonation, stress and pauses.	81 children; mean age 9.3 years (*SD* = 4.58 months), ranging from 8.8 to 10.5 years.

Speech rhythm studies (in order of publication)	**Description of speech rhythm measure, stimuli used and presentation of task**	**Sample details**
De Bree *et al.* (2006)	Children had to repeat nonwords presented through speakers, which were recorded for later analyses. Words contained varying stress patterns that varied in terms of regularity according to Dutch language norms.	49 Dutch children at risk of dyslexia (mean age 3.3 years, *SD* = 4 months) and 28 Dutch speaking controls (mean age 3.1 years, *SD* = 3 months).
Thomson *et al*. (2006)	Tasks included discrimination of tone intensities, tone durations and sound sequences' amplitude rise time modulations, which were presented over a computer (using the dinosaur paradigm) with headphones. Also motor rhythm task including receptive rhythm skills and tapping to a metronome (expressive rhythm).	19 dyslexic adults (mean age 22;3 years, *SD* = 3;3 years) and 20 adult controls (mean age 22;3 years, *SD* = 2;11 years).
Holliman *et al.* (2010a)	Revised mispronunciations task; presentation of pre-recorded words from a minidisc over external speakers. The words' stress was reversed and identification of heard word from a choice of four pictures was required from participants.	102 children, mean age 6.7 years, from reception class (*n* = 4), Year one (*n* = 57) and Year two (*n* = 41).
Corriveau *et al*. (2010)	Using the dinosaur paradigm, presentation of tones to children over headphones; required intensity discriminations, amplitude rise time discriminations, and frequency discriminations of tone sequences.	88 children, age range 3 to 6 years. 16 with mean age 3;3years, 29 with mean age 4;6 years, 27 with mean age 5;5 years and 16 with mean age 6;6 years (all *SD* = 4 months).
Leong *et al*. (2011)	Using the dinosaur paradigm, presentation of tones to adults over headphones; required intensity discriminations, amplitude rise time discriminations, and frequency discriminations of tone sequences. Also, syllable stress task requiring same-different judgment of pre-recorded word pairs which either followed same or different stress patterns.	20 adult dyslexics (mean age 25.3 years, *SD* = 5.6 years) and 20 adult controls (mean age 26.3 years, *SD* = 5.2 years).
Mundy and Carroll (2012)	Adaptation of DEEdee task; utterances heard over headphones followed by visual presentation of stimuli to match to heard utterance (prosodic awareness task); also Cross-modal fragment priming task to measure implicit prosodic awareness. Spoken prime followed by visual target (stress congruent; stress incongruent or phonologically unrelated). In second experiment DEEdee task replaced by fragment identification task; matching of heard word fragment (e.g. prósec) to visual presentation of word (which matches (or not) the lexical stress of fragment, e.g. prósecutor).	Experiment 1: 32 adult dyslexics (mean age 20 years, SD = 4.23) and 48 adult controls (mean age 21 years, SD = 7.11). Experiment 2: 16 adult dyslexics (mean age 24 years, SD = 10.98) and 24 adult controls (mean age 19 years, SD = 3.36).

Some of these studies and tasks will now be reviewed to provide greater insight into the measures used, to present a clear justification why a new speech rhythm (stress) sensitivity measure needed to be developed.

Rhythmic (Sentence) Matching Task

Wood and Terrell (1998b) devised a *sentence matching task* to measure children's sensitivity to metrical stress in speech. Children aged between 5 and 10 years were presented with a recorded low-pass filtered sentence which followed a particular rhythm of strong and weak syllables (e.g. SWWSSS). The researcher then read out two sentences which either matched the metrical rhythm of the low-pass filtered phrase or differed by one syllable (e.g. SWWSWS). The filtering removed the phonemic cues from the utterances and the children were asked to match one of the spoken sentences to the previously heard recording. A correct response could be made by correctly matching the metrical pattern of the two sentences and thus indicating sensitivity to rhythm. One limitation of this task however was the intensity of the memory load, as the children had to remember the recorded sentences in order to match the spoken ones to it. This represents a significant load in phonological short-term memory, something which was noted in Chapter 1 as being impaired in children with reading difficulties. This could have negatively influenced the children's performance on the task and implicated on the results.

(Revised) Mispronunciations Task

Following the use of the sentence matching task, Wood (2006b) developed the *mispronunciations task* to further analyse children's ability to identify metrical stress changes and how this relates to phonological awareness and reading. This task was designed in order to be used with very young children in the earliest stages of learning to read and to have a limited memory load. The children were presented with a picture of a house which was filled with several items (e.g. sofa, table, teddy, carpet etc.). They were introduced to Blueberry (a toy dog) who was the owner of the house. As a baseline measure the children were then required to identify all the items in the house that they heard from a female speaker (played to them from a recording). This was done for all 25 items but only 12 items were scored (the ones used in the subsequent trials). All the items were two syllable words with the primary lexical stress on the first syllable and a vowel reduction (schwa) on the second syllable.

There were four different conditions that the children were presented with on different occasions (each child was presented with each condition and the order of items presented were randomised). For each condition, the children were introduced to other toy animals who were Blueberry's friends. Each of these toy friends had diffculties saying words correctly and the children were asked to help out with identifying the objects they heard. The four different conditions were as follows: A) word stress was reversed, first syllable vowel was reduced and second syllable vowel fully articulated, B) only first vowel was changed, second vowel stayed reduced, C) primary lexical stress was placed on second syllable and reduced vowel fully articulated, D) two vowels were changed but both fully articulated. The conditions were ordered as A being most difficult, B the easiest and C and D somewhat of medium difficulty.

The children tested in Wood's (2006b) first study were 4- and 5-year-old children and it was shown that Condition A proved most difficult for both age groups but Condition B was not regarded as the easiest. It was concluded that performance was not dependent on how many factors were changed but which one, showing that metrical stress was an important aspect for word identification.

A second study was designed as a small cross-sectional comparison of 5-, 6- and 7-year-old school children on the stress reversal condition (A) only, to investigate any performance differences among a wider age range. Examining these children also allowed for phonological awareness and literacy assessments to be taken in order to analyse whether metrical stress reversal was associated with either of these variables. More test items were included in this study (15 items in total plus one practice item ‘money’) and the picture was amended accordingly.

The 5-year-old children were outperformed by the 7-year-old children and it was found that, after taking age, vocabulary and phonological awareness into account, metrical stress was associated with literacy and able to account for variance in spelling. These findings suggest that metrical stress is associated with spelling beyond phonological awareness and offered a good indication for stress sensitivity’s link to literacy. Holliman *et al.* (2008) also used this task in their research with 5- to 6-year-old children (employing the stress reversal condition only) and found that stress sensitivity also predicted unique variance in reading attainment (after controlling for age, vocabulary and phonological awareness).

Although the task was theoretically sound, simple to administer to the children and provided further empirical support for the importance of speech rhythm to literacy development there were also some limitations. A direct comparison of the results from both of Wood’s (2006b) studies was limited as the samples’ ages were different and also the task varied (in terms of the words used and the inclusion of more distracter items). Further, having to hold a mispronounced word in mind whilst looking for the object in the picture drawing might have still been too memory intensive for the children. Additionally, Wood (2006b) did not control for vocabulary, which may mediate the link between spoken word recognition skills and reading; although this was shown not to be the case in the later study by Holliman *et al*. (2008). Another criticism of this task was that the children could have used phoneme-based strategies to match the heard mispronunciations to items in the house rather than trying to resolve the stress reversal itself, for example hearing *s'far* instead of *sofa* could have let the children to seek out items in the house that began with /s/.

Bearing these limitations in mind, Holliman, Wood and Sheehy (2010a) revised the mispronunciations task. To simplify the task, they presented the children with a recording of a word followed by four pictures from which the child had to choose the correct one. These items all began with the same letter-sound and phoneme and were all two syllable words with the primary lexical stress on the first syllable and with a schwa on the second syllable and were matched for their frequency. In total 19 words were presented to the children through recordings (one practice item and 18 test items). In the baseline condition the recorded words were pronounced correctly and the recorded words for the experimental condition all had their metrical stress patterns reversed (reduced vowel on first syllable and fully articulated vowel on the second syllable). Both conditions were administered, in a counterbalanced way, one week apart to each child to avoid memory effects.

High correlations with the phonological awareness tests and speech rhythm as measured by the revised mispronunciations task indicated that either the construct of speech rhythm is highly correlated with phonology or that the task measured to assess speech sensitivity is highly contaminated by phonological cues. The fact that the words and pictures presented to the children were matched to share the same phoneme is an issue that needs to be examined closer. This could have aided the children to apply a phonemic strategy and it cannot be said clearly that pure speech rhythm sensitivity was measured by this task.

As phonological awareness can be linked to segmental phonology and speech rhythm sensitivity can be linked to suprasegmental phonology, it can be hypothesised that these constructs are highly linked and the high correlations of PA and speech rhythm in Holliman *et al.*'s study (2010a) are to be expected. Nevertheless, it needs to be ensured that speech rhythm assessments are not contaminated by segmental phonology, so that it can be concluded that the strategies employed by the child to complete the task were not relying on multiple strategies but purely relying on speech rhythm sensitivity.

DEEdee Task

Kitzen (2001) created the DEEdee task, employing a reiterative speech technique (Nakatani and Schaffer 1978), which, through the replacement of syllables with the same syllable ('dee') results in the removal of phonemic information whilst retaining stress, rhythm and intonation patterns. This task was initially used with adults, presenting them with DEEdee phrases based on movie and children's story titles. The participants were given a list of three English language titles which the researchers read out to them (to reduce any difficulties the participants may have had with reading the stimuli). They were then played a pre-recorded DEEdee phrase which matched one of the presented English titles based on the stress pattern. After 15 seconds the recording was played again so that the participant could make a decision regarding which phrase matched the DEEdee phrase without having to rely solely on the memory of the phrase. Participants were given two practice examples of the DEEdee task before completing 20 test items.

Whalley and Hansen (2006) adapted the DEEdee task to be used with children. They chose different movie or book titles to be changed into DEEdee phrases, which the children could relate to (e.g. Snow White and The Lion King). The phrases varied in number of syllables from two to five. The target and foil DEEdee phrases were all matched according to syllable length. The children were presented with two practice trials to explain the task, followed by 18 test trials. The original phrase (e.g. The Simpsons) was always presented first followed by two DEEdee phrases, e.g. 'DEEdee DEE' (Peter Pan) and 'dee DEEdee' (The Simpsons). These phrases were presented twice in total in the same order. The children then had to decide which DEEdee phrase matched the original utterance.

Similar to the sentence matching task devised by Wood and Terrell (1998b) this prosodic sensitivity task was also very memory intensive. Vocabulary or IQ was not controlled in Whalley and Hansen's analyses; which may have indicated that the completion of the task is relying on vocabulary knowledge or cognitive demands. Yet the DEEdee task appeared to be a good predictor of reading comprehension, again indicating some relation between speech rhythm and reading skills.

However, examining the stimuli in this stress sensitivity task more closely, it can be hypothesised that the exchange of syllables for stressed and unstressed 'dees' is in effect not entirely stress-based. The use of 'dees' could guide the children tested on this task to listen out for phonological cues hidden in the 'dees' themselves instead of listening for stress changes in the stimuli. For instance, when the /d/ and /e/ sounds in the 'dee' map onto the same phoneme in the target phrase, e.g. 'Sesam**e** Str**ee**t' (DEEdeed**ee** D**EE**) compared to 'Bob the Buil**d**er' (DEE dee DEE**d**ee), and less so in the distracter phrase, the children could be making their decisions based on sophisticated phoneme strategies rather than stress sensitivity. Moreover, in terms of the tasks' reliability, the DEEdee task's Cronbach's alpha has only been reported twice before. Goswami, Gerson and Astruc (2009) reported α .45, when they assessed 8- to 15-year-old children, and Holliman *et al.* (2012) reported α .37, when assessed with 7- to 10-year-old children. These levels of internal reliability are poor for an assessment of this nature, and highlight potential weaknesses with the item selection within the task itself.

Nevertheless, the DEEdee task has been widely used following its redevelopment by Whalley and Hansen (2006) and findings from these studies show associations between stress sensitivity and reading comprehension and word reading (e.g. Whalley and Hansen 2006; Goswami, Gerson and Astruc 2009; Mundy and Carroll, 2012; Holliman *et al.* 2012). Disregarding its potential inclusion of phonological cues, this task is regarded as a well- structured measure of stress sensitivity and thus was used in the pilot study as an additional speech rhythm assessment; it was further included to analyse the construct validity of the Lexical Judgement Task (see below).

Compound Noun Task

Originally developed by Blumstein and Goodglass (1972), the compound noun task has since been adapted and used repeatedly to assess stress contrasts made by individuals. Kitzen (2001) for example adopted this task with minimal changes to the stimuli used (see also Wells and Peppé 2003). Participants were presented with an audio recording of a word followed by the presentation of a picture card with four different pictures depicted on it. These words were either compound nouns (*HIGHchair*), noun phrases (*high CHAIR*), a noun (*CONvict*) or the corresponding verb (*conVICT*). Each picture card included two drawings of either compound noun and noun phrases and two distracter items (foils) or two drawings of noun and verbs and two foils. The participants were asked to point to the corresponding picture after hearing the audio recorded prime. There were 17 noun/verb and compound noun/noun phrase pairs which differed in stress placement but were phonemically similar. The picture cards were randomly presented one to four times upon hearing of a word or phrase, for a total of 40 times. Blumstein and Goodglass (1972) pointed out that this task appeared to be somewhat artificial and difficult and hence could result in ambiguous findings, in such that listeners may rely more on context than mere stress perception to classify the words' meanings. It appears more likely however that this task relates more to listening comprehension of intonational patterns rather than pure stress perception (e.g. Holliman, Wood and Sheehy 2012).

Wells and Peppé (2003) designed a whole test battery (Profiling Elements of Prosodic Systems – Child version [PEPS-C]) to assess intonation in different areas (grammar, affect, interaction and pragmatics). Amongst their 16 assessments they used a task similar to the Compound Noun Task used by Kitzen (2001). The "chunking" task required delimitation of utterances into intonation phrases (e.g. coffee-cake and honey versus coffee, cake and honey. The first utterance resulted in a compound noun (coffee-cake) and a noun (honey) whereas the second utterance constituted three intonation phrases resulting in a list of three food items. The participants were presented with one such utterance per trial and had to choose from a line drawing representing both possible utterances which one represented the heard utterance best. Whalley and Hansen (2006) also adopted this task to measure word-level prosodic sensitivity. They also included another subtest where the participants were presented with sentences including either a compound noun (such as 'highchair') or a noun phrase (such as 'high chair') which did not offer contextual cues for the correct answer. They concluded that this task offers a good measurement of word-level prosodic sensitivity and it was shown to predict unique variance in word identification accuracy (Whalley and Hansen 2006).

Amplitude Rise Time Measures

Goswami *et al.* (2002) also assessed speech rhythm sensitivity indirectly, using an amplitude modulation/beat detection task and assessed 7- to 9-year-old children's ability to detect changes in sound sequences. These sound sequences had fixed fall times at 350ms, but manipulated rise times (ranging from 15 ms to 300ms). Stimuli presented with 15ms rise times appeared as clear beats whereas stimuli with longer rise times (300ms) appeared to be a continuous sound that varied in loudness (see Chapter 1, p. 61 for further task details). Thus, this task assessed children's sensitivity to different rise times (beat detections). Richardson *et al*. (2004) and Thomson *et al.* (2006) for instance used similar auditory stimuli as Goswami *et al*. (2002) but presented these in a "dinosaur game" with two different rise times being assigned to specific dinosaurs, and the participants had to identify which dinosaur had a clearer (sharper) beat. Further rise time tasks were used across studies, with different samples, and all were constructed using similar principles but sometimes varied in overall stimuli durations, inter-stimulus intervals or in presentation paradigms used (e.g. using two-interval forced-choice paradigm (2IFC), e.g. Corriveau *et al.* 2010; AXB paradigms, e.g. Richardson *et al.* 2004 or ABABA formats, Goswami *et al*. 2009).

Overall these studies assessed a range of different participants, ranging from 3- to 6-year-old kindergarten and preschool children (e.g. Corriveau *et al.* 2010), over primary school aged (6-12 years) children (e.g. Corriveau, Pasquini, Goswami 2007; Goswami *et al.* 2002; Thomson and Goswami 2008) to adults (e.g. Leong *et al.* 2011; Pasquini, Corriveau and Goswami 2007; Thomson *et al*. 2006). The predominant and reoccurring findings obtained from these studies are that dyslexic individuals are presented with a deficit in auditory processing compared to normally developing controls and that the rise time tasks are strong predictors of reading (and spelling) skills across a range of ages; mostly also predicting unique variance over and above phonological awareness skills.

Although this rise time paradigm appears to be a good way to assess rhythm sensitivity, there are several limitations that need to be highlighted. As already mentioned in Chapter 1, the use of non-speech stimuli (beats and tones) may not adequately reflect associations of speech rhythm sensitivity with reading and may be more closely related to sensitivity to non-speech rhythm. The tonal nature may also appear too abstract for the participants, especially young children, and may influence their understanding of the task. In order to overcome these limitations it seems more appropriate to use speech derived stimuli, presented in a format that is child friendly and easy to use.

Prosodic reading analysis

Other researchers have adopted a more "naturalistic" approach to measuring prosody. Schwanenflugel and colleagues (e.g. 2004, 2006; Benjamin and Schwanenflugel 2010; Miller and Schwanenflugel 2006, 2008) assessed the passage reading of children and later analysed these recordings for the inclusion of prosodic aspects. Although this method enables the analyses of the production of prosody in (fluent) reading it is not appropriate to use this with very young children given their less developed reading skills and also due to the fact that children's ability to produce prosodic features in their speech is apparent later than their understanding of prosody (e.g. Atkinson-King 1973).

2.3 Lexical Judgment Task

Rationale

The focus of the newly developed speech rhythm task was on the stressed aspects of words (the stressed syllables within words) and also the underlying sensitivity to these stressed aspects, rather than assessing production of stress within words and sentences. Taken all the provided information together it can be stated that, generally, a good measure needs to clearly indicate what it is assessing, be based upon a theoretical framework and further, have been validated against other assessments. The DEEdee task was chosen as a comparison measure for the new assessment. Several reasons underlie this decision: (1) in order to keep the assessment battery to a minimum only one already established speech rhythm measure was intended to be used for comparison with the newly developed task, (2) the DEEdee task has been widely used with a range of adult and children samples to date (e.g. Goswami *et al.* 2009; Holliman *et al.* 2012; Leong *et al.* 2011; Mundy and Carroll 2012; Whalley and Hansen 2006) and so comparing the effectiveness of the new measure across different age groups in comparison to the DEEdee task would yield more comparison sources than other measures, and (3) it was deemed more appropriate to include a measure that also included stimuli derived from speech rather than non-speech. Additionally, it was of interest to assess whether correlations between the two tasks (if apparent) also reflected in similar correlations with the reading skills assessed. Lastly, judging by the hypothesised contamination of segmental cues in the DEEdee task, it was of interest to see whether a task that "claims" to have removed phonemic cues would display stronger correlations to phonological awareness assessments compared to the Lexical Judgement Task.

The Lexical Judgement Task Paradigm

In order to measure “pure” stress sensitivity, a reliable assessment tool needs to be available. Based on previously used tasks (Wood and Terrell 1998; Wood 2006; and Holliman *et al*. 2010b), and as a close replica of a prosodic sensitivity measure by Williams and Wood (2010), the Lexical Judgment Task was devised. The task created by Williams and Wood (2010) was computer-based and designed to be used with adults. It comprised three different conditions, using word stimuli and employed low band-pass filtering.

Initially, participants were presented with a baseline (control) condition, which required the participants to make judgements about aurally presented words and visually presented target words. The left mouse button needed to be clicked when the words seen and heard were the same and the right mouse button needed to be clicked when the words were different. After an initial trial to familiarise the participants with the equipment, they completed the baseline measure. Following this, another familiarisation procedure was completed for the second condition. This time the participants were presented with a recording of a low-pass filtered word (at 400 Hz) followed by the presentation of a word on the screen. The participants again had to click the left or right mouse button to give their responses, according to whether or not the aurally presented filtered word was the same or not as the visually presented word. After completion of this condition, the assessment changed, without another practice session. The structure stayed the same however the participants were instructed to click the left mouse button when they thought the filtered word was similar to the presented word and the right mouse button when they thought the heard word was different to the displayed word. In this third condition, the filtered word was never the same as the word presented on screen; a “match” only occurred when the words followed the same lexical stress pattern. For example, the low band-pass filtered word was ‘acTIVity’ followed by a visual presentation of ‘comMUNity’. Both words follow the same stress pattern, with primary stress on the second syllable. Hence a correct response would be to click the left mouse button which would indicate that the words were similar. In contrast, if the filtered word was ‘imPOSSible’ followed by the visual presentation of ‘UNdertaker’ the response should be clicking of the right mouse button to indicate that the words were different from one another. ‘ImPOSSible’ has primary stress on the second syllable whereas ‘UNdertaker’ has primary stress on the first syllable; hence both words follow a different stress pattern. All the words used in this task were three syllables long, which followed four different stress patterns.

The newly developed Lexical Judgement Task (LJT) differed from this measurement on several aspects. Firstly, the presentation of the words on the screen was removed. This would ensure that the task stayed within one modality (namely the aural modality) to reduce memory load. Secondly, the second condition was removed as it would be too time consuming and possibly introduce fatigue effects if the children completed all three conditions. Additionally, presenting the children with clear words followed by the same word filtered might have encouraged the children to listen out for fragments of the actual word. That is, despite the filtering, some residual segmental information may still be present in the filtered words, so to reduce the possibility of any phonemic priming from these potential cues, different words were used. The second condition in this assessment was hence similar to the third condition in Williams and Wood’s task. The children were presented with a recording of a clear spoken word followed by a low band-pass filtered word. This word never matched the initial word however, it either matched (or did not) the stress pattern of the clear spoken word. For example, the children heard the clear spoken recording of *alphabet* followed by the filtered recording of *jellyfish*. The words follow the same stress pattern, namely with primary stress on the first syllable, and thus the children should respond by clicking a red button on the laptop to indicate that the words were similar. When presented with the clear word *bricklayer* followed by the filtered word *umbrella* the participants should press a blue button on the laptop to indicate that the words were different, as they follow a different stress pattern. *Bricklayer* has its primary stress on the first syllable and secondary stress on the second syllable whereas *umbrella* has the primary stress on the second syllable.

In total, forty different words were used within this assessment, all having three syllables and stemming from four different stress patterns. Three syllable words were chosen in order to have words with varying rhythmic contours and also to assess children with more challenging words; previously most assessments used disyllabic words which may have been too easy and also did not contain many stress variations. The words were derived from the 'Children's Printed Word Database' (Masterson, Stuart and Dixon 2002) and were selected based on the criteria of being known to children in Year 1 (aged 5- to 6-years-old) and contained three syllables. In total 860 words were found and these were checked for their stress patterns using a pronunciation dictionary (Wells 2008). Four prominent stress patterns were found and chosen to be incorporated in the stimuli list for the LJT. It was decided to include ten words from each stress pattern category, with half being low and half being high in frequencies. When selecting the words it was also attempted to choose words with similar letter and phoneme counts and the frequency cut-off for low frequency was 55 per million, whereas words with frequencies above 73 per million were classed as high frequency words. These cut-off points were derived from the database, which did not yield any words with frequencies below 18 per million and did not contain many with frequencies below 55 per million. Frequencies between 55 and 73 were also non-existent which subsequently resulted in the 73 per million and above cut-off for the high frequency words.

The words for the task were then randomly selected (using the "random sample of cases" function in SPSS) from the initially found word list and are depicted in Table 2.2, including the phoneme and letter count, the frequency and the stress pattern "code". Words with primary stress on the first syllable received the pattern code 200 (e.g. ALphabet); when the stress fell on the second syllable the code 020 was used (e.g. comPUter). The remaining two categories included words that also had secondary stress on either the first or the second syllable. Category 102 included words with primary stress on the last syllable and secondary stress (in italics) on the first syllable (e.g. *af*terNOON). Words in the 210 category on the other hand had primary stress on the first syllable, secondary stress on the second syllable and were unstressed on the final syllable (e.g. NEWS*pa*per).

These randomly chosen words where then recorded by a British English speaking female using a digital voice recorder (Olympus WS-100), who spoke each word in a short sentence and then repeated the words four times. This was done in order to achieve a neutral and natural way of saying the words. Each recording was then imported onto a computer as a *.wav* file and played back several times to determine the best sounding word within each recording. This word was then cut out of the sequence using Sound Forge Audio software and was then cut to a duration of ~1000ms. This was followed by the application of low band-pass filtering, using GoldWave Digital Audio Editor (v5.57 software 2010).

The words were filtered at 500 Hz and at 400 Hz to reduce the segmental phonological information carried by the words. Initially, the 500 Hz filtered words were presented to independent researchers to determine whether they were able to hear which word was played.

Table 2.2 Lexical Judgement Task (experimental condition) word stimuli

Word	Letter Count	Phoneme Count	Frequency value	High/Low Frequency	Stress pattern code
1. Alphabet	8	7	91	High	200
2. Astronauts	10	9	128	High	200
3. Factory	7	7	292	High	200
4. Suddenly	8	6	987	High	200
5. Vitamin	7	7	91	High	200
6.Burglary	8	7	18	Low	200
7. Honeycomb	9	7	18	Low	200
8. Jellyfish	9	7	18	Low	200
9. Officer	7	6	37	Low	200
10. Pantomime	9	8	18	Low	200
11. Afternoon	9	7	219	High	102
12. Disappear	9	7	91	High	102
13. Kangaroo	8	7	913	High	102
14. Lemonade	8	7	73	High	102
15. Magazine	8	7	164	High	102
16. Anymore	7	6	37	Low	102
17. Introduce	9	9	18	Low	102
18. Mandolin	8	8	18	Low	102
19. Overhead	8	6	37	Low	102
20. Siamese	7	6	18	Low	102
21. Grandmother	11	9	201	High	210
22. Caretaker	9	7	128	High	210
23. Grasshopper	11	9	128	High	210
24. Newspaper	9	9	146	High	210
25. Shopkeeper	10	8	91	High	210
26. Bonfire	7	7	18	Low	210
27. Sunglasses	10	9	37	Low	210
28. Bricklayer	10	8	37	Low	210
29. Kingfisher	10	8	37	Low	210
30. Timetable	9	7	18	Low	210
31. Bananas	7	7	146	High	020
32. Computer	8	9	639	High	020
33. Remembered	10	8	128	High	020
34. Umbrella	8	7	329	High	020
35. Amazing	7	6	384	High	020
36. Allotments	10	9	55	Low	020
37. Commotion	9	6	18	Low	020
38. Forever	7	7	18	Low	020
39. Inspector	9	9	37	Low	020
40. Performance	11	8	18	Low	020

It was found that most words were easily recognizable thus the 400 Hz versions were presented next. These appeared to be harder to identify and it was deemed appropriate to use these stimuli for the Lexical Judgement Task. Additionally, this 400 Hz low-pass filtering cut-off had previously been used by other researchers employing this technique (e.g. Nazzi, Bertoncini and Mehler. 1998; Williams and Wood 2010).

By taking away the segmental information of a word, a “bare” construct of the word is left (keeping the prosodic contour intact), which makes it difficult for the listener to determine which word is being heard. By comparing words which share the same stress pattern it could reveal underlying cognitive constructs which are activated when listening to words or even when reading those, through the ability to identify rhythms following the same stress pattern. Slowiaczek, Soltano and Bernstein (2006) for example suggested that strong syllables influenced the processing of aurally presented words and that strong syllables may be used to initiate lexical access through the promotion of phonetic information processing, which aids the access of lexical structures. As Cutler and Norris (1988) showed, being sensitive to (strong) syllables aids speech segmentation and this sensitivity also draws attention to vowels and onset-rimes, which subsequently can aid phonological awareness development (e.g. Wood *et al*. 2009). Therefore, assessing children’s sensitivity to prosodic contours could indicate their stress sensitivity, which subsequently has been said to be linked to phonological awareness development and reading attainment.

The computer task was created using Eprime 1.0 and was presented to the participants on a Toshiba Portégé R500 (Intel (R) Core (TM) 2 CPU, 1.2 GHz processor) laptop computer and the sounds were heard through Lowrider Skullcandy headphones. Task screenshots and order of presentation as well as the stimuli list for the LJT baseline condition (including clear spoken stimuli pairs) can be found in Appendix 1 and 2. In brief, the task comprised an introductory screen, followed by the presentation of the four practice items (with corrective feedback). During the main experimental trials, a picture of a cartoon character was always presented prior to the presentation of the sound stimuli; this picture was on screen for 1200ms. This was used to maintain their attention on task and cue them that another sound was about to be played. Then the first (clear spoken) stimuli was heard (maximum length of 1000ms). The inter-stimulus-interval between the words was always 1000ms, then the second (either clear or filtered) stimuli was heard; the screen remained blank until a response was given (by button pressing). The items were presented in a computer generated randomised order.

The Lexical Judgement Task was piloted and subsequently validated in several research studies (see Chapters 3 to 7).

2.4 Ethical considerations and participant recruitment

The Research Governance of the Coventry University Ethics Committee was adhered to and the British Psychological Society's (BPS) Code of Ethics and Conduct (2009) was followed in all the presented studies; and all studies were cleared by the University's Ethics Committee (see Appendix 3A to 3C).

Participants for all the studies in this thesis were recruited from primary schools in the Midlands, UK. The schools' headteachers were initially contacted by letter followed by a phone call to verify their interest as participating schools. A meeting was then scheduled with the headteacher to discuss the process and procedures of the studies. Once mutually convenient times to run the project were agreed, the children were approached. Initially, the researcher spoke to all the children in the classroom and introduced the study. Following this the children were asked whether or not they would be interested in taking part but that they did not have to if they did not want to do so. They were then given information sheets for their parents and opt-in consent forms (for Pilot study – see Chapter

3). The researcher collected the forms within a week from the schools. The children whose parents agreed to participate in the study were asked individually whether or not they still wanted to be a participant in the study.

For the remaining studies in this thesis an opt-out method was employed, which under the University's governance statement is permitted in the case of reading-based research. The parents received a participant information sheet (see Appendix 4A to 4 C) explaining the study their child had been selected to take part in. All efforts were made to ensure the parents were aware of the research conducted and that they were informed about their right to withdraw from the study; the teacher also informed the parents about the research during parents' evenings. If they did not wish their child to take part they were asked to fill out a form and return it to the school within one week. Those children, whose parents did not return the form, were approached and asked to participate in the research study.

Next, dates which suited the class teachers and the researcher were arranged to test each child individually. The study and the assessments as well as their right to withdraw were explained again to the child before the testing began and they were asked to sign a consent form stating that they understood the study and were happy to take part. Children younger than 7-years-old (see Chapter 6) did not sign a consent form, due to their age but oral assent was obtained. Throughout testing the children's behaviour was observed for any signs of distress or discomfort to ensure the children were still happy to continue with the assessments.

After each study was completed, the children received a certificate (see Appendix 5) and stationary as a thank you gift. The children were not aware that they would receive these items at the point at which they agreed to participate in the research, so that this could not be used as an inducement to participation.

2.5 Test Battery Overview and Procedures

2.5.1 Study 1 - Pilot Study: A new speech rhythm sensitivity measure, and Study 2: Task Validation Study: Investigating 7- to 9-year-olds' speech rhythm sensitivity and its relation to reading abilities

The children in the first two studies were tested on the same assessments. Participants in Study 2 received a revised, shortened version of the Lexical Judgement Task however, which was the only change in assessments across these two studies (see Chapter 3 for task revision details). Testing occurred on two or three different occasions, individually, in a semi-quiet area at the children's school. The assessments were randomly divided into two or three testing blocks which were counterbalanced across participants. The order of assessments within each block was chosen by the participants to enhance their engagement during testing. Order effects were assessed within each study. The measures used were as follows:

General Ability

The vocabulary and matrix reasoning subscales from the *Wechsler Abbreviated Scale of Intelligence* (WASI, Wechsler 1999) were used to provide a short full scale IQ assessment (FSIQ -2) of the participants' general ability.

The vocabulary subscale of the WASI consisted of four picture items and 38 single word items, ranging from easy to more difficult (e.g. *shell* and *impertinent*). Depending on the age of the participant different items were used as starting points and the children were asked to either state what the picture shows or asked to explain what the meaning of the word heard is. The test stopped when the stop point item was reached (for ages 6- to 8-years stop after Item 30; for ages 9- to 11-years stop after item 34), or until the discontinuation rule applied (five consecutive scores of zero).

The matrix reasoning subtest comprised four types of nonverbal reasoning components. These included pattern completion, classification, analogy and serial reasoning. The test consisted of two practice items (A and B) and 35 test items in total, showing a matrix with one missing section, which the participant had to identify and complete by saying or pointing to the correct item (from a choice of five) to complete the matrix. All the children started with the two practice items (A and B) and depending on age started the test items with item 1 (ages 6- to 8-years) or item 5 (ages 9- to 11-years). The test stopped when the stop point was reached (after item 28 for 6- to 8-year-olds or after item 32 for 9- to 11-year-olds) or when four consecutive scores of zero, or four scores of zero on five consecutive items was scored.

The vocabulary and matrix reasoning raw scores were converted into t-scores, and then added to a sum of t-scores to be converted into a standardised IQ equivalent score. The reliability coefficient for the FSIQ-2 ranged from .93 to .98, according to the WASI manual.

Phonological Awareness

Phonological awareness (PA) and reading development have been researched extensively in the past years and it has been shown that PA plays an important role when learning to read (Bradley and Bryant 1983). The ability to understand sounds and the awareness of these sounds which constitute words is essential to reading (e.g. Goswami and Bryant, 1990) and PA is seen as a strong predictor for future reading ability (e.g. Adams, 1990).

The Spoonerism subscale from the *Phonological Assessment Battery* (PhAB, Frederickson, Frith and Reason 1997) was administered to assess the children's phonological awareness (more specifically, their complex phonemic awareness). It was designed to assess children's ability to segment single syllable words and their initial phonemes to then combine the segments to create new words or combinations of words. This subtest consisted of two parts, each with three practice items and 10 test items. A time limit of three minutes each for completion was given. The children were asked to change words into new words by swapping the beginning sound of the word with a new sound (e.g. *cat* with a /f/ gives *fat*). After completing the three practice items of the first part, for which the children received feedback to ensure they have understood the task, the 10 test items were administered verbally.

The assessment of these semi-spoonerisms was either discontinued after the children answered three consecutive items incorrectly or after three minutes elapsed. Children over the age of seven were administered part two (the "full" spoonerisms) if they scored on part one. In part 2, the children were asked to exchange the initial sounds of two words (e.g. *lazy dog* gives *daisy log*). Again, a time limit of three minutes was given after which the test was discontinued, or when the children answered three consecutive items incorrectly. By adding both test part scores together a total score of 30 could be obtained. The raw scores were used during data analysis as the conversion to standardised scores was not possible for children younger than six. According to the PhAB Manual the internal consistency reliability coefficient (Cronbach's alpha) ranged from .89 to .95 across 6- to 14-year-olds.

Rapid Automatised Naming

The ability to quickly and accurately name objects, colours, digits or letter strings is linked to the retrieval of phonological information in the long term memory, and a strong, early, predictor of later reading skills (e.g. Schatschneider *et al*. 2004). Being slow in identifying letters (or objects, numbers or colours) is said to be due to an inability or difficulty accessing phonological codes from memory (Torgesen *et al.*1997). Researchers are debating whether RAN is a subset of phonology or a separate construct (see Wolf, Bowers and Biddle 2000 for a review) and a recent literature review stated that PA and RAN should be considered as distinct constructs as their contributions to reading are different and both measures are not always highly correlated (Norton and Wolf 2011). No consensus has been reached yet about the underlying nature of RAN, and the relationship between RAN measures and reading may also depend on the task formats and the children's age as well as on the type of reading skills that are measured (e.g. de Jong 2011) However, since the RAN - CTOPP measure was used here (see below) it will be described as part of phonological processing (alongside phonological awareness and phonological memory), as Wagner, Torgesen and Rashotte (1999) conceptualised and constructed this measure in this way. Therefore, the RAN tasks were included in the following studies to assess children's efficiency in retrieving phonological representations from memory and to assess whether this ability was associated with phonological awareness skills, reading abilities and also with speech rhythm sensitivity.

The children's rapid naming was assessed using the rapid colour, object, digit and letter naming subtests from the *Comprehensive Test of Phonological Processing* (CTOPP, Wagner *et al.* 1999). The assessment consisted of rapid digit naming and rapid letter naming for children aged seven years and above and rapid object naming and rapid colour naming for children aged below seven years. Each subtest consisted of six practice items and two test forms. For example, the rapid digit naming test forms (A and B) included 36 digits each. These numbers were presented on a sheet on four lines, with nine numbers each, from left to right. After the practice numbers were given to the children to establish whether or not they could identify digits, they were given Form A and asked to read each number out loud as fast as they could. This was measured using a stop watch. Omissions of numbers or incorrect naming of digits were recorded. In the case of omission of a whole line of numbers the researcher pointed this out to the child and asked if they could quickly read that line again. The first digit on that missed line was marked as incorrect. In the case of more than four incorrect namings of digits, the form was not scored. After completion of Form A the second form was administered. The same procedure was used for the other rapid naming subtests. The times taken to complete both forms were added together to provide overall rapid naming scores (times in seconds).

Literacy Skills

Decoding

The word reading subtest (blue form) from the *Wide Range Achievement Test 4* (WRAT 4, Wilkinson and Robertson 2006) was administered to the children in Studies 1 and 2 to assess their decoding skills. The word reading subtest comprised two parts – letter reading and word reading. The first part included 15 single letters which the children were asked to read one by one. The second part included 55 words which increased in difficulty (e.g. *cat, laugh, gigantic* and *pseudonym*). Children aged seven years or younger started with part 1 of the reading test, children aged eight years and older started with part 2. Older children had to read at least five items correctly in part 2 in order not to go back to part 1. The stopping point for the assessment was after incorrect reading of 10 consecutive items. A total raw score of 70 could be achieved; the raw scores were also converted into standardised scores for subsequent analyses.

According to the WRAT 4 manual the internal consistency reliability coefficient for the blue form word reading ranges from .90 to .94 in 5- to 12-year-olds.

Comprehension

The sentence comprehension subtest from the Wide Range Achievement Test 4 (WRAT 4, Wilkinson and Robertson 2006) was used to assess reading comprehension. This test consisted of 50 sentences that have one blank space either in the middle or the end of the sentence (e.g. 'The television was so loud that the children could not ___________ their sister calling them'). These sentences were divided into six blocks (A to F) which function as starting points, and each starting point has several practice items.

The raw score for the word reading subtest can be used as a determinant for the starting point in the sentence comprehension task. During the projects (Studies 1 and 2) all children started at starting point A however and therefore all received practice items 1-3 and then carried on completing the sentences until they either answered seven consecutive sentences wrong or reached item 50. A total score of 50 could be achieved for this subtest (awarding one point per correct answer for each sentence). The internal consistency reliability coefficient for the blue form sentence comprehension ranges from .92 to .95 in 6- to 12-year-olds.

Fluency

To determine whether the children in the pilot and Study 2 sample were able to read fluently they were asked to read a short passage, taken from the *Neale Analysis of Reading Ability – Revised manual* (Neale 1997). Giving children a passage at or below their Grade level was recommended by Rasinski (2003) when assessing children's fluent reading. Schwanenflugel *et al*. 2006 on the other hand suggested that the reading of more complex stories and literature enhances reading with expression. It was thought that choosing a very easy and short passage (level one passage) would be best to allow the children to demonstrate their fluency skills rather than having to focus their time and energy on decoding (difficult) words however. Nevertheless, this was not always the case, as some children still struggled to read this easy passage.

The children's reading was recorded using a digital voice recorder (Olympus WS-100) so that the passages could be rated later on, following the *Multidimensional Fluency Scale* (Rasinski 2003). This scale allowed for four different ratings of the children's reading, the accuracy, phrasing, smoothness and pace. Scores between 1 and 4 were given for each category, resulting in score ranges from 4 to 16. In the pilot study some young children were not able to read the passage at all and were therefore given zero points for fluency. The recordings were scored by the principal researcher and additionally by an independent researcher to assess the inter-rater reliability. This will be further reported in Chapters 3 and 4 (for Studies 1 and 2 respectively).

Prosodic Sensitivity

Phrase-level prosody

The speech rhythm sensitivity measure that was chosen to be compared to the newly developed Lexical Judgement Task was the *DEEdee* task (Whalley and Hansen 2006), which has been described in detail previously (see Chapter 2.2.). The DEEdee task has been used in previous research studies to measure children's speech rhythm sensitivity and it was found to be a good measure, which was able to highlight correlations with reading skills (especially with comprehension skills) and also showed that speech rhythm sensitivity could predict unique variance in comprehension skills, over and beyond phonological awareness (e.g. Whalley and Hansen 2006).

In brief, this task measured prosodic sensitivity at the phrase-level by presenting the participants with a target phrase (e.g. The Simpsons) followed by two foil phrases which had their syllables replaced with the same nonsense reiterative syllable ('dee'), e.g. DEEdee DEE (Peter Pan) and dee DEEdee (The Simpsons). Each trial item was presented twice in total in the same order. The children then had to decide which DEEdee phrase matched the original utterance. In total the tasks comprises two practice items and 18 trial items. Internal reliability coefficients for this task with the Pilot as well as Study 2 samples are reported in Chapters 3 and 4.

Word-level prosody

In the pilot study, the children were presented with the *Lexical Judgement Task*, comprising the 40-item baseline condition (clear words) and the 40-item experimental condition (clear-filtered word pairs). For the detailed overview see Section 2.3. In brief, this computer-based task was presented to the children in the same order, baseline (only clear words) first, followed by the experimental (clear and filtered words) condition. The words were played over headphones at a volume adjusted to suit each child's preference. After four practice trials with feedback, the children completed both sub-tests individually, without corrective feedback being provided. The children had to decide if the heard word pairs sounded the same/similar or different and respond by pressing the corresponding buttons on the keyboard. Cronbach's alpha coefficient analyses of this measure can be found in Chapter 3 and in each subsequent study chapter for each sample.

2.5.2 Study 3:

9- to 11-year-olds' speech rhythm sensitivity and its associations with reading skills

During this study 56 children were assessed on the same IQ, phonological awareness and phonological processing measures as in the previous two studies (see Section 2.5.1.). The shortened Lexical Judgement Task was administered but the DEEdee task was not used. It was decided that the task is too memory intensive and that the items used may be not purely assessing speech rhythm sensitivity but also aspects of phonemic sensitivity. Detailed assessments of the DEEdee task in comparison to the LJT are reported in Chapter 4 and highlight these issues with the DEEdee stimuli.

Literacy Skills

The *York Assessment of Reading for Comprehension* (YARC, Snowling, Stothard, Clarke *et al*. 2011) battery was administered to children in this third study, instead of the WRAT 4. This assessment battery was deemed more appropriate for a British English speaking sample and offered one assessment to measure reading accuracy, reading comprehension and reading rate (as a means to evaluate reading fluency). This test comprises different passages which the children have to read, followed by questions about the passages.

The *Single Word Reading Test* (SWRT) from the YARC was used prior to administration of the passage reading to determine children's decoding skills out of context and to determine the starting point for the passage reading. All children were presented with a list of words ranging from monosyllabic words, such as *see*, *this* and *hang* to more difficult, polysyllabic words, such as *eventually*, *excitable* and *pseudonym*. The test comprises 60 words in total and the children were asked to read as many words as they could, and they were encouraged to try to read any unfamiliar words.

To measure comprehension, the YARC passage reading Forms (either A or B) were administered to the children in Study 3. Each form comprises seven passages in total, varying in difficulty. Children from Study 3 were assessed with the Form A passages.

The SWRT scores were used to determine the starting passage and the children were asked to read a story, and then answer questions about it. Each child had to correctly answer four out of eight comprehension questions correctly to proceed to the next passage; failing this, they were asked to read the previous, slightly easier, passage. When they correctly answered a minimum of four questions, this passage was used as the basal level and the next passage was used as their ceiling level. The children were timed and recorded whilst reading and the errors made in a passage were scored along with the time it took the children to read the passage. Three ability scores and three standardised scores were obtained from the passage reading, one for each aspect: reading accuracy, reading rate and reading comprehension.

According to the YARC passage reading manual the internal reliability coefficient for reading accuracy, reading rate and reading comprehension ranges from α .72 to α .93, from α .90 to α .95 and from α .48 to α .77, respectively. The reliabilities for reading comprehension for the individual passages are below the desirable level of .70. However, the reliabilities are higher, when the passages are administered using consecutive pairs, .71 to .83 (based on Spearman-Brown Prophecy Formula estimates).

When combining the reading accuracy, reading rate and reading comprehension standard scores of the Study 3 participants the Cronbach's alpha reliability coefficient is .84.

2.5.3 Study 4:

Speech rhythm sensitivity's link with early reading and phonological processing skills in 4- to 7-year-olds

This study examined literacy skills and speech rhythm sensitivity in 4- to 7-year-old children (*N* = 112). Due to the age of the children most assessments differed compared to the previous studies. LJT was used to assess the children's speech rhythm sensitivity.

Receptive Vocabulary

As a measure of the children's vocabulary knowledge the *British Picture Vocabulary Scale III* (BPVS III, Dunn *et al.* 2009) was used. This assessment contains four practice plates and 14 test sets of 12 test items each (168 test items in total). Each plate (or page) consists of four colour illustrations, two on the top and two on the bottom of the page. The children are presented aurally with a word and have to point to (or say the corresponding number of) the picture which best shows the meaning of the stimuli heard. Depending on the age of the child, different test plates are used as starting points. All 12 items are administered in each test plate in the given order.

The basal level needed to be established first, indicated by no more than one or no error on a test set. If this occurred on the first test set then testing continued forwards until the ceiling level was found. If the child made more than one error on the first test set, the previous ones needed to be administered until the basal level was found. The ceiling level was found when eight or more errors were made within one testing set. The BPVS III manual does not provide reliability coefficients but does however present a discussion of reliability (see pages 31-32 of the manual); the alpha with this sample is reported in Chapter 6.

Phonological Awareness

The children's ability to manipulate sounds was measured with two assessments from the *Phonological Assessment Battery* (PhAB, Frederickson, Frith and Reason 1997), the *Rhyme* and *Alliteration* tests. During the *Rhyme* test, the children were presented verbally with a set of three single syllable words and are asked to repeat the two words that end with the same sound (rhyme). For example, the child heard *sail, boot, nail*, and the correct response was *sail* and *nail*. The test comprised three practice items, followed by 12 test items in part one and nine test items in part two (comparably more difficult to the part one items). All children started with part one and completed as many items as they can. If they failed to correctly identify the first four items in part one, the test was discontinued. In order to progress to part two, a minimum of eight correct responses in part one was required.

The PhAB assessments were for children aged six years and older, thus the Cronbach's alpha for this assessment does not cover children younger than six years of age. According to the manual, the internal consistency reliability coefficient (Cronbach's alpha) for the *Rhym*e subtest (for the age group 6- to 7-years) is α .92.

The second phonological awareness measure used was the *Alliteration* subtest, which assesses the children's ability to isolate the first sound in words. The children were presented verbally with three single syllable words (e.g. *shop, mat, shell*) and were required to repeat the two words that start with the same sound (in this example *shop* and *shell*). The test consisted of ten items in total, five in part one and five in part two. Each test part began with three practice items. The part one items were easier compared to the part two items, and they started with single consonants compared to consonant clusters in the second part. In order to proceed to part two children had to score three or more items correct on part one. According to the PhAB manual, the reliability coefficient for this subtest with the age group 6- to 7-years is α .90.

Reading skills

Real word reading

To measure the children's reading levels they were assessed on the single word reading test from the *British Ability Scales II* (BAS, Elliot, Smith & McUlloch 1996) battery. This single word reading test comprised 90 words (9 blocks of 10 words), ranging from 32 single syllable words (e.g. *in*, *cat*) to 58 polysyllabic words (e.g. *electric*). The test was discontinued after a child made eight or more errors in any block of 10. For every word read correctly, one point was scored. The BAS II technical manual reports the Cronbach's alpha for 5-, 6- and 7-year-olds as α .88, α .95 and α .98 respectively; the alpha with this study sample is reported in Chapter 6.

Nonword reading

Different strategies can be used by children to read words (e.g. using sight word or spoken word vocabulary or drawing on letter-sound relationship knowledge). In order to examine the phonological processing involved in regular word decoding, nonwords can be used as they cannot be identified through visual processes or meaning. The nonword subtest used in this study was taken from the PhAB (Frederickson, Frith and Reason 1997) and comprises 10 monosyllabic nonwords (e.g. *gat*) and 10 bi-syllabic nonwords (e.g. *shendom*). One practice sheet, containing three practice items was presented first, followed by the second sheet (Card two), which contained five words on the left hand side and five words on the right hand side. If the child could not read any of the five items on the left hand side, the right hand side nonwords were not administered. In order to proceed to Card three, the child could not make more than six errors on Card two. The internal consistency reliability coefficient (Cronbach's alpha) for 6- to 7-year-olds on this assessment, according to the manual, is α .95.

2.5.4 Study 5:

Longitudinal Investigation: Relationships between speech rhythm sensitivity, morphological awareness, reading and phonological processing skills over time

The final research study in this doctoral thesis examined 77 children from Study 2 (*n* = 47) and Study 3 (*n* = 30), to assess longitudinal changes in their reading abilities and speech rhythm sensitivity. The children were re-assessed on the Lexical Judgment Task and tested with the YARC reading assessment. In this study the YARC Form B passages were used. The children's fluency was scored according to the Multidimensional Fluency Scale (see Section 2.5.1); in order to compare Time 1 fluency scores across sub-samples, the Study 3 sample's earlier passage reading was also assessed using this scale.

Additionally, a morphological awareness (MA) measure was used (Duncan, Casalis and Cole 2009). Previous studies have shown that phonological awareness and prosodic sensitivity are related to morphological awareness (e.g. Clin *et al.* 2009) and it was found that MA could predict reading skills above and beyond phonological awareness skills. Thus this assessment was included in this study to measure if stress sensitivity could explain unique variance in reading skills after controlling for phonological and morphological awareness.

The measure used comprised two parts; part one uses real words and part two uses nonwords. Each part consisted of three practice items (with corrective feedback) and 18 test items. A total score of 36 could be achieved overall. The children were provided with a sentence, which contained the lexical root of a word and were asked to state the lexical derivation, e.g. "When there is *dust*, it is...?", the correct answer being "*dusty*".

The nonword part of this assessment followed the same structure as the real word part, were children were asked to provide novel derivations based on non-lexical roots, e.g. "A *gress* person behaves very...?", with the correct answer being "*gressly*".

2.6 Summary

This chapter provided an overview of previously used speech rhythm measures and described the development of the Lexical Judgement Task, which was subsequently trialled (see Chapter 3). The prosodic tasks used so far in the literature all demonstrated links with reading skills, but these varied in strength across studies and participants. This indicated that the underlying skills associated with stress sensitivity may differ across samples, but this may have been due to the various tasks used. In order to further this understanding it is essential to assess a range of children with the same stress sensitivity measure to explore whether this skill varies across samples and how it links to different reading (related) skills. The following chapters present the studies conducted as part of this doctoral research, each exploring different samples of participants to further assess how the LJT links to reading skills within different age groups (see Chapters 4-6) and how it may changes over time (see Chapter 7).

Chapter 3 – Study 1

Pilot: A new speech rhythm sensitivity measure

3.1 Overview

The newly developed computer-based Lexical Judgement Task (LJT), described in Chapter 2.3, was piloted to assess children's stress sensitivity. Focus was further placed on the children's reading ability and phonological awareness and how this related to stress sensitivity measured by the LJT. To analyse LJT's effectiveness as a measure, it was compared to an existing speech rhythm measure, the DEEdee Task (e.g. Whalley and Hansen 2006). Findings suggest a relationship between reading abilities, phonological awareness and speech rhythm, but the developed task required some amendment.

3.2 Introduction

This chapter describes the pilot study conducted to analyse the effectiveness of the newly developed stress sensitivity assessment and its relationship to reading abilities in comparison to an existing speech rhythm task – the DEEdee task (e.g. Whalley and Hansen 2006). As Chapter 1 offers an overview of the theoretical underpinnings of speech rhythm sensitivity and reading, only a brief summary of this literature is provided here.

Prosodic cues are argued to aid the listener in segmenting speech into phrases and words and can enable better understanding of speech; the syntactic structure becomes more apparent after segmenting the speech into "chunks", which reduces the memory load and causes more complex syntactic and semantic processes to occur (Speer, Crowder and Thomas 1993). This ability is already present in very young babies and the preference to attend to one's native language and its rhythmic pattern has been shown to be established in infants by nine months (Jusczyk, Cutler and Redanz 1993) and neonates show the ability to cry in melodies typical to their native languages' rhythm (Mampe *et al.* 2009).

Therefore this general prosodic sensitivity aids the child in segmentation of speech and is a salient property that can aid infants in the process of word learning and thus in the later production of correctly pronounced words (e.g. Curtin, Mintz and Christiansen 2005). In the English language most words begin with a strong (stressed) first syllable followed by weak (unstressed) syllables (e.g. Cutler and Carter 1987). However in multisyllabic words stress placement can vary from this general lexical stress pattern. For instance, the word *alphabet* consists of three syllables, with the first syllable -AL being a strong syllable as it has strong primary stress, followed by the second (-PHA) and third syllable (-BET) being weak (unstressed). In comparison, the word *overhead* has the primary lexical stress on the third syllable (-HEAD), the secondary stress on the first syllable (-O) and is unstressed on the second syllable (-VER). An example of primary stress placed on the second syllable would be the word *banana* (with primary stress on -NA). Furthermore, most multisyllabic words cannot merely be decoded letter-by-letter. There are two reasons for this. Firstly, grapheme-phoneme correspondences are not always transparent. Secondly, even if successfully decoded at the alphabetic level, the overall stress of the word may not be placed correctly, resulting in a mispronunciation, because stress placement also affects phoneme identity, as weak syllables typically contain reduced vowels such as the schwa (e.g. the 'a' in *away* /ə□weɪ / or the 'e' in *officer* /'ɒ fɪ sə/). Thus the correct pronunciation of multisyllabic words may be aided by sensitivity to speech rhythm and the storage of stress patterns for words in the mental lexicon.

Additionally, as prosodic skills are linked to listening comprehension it can be argued that sensitivity to speech prosody is important for the development of reading comprehension (Schreiber 1987). The minimal presence of prosodic cues in written language compared to spoken language however may require higher demands of prosodic sensitivity, which go beyond those required in spoken language (Whalley and Hansen 2006) and may not be linked merely to the decoding of words. Other cues such as punctuation and morphological rules need to be extracted from print, but to use these cues effectively the reader needs to have prosodic skills to convey these written cues in spoken language. This would enhance not only multisyllabic word reading, but also fluency and comprehension.

Reading fluency is seen as essential for good comprehension and as an overall indicator for reading competence (Fuchs, Fuchs, Hosp & Jenkins 2001) and according to the automaticity theory (LaBerge and Samuels 1974) skilled word-recognition skills underlie fluent reading and subsequently text comprehension. To achieve fast and accurate reading, practice is needed to strengthen connections between words and letter patterns in long term memory so that they can be processed and stored as whole units (Ehri 2005). This would enable the child to use attentional resources for text comprehension rather than letter-by-letter decoding and enhance their fluency and understanding (Logan 1997).

More recent studies have added research evidence to support the relationship between stress sensitivity and reading abilities (e.g. Holliman *et al.* 2010a and b; Goodman *et al.* 2010). Whalley and Hansen (2006) found that word-level stress was able to predict word reading accuracy and that phrase-level stress was able to predict decoding and comprehension for example. Others have found support for a link between prosody and decoding but not for comprehension and prosody (e.g. Schwanenflugel *et al.* 2004). Furthermore, different age groups have been investigated with different speech rhythm assessments and these studies have demonstrated reduced stress sensitivity in younger children, which was also linked to their reading skills (e.g. Wood and Terrell 1998b; Goswami *et al.* 2002).

In order to establish the magnitude of the contribution this suprasegmental skill makes to reading-related processes and outcomes, stress sensitivity needs to be assessed more consistently. It is proposed that ideally the same task should be used with different age groups to establish how the skill differs in relation to reading skills (i.e. decoding, comprehension and fluency) across different age groups and even with the same individuals over their lifespan.

The assessment of speech rhythm is particularly important as not all speech rhythm assessments are equivalent; some focus only on metrical stress across phrases or the lexical stress within words and others use non-speech stimuli to assess stress sensitivity (for an overview of tasks see Chapter 2.2). One of the main considerations for the development of a new task is that it should be clear which aspects of speech rhythm are measured by it, and that it can be used with a range of children from different age groups. This predominantly means that the task should be administered easily and should keep the demands on the children's working memory to a minimum. The sentence matching task (Wood and Terrell 1998b) for example used stimuli which emphasised speech rhythm patterns in phrases through the use of low band pass filtering, but the presentation of these phrases was designed in too memory intensive a way. The development of such a task would enable its use in different studies interested in stress sensitivity and would enable comparison between studies.

Additionally, a speech rhythm task needs to be easily understood by children, therefore showing high face validity. This has not always been the case with other measures reported in the literature. For example, the instructions and format of the beat detection task (Goswami *et al.* 2002), do not appear to be clear enough for very young children to understand, which could result in some children not understanding exactly what they are supposed to listen out for and what their decision should be based upon when listening to the sounds with varying rise times. Therefore, a simple task format needs to be employed to ensure that even very young children are able to understand what they have to do in order to complete the task. The results would consequently indicate the children's stress sensitivity and not merely their cognitive ability to understand the task itself. Lastly, the stimuli used in a stress sensitivity task need to measure stress sensitivity without the influence of segmental phonological information. This issue is apparent if we examine the DEEdee Task (e.g. Whalley and Hansen 2006), as it could be said that the stimuli used still include phonemic cues which might influence the children's performance on the task. Based on these negative aspects of previously used tasks, a new task was developed which retained the strengths of previous measures and omitted as far as possible the weaknesses identified above.

This study therefore set out to analyse and validate the newly developed task in comparison to the existing DEEdee task and to address the following research questions in this initial study:

1. Does the Lexical Judgment Task correlate with a widely used speech rhythm measure and does it show better internal reliability than this other measure?

2. Do children who perform better on the Lexical Judgment Task show greater reading ability?

It was predicted that the DEEdee task and the LJT would be correlated with one another but that this correlation may not be very strong. This assumption is based on the methodology of the DEEdee task and the stimuli used; different cognitive strategies could be employed to solve the tasks and additionally different aspects of speech rhythm may be measured by both tasks. The LJT uses "purer" stimuli and solving of this task appears to be linked more clearly to stress sensitivity compared to the DEEdee task. Additionally, the DEEdee stimuli include phonological cues, therefore it is expected that the DEEdee task will correlate with phonological awareness (PA) more than the LJT correlates with PA.

It is expected that the internal reliability of the LJT will be satisfactory, and higher than that found for the DEEdee measure (the alpha for which has been rarely reported in studies; e.g. Goswami *et al.* 2009; Holliman *et al.* 2012). However, it needs to be born in mind that the stimuli used in LJT are filtered words paired with non-filtered, clear words; some of which stem from the same speech rhythm pattern and others which do not. This difference in stress patterns may be an aspect which needs to be investigated further. Some stress patterns are more common or dominant in the English language (such as strong and weak alternating syllables), which may be more familiar to children and therefore not provide a strong indication of differences between children with good or poor sensitivity to stress compared with items that stem from more unusual stress patterns. Further, the different processes applied when making same/different judgements may influence the overall reliability value and it may be advisable to assess the Lexical Judgement Task as two sub scales rather than as one.

Based on previous findings (e.g. Goswami *et al*. 2002), it was additionally hypothesised that children who have greater stress sensitivity will display greater reading abilities. Being sensitive to speech rhythm could function as an additional "reading strategy", enabling children to draw on the written cues presented in print (such as morphology, semantics and syntax) to enhance multisyllabic word reading. This would enhance decoding using grapheme-phoneme-correspondence and analogy use, and thus provide a larger repertoire for children to master proficient word reading and subsequently enhance fluency and text comprehension.

3.3 Method

This study investigated children's reading performance and stress sensitivity using a range of literacy assessments. All assessments were presented in three separate blocks; the order of blocks remained the same throughout testing but the order of assessments varied. The children were asked to choose which "game" they wanted to complete next, in order to maintain their engagement during assessments. Thus systematic counterbalancing was not conducted.

To address the first research question, whether the newly developed speech rhythm task was correlated with an existing speech rhythm task, Pearson correlations were conducted and internal reliability was assessed using Cronbach's alpha. In order to assess the second research question of whether poor or good readers performed differently on the Lexical Judgment Task, the children's word reading and reading comprehension standard scores were used to group the children into three separate reading ability groups. Scores lower than one standard deviation (15) or more from the standardised mean (100) were taken as indicative of poor (or delayed) reading abilities (scores of 84 or below) whereas scores more than one standard deviation from the standardised mean were seen as indicative of advanced reading skills (116 and above). Standardised scores in the midrange (85 to 115) were classed as typical. In order to conduct the same grouping for the fluency scores a different method needed to be employed however.

According to Rasinski (2003), the fluency scores obtained from the Multidimensional Fluency Scale should be viewed as follows: scores of 8 and below are indicative of less developed fluency skills whereas scores of 9 and above are indicative of good levels of fluency. For this reason, the children's fluency scores were grouped as either weak (scores of 8 and below) or good (scores of 9 and higher). Therefore, no advanced fluency group was created and comparisons were made between weak and good fluent readers, whereas the decoding and comprehension groups were analysed in terms of whether children in typical or advanced reading ability groups had significantly higher LJT performances compared to the delayed reading groups. For these analyses, separate ANOVAs were performed.

3.3.1 Participants

Sixty-nine children, recruited from two primary schools in the West Midlands, were assessed for this pilot study. The schools were from two different Wards within one city, which are classed as the third and seventh most deprived wards in the city (out of 18) (City Council 2010). Of those children tested, 37 were males and 32 were females. The ages ranged from 62 to 112 months, with a mean age of 90.86 months (SD = 13.391).

3.3.2 Test Battery

A detailed overview of the measures used can be found in Chapter 2.5.1. The assessments were divided into three blocks which were administered on separate occasions (see general procedure for details) to keep the time the pupils were out of the classroom at any one time to a minimum. The different assessments within each block can be seen in Table 3.1. The blocks were administered in the same order but the participants were encouraged to select the order of tasks. MANOVA showed that no order effects were caused by this, $F(45, 220) = 0.976$, $p = .521$. When completing the RAN measures, two children did not complete both subtests (they either failed to complete rapid colour naming or rapid letter naming). In those cases only one subtest was completed and those children's RAN scores were marked as missing values and not included in the analyses.

Table 3.1 Assessment blocks and assessment distribution within blocks used in this study

Block 1	Block 2	Block 3
1. Word reading (WRAT 4) **2. Reading comprehension** (WRAT 4) **3. Fluency** (Multidimensional Fluency Scale) **4. Phonological Awareness** (PhAB, Spoonerisms)	**5. Rapid automatised naming** (CTOPP) **6. Speech rhythm sensitivity** (DEEdee) **7. Speech rhythm sensitivity** (LJT, Baseline)	**8. Verbal and Non-verbal IQ** (WASI) **9. Speech rhythm sensitivity** (LJT, Experimental)

3.3.3 General Procedure

Before testing, the researcher explained the purpose of the study to each child again and asked if they had understood the procedures and were happy to take part. They were then asked to sign a 'consent' (assent) form (see Appendix 6). Each child was assessed individually on three separate occasions, each one not lasting longer than 30 minutes. The order of blocks administered did not vary but the order of the individual assessments did (see Section 3.3.1.). The three blocks were administered on consecutive days, if the child was present at school. Otherwise a gap of one or two days (including weekends) was present in some cases.

3.4 Results

Initially, the data were screened for normality and checked for outliers. One outlier was found in the LJT baseline task (z = - 3.356) and one in the LJT experimental task (z = - 3.335) and marked as missing values. Outliers (values greater than +/- z = 3.29; Field 2009) were also found in the reaction time data (RT) for the RAN measure and in the RTs for the LJT baseline and experimental condition. These were also marked as missing values and excluded from the analyses. Subsequently, the LJT baseline and experimental condition data as well as the RT data were based on n = 68; RAN data were based on n = 66.

Performance on assessments and variable correlations

The mean scores obtained by participants (and the standard deviations, SD) on the assessments used are reported in Table 3.2, which also indicates maximum possible scores and score ranges as well as internal reliability coefficients. The mean standardised scores were within normal range for the participants (i.e. between 85 and 115; see IQ and word reading). The average comprehension score for the sample was 95.45 (SD = 17.73), which is only marginally below the mean. Due to comprehension score transformation only being possible from age six, the 11 five-year-olds' scores had to be removed from analyses; however their comprehension raw scores were included (based on n = 58). No standardisation for the fluency scores was available thus only the raw scores are reported.

Table 3.2 Means and standard deviations (SD) and internal reliability coefficients (α) for all measures used in this study

Assessments	Minimum	Maximum	Mean	SD	Internal α
IQ	78	141	97.87	13.84	.92
Vocabulary / 70	11	42	25.16	7.32	.84
Matrix/ 32	1	27	13.00	7.30	.94
Spoonerism / 30	0	29	13.36	7.95	.93
RAN	54	369	127.52	72.97	-
DEEdee / 18	4	16	10.13	2.81	.47
LJT baseline / 40	17	40	36.15	5.71	.92
LJT base RT	1098	3984	1927.17	506.72	-
LJT filtered / 40	15	31	23.15	3.30	.17
LJT filtered RT	1262	5195	2470.72	702.84	-
Word reading	55	136	99.36	20.80	-
WR raw / 55	4	51	28.77	11.83	.93
Comprehension / 50	63	145	95.45	17.73	-
RC raw / 50	0	37	10.58	9.03	.95
Fluency	0	16	10.82	5.17	.97

Note. IQ, word reading (WR) and comprehension (RC) used standardised scores; all other variables based on raw scores; RAN = rapid automatised naming; Matrix = nonverbal reasoning; Spoonerism = phonological awareness; DEEdee = speech rhythm measure; LJT base = Lexical Judgement Task baseline condition; LJT filtered = experimental condition; LJT RT = mean reaction times in milliseconds (ms).

The internal reliability for IQ and the phonological awareness assessments (Spoonerisms) were both very good for this sample of children (α .92 and α .93 respectively). Each reading assessment also showed good internal reliability; word reading had an alpha of .93, reading comprehension was α .95 and reading fluency was α .97.

The recordings of the children's reading were analysed for accuracy, phrasing, smoothness and pace by the primary researcher and additionally, by an independent researcher to ensure good inter-rater reliability. Spearman correlations were conducted for each of the fluency aspects and the total fluency scores from the researcher and the independent researcher. The relationships between the researcher's ratings and the independent researcher's ratings were significant for accuracy (r_s = .881, p < .001), phrasing (r_s = .840, p < .001), smoothness (r_s = .868, p < .001) and pace (r_s = .781, p < .001) as well as for total fluency ratings (r_s = .860, p < .001). These findings indicated good agreement between the primary and the independent researcher; thus the primary researcher's scores were used in the subsequent analyses.

The baseline condition of the Lexical Judgment Task showed an internal reliability of α .92. This high alpha was expected as the children were asked to decide whether two word stimuli were the same or different and the near ceiling effect (mean = 36.15, SD = 5.70) indicates a good word perception ability of the children. The alpha for the experimental LJT condition and for the DEEdee task will be discussed further shortly.

Further, Pearson correlation coefficients were calculated to establish the linear relationship between variables to examine whether the data could be used for ANOVA analyses and whether the variables used in this sample were linked to one another. These correlations are presented in Table 3.3. The standardised IQ scores were used and rapid automatised naming used reaction times (in seconds); all other variables' raw scores were used.

The reading components (word reading, reading comprehension and reading fluency) as well as vocabulary, phonological awareness and the rapid naming measure were correlated with all variables measured in this study, apart from the LJT baseline condition; age was also correlated with all variables, except IQ (p = .197). Both tasks showed significant correlations with phonological awareness, with LJT being somewhat more strongly correlated to PA (r = .447, p < .001) than the DEEdee task (r = .371, p = .002). Given the documented relationship between stress sensitivity and phonological awareness in previous studies, this finding was anticipated.

Table 3.3 Correlation matrix between cognitive, phonological and literacy skills and speech rhythm measures

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
1. Age										
2. Voc	.632***									
3. IQ	.157	.686***								
4. PA	.451***	.586***	.620***							
5. RAN	- .636***	-.618***	-.423***	-.653***						
6. DEE	.343**	.365**	.268*	.371**	-.353**					
7. LJT	.312**	.353**	.270*	.447***	-.289*	.292**				
8. LJTb	.305*	.205	.202	.196	-.191	.174	.243*			
9. WR	.518***	.606***	.603***	.799***	-.781***	.391**	.401**	.172		
10. RC	.549***	.696***	.609***	.752***	-.676***	.414**	.400**	.181	.858***	
11. RF	.501***	.563***	.519***	.758***	-.736***	.350**	.405**	.159	.862***	.821***

Note. Vocab = vocabulary; IQ = verbal and nonverbal intelligence; PA = phonological awareness task; RAN = rapid naming reaction times in seconds; DEE = stress sensitivity measure (DEEdee); LJT = stress sensitivity measure (Lexical Judgment Task experimental condition); LJTb = Lexical Judgement Task baseline condition; WR = word reading; RC = reading comprehension; RF = reading fluency.
*p < .05, **p < .01, ***p < .001

To further investigate the Lexical Judgment Task, the data needed to be examined with regards to the initial research question, which asked whether the Lexical Judgment Task correlates with a widely used speech rhythm measure and whether it shows greater internal reliability. In order for the newly developed stress sensitivity task to be seen as measuring what it was intended to measure, several assumptions needed to be fulfilled. The first assumption was that the measure needed to correlate with reading measures and foremost with another stress sensitivity measure, which has been validated and widely used by other researchers in the area. When analysing the relationship between the Lexical Judgment Task and an existing stress sensitivity measure it can be seen in Table 3.3 that they do correlate significantly, although weakly, with one another (r = 0.292, p = .016). This finding offers some support for a relationship between the two speech rhythm tasks.

To expand upon the research question, the relationships between the DEEdee task and LJT and the reading measures (decoding, comprehension and fluency) was examined. DEEdee did significantly correlate with decoding (r = .391, p = .001), comprehension (r = .414, p = .001) and fluency (r = .350, p = .003). LJT displayed similar relationships; showing significant correlation with word reading (r = .401, p = .001), reading comprehension (r = .400, p = .00) and fluency (r = .405, p = .001).

Both tasks showed a link with all three reading skills, which has previously been shown for speech rhythm sensitivity measured by the DEEdee task for word reading and comprehension but not for reading rate (e.g. Whalley and Hansen 2006); however the fluency measure used here included aspects of prosodic reading therefore this finding is not surprising given the documented link between prosody and fluency (e.g. Kuhn and Stahl 2003). These findings taken together seem to indicate that the LJT does appear to be measuring stress sensitivity, as shown through the correlation to the DEEdee task and also its relationship with reading skills, which is in line with previous research findings.

Internal reliability

To examine the second part of the first research question, the internal reliability of both speech rhythm measures was assessed. In both cases, low reliabilities were found. The DEEdee task had internal reliability of α .47 and the experimental condition of LJT had an overall α .17. Neither of these alpha values are satisfactory (above 0.70) or high enough to indicate consistency of performance across items included in the task. However, the DEEdee task's alpha was comparable to that obtained by Goswami *et al.* (2009), who obtained an alpha of α .45 with their 8- to 15-year-old sample.

One aspect worth exploring is the nature of processes required to respond to the stimuli presented in the LJT. Some of the stimuli are matched for speech rhythm, others stem from two different rhythmic patterns, thus are *no-match* items. It may be the case that children find it easier to discriminate between match stimuli compared to no-match stimuli, or vice versa. In order to further analyse whether there were differences between these items the LJT total scores were separated into match and no-match item total scores. The mean scores for match-items was 10.94 (SD = 4.08) and for no-match items was 12.21 (SD = 4.07). A significant negative correlation was found between these item groups, $r = -.672$, $p < .001$, but a paired t-test showed no significant difference between both scores ($t(67) = -1.400$, $p = .166$). An analysis of the mean reaction times for the match and no-match stimuli showed that the match items were responded to faster (mean 2358 ms, SD = 791 ms) compared to the different items (mean 2569 ms, SD = 940 ms), which was significant, $t(67) = -2.992$, $p < .001$. Although there were no significant differences between the mean correct scores of match or no-match items, the match items were responded to significantly faster. The Cronbach's alpha for match-items only (20 items) was α .76 and the alpha for no-match items only (20 items) was α .78. As suggested earlier, treating the LJT as two sub-scales when analysing the Cronbach's alpha is warranted, and indicates satisfactory levels of internal consistency.

Stress sensitivity and reading performance

To assess the second research question, namely whether children who perform better on the LJT also display better reading skills, the children's decoding and comprehension scores were used to group the children into *delayed, typical* and *advanced* readers, and the children's fluency raw scores were used to group them into *weak* and *good* fluency ability groups. For word reading and reading comprehension the standardised scores were used. Children with scores of or below 84 were classed as delayed and children with scores of or higher than 116 were classed as advanced. Children with scores in the midrange (85 to 115) were classed as typical. For fluency, the raw scores were used as grouping guideline according to Raskinski's (2003) suggestion. The sample size for the comprehension ability group was smaller (n = 58) than the other two ability groups (n = 68), due to the exclusion of the five-year-olds.

Table 3.4 shows the distribution of participants in each of these ability groups and the mean LJT scores obtained; for ease of grouping these together in one table, the weak and good fluency groups were labelled as delayed and typical (in line with the decoding and comprehension ability groups).

Table 3.4 Distribution of children across delayed, typical and advanced reading ability groups, indicating mean scores (SD) achieved on LJT by groups

Groups	Word Reading		Comprehension		Reading Fluency	
	n	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)
Delayed	16	21.44 (2.31)	15	22.28 (2.49)	20	21.70 (2.90)
Typical	33	23.64 (3.22)	38	23.74 (3.55)	48	23.75 (3.30)
Advanced	19	23.74 (3.78)	5	25.40 (1.14)	-	-

To assess whether children who are more sensitive to stress are better readers, several one-way ANOVA analyses were conducted to establish group differences between delayed, typical and advanced readers and their performance on LJT. Focussing on the decoding ability groups first, the delayed group demonstrated slightly lower mean scores compared to the typical and advanced groups (see Table 3.4). Figure 3.1 depicts these mean scores achieved on the LJT by decoding ability groups. *Levene's F* test revealed that the homogeneity of variance assumption was met (p = .066). The ANOVA showed marginally significant group differences on LJT performance by decoding ability groups, $F(2, 65) = 2.975$, $p = .058$.

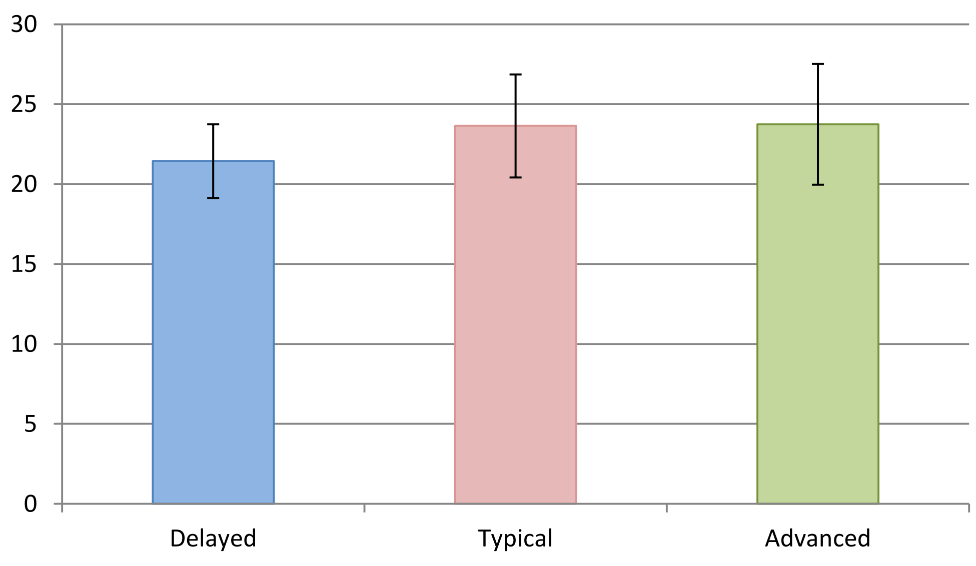

Figure 3.1 Mean scores on Lexical Judgement Task by decoding ability groups

When analysing the differences between comprehension ability groups on their LJT performance the test of homogeneity of variance was statistically significant (*Levene's F*(2, 55) = 5.022, *p* = .010). Therefore *Welch's F* test was used, revealing a statistically significant main effect, *Welch's F*(2, 19.169) = 6.911, *p* = .005, ω^2 = .033. To determine which comprehension ability groups differed on their LJT performance, Games-Howell post hoc procedure was used. This showed that the delayed comprehension ability group differed significantly from the advanced comprehension group (mean difference = - 3.11, *p* = .005). The mean scores can be seen in Table 3.4 and are illustrated in Figure 3.2.

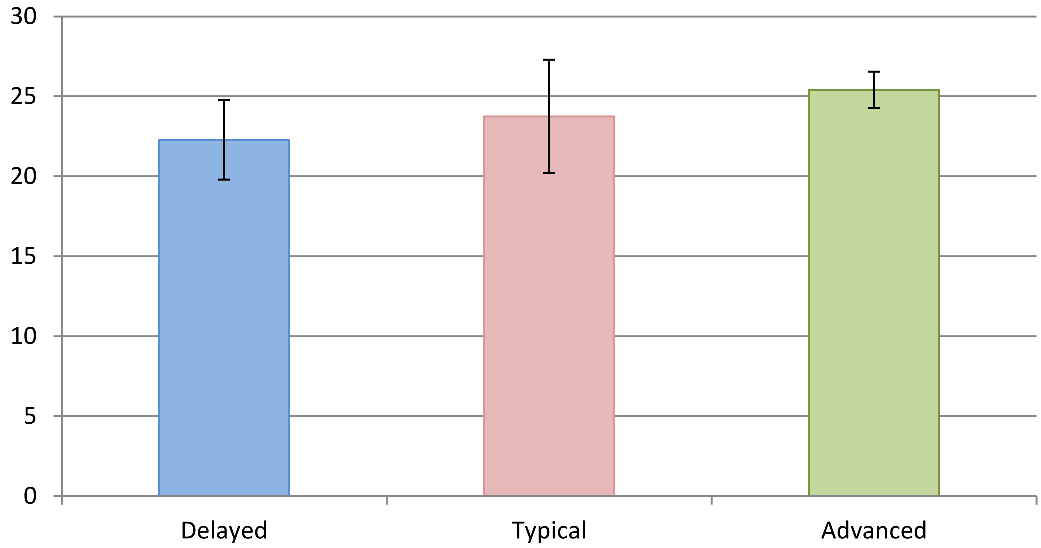

Figure 3.2 Mean scores on Lexical Judgement Task by comprehension ability groups

Finally, the fluency ability groups were examined. Homogeneity of variance assumptions were met (*Levene's F*(1, 66) = 1.475, *p* = .229) and the analysis of variance showed an overall significant main effect (*F*(1, 66) = 5.834, *p* = .018, ω^2 = .066). The significantly higher performance of the good fluency group on LJT compared to the weak fluency group can be seen in Figure 3.3.

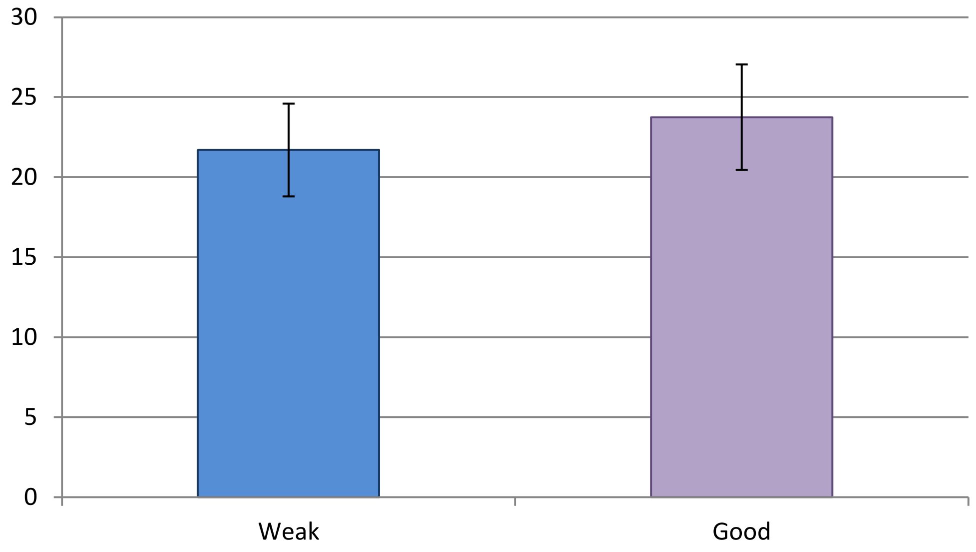

Figure 3.3 Mean scores on Lexical Judgement Task by fluency ability groups

Overall, these analyses of group differences indicated that children who are more sensitive to stress (as assessed by the LJT task) are those children with better reading skills. The association between speech rhythm and reading abilities will be discussed further.

3.5 Discussion

The main focus of this initial investigation was on the development of a new stress sensitivity measure, which encompassed the positive aspects of previous stress measures and minimised the negative features. This pilot study indicated that the developed measure showed an association with literacy skills and also to an existing speech rhythm measure (DEEdee task).

Given the association of the LJT to the DEEdee task it was assumed that both measure aspects of stress sensitivity. It cannot be said that both tasks measure stress sensitivity in the same way, however. When examining the construct and stimuli of each task it becomes apparent that the DEEdee task encompasses a different type of stimuli which consequently may measure different aspects of speech rhythm. The stimuli in the DEEdee task are created based on the syllabic structure of a phrase and the stress placed on these syllables. In order to convey this stress placement, the individual syllables of the target phrase were replaced by reiterative syllable *dee* utterances, which were stressed according to the target phrases' stress pattern. When including these stimuli and having to make a decision between which of the two DeeDee utterances (e.g. *DEE DEE* and *DEE dee*) sound most like the target phrase (e.g. *Snow White*) phonological cues may still aid or even interfere with this decision making process. Although phonemic cues are removed from the DEEdee phrases and emphasis is placed on the stressed Dees, the use of /d/ and /e/ phonemes in the utterances may still prime performance for some items.

In comparison, the Lexical Judgment Task's stimuli were created using low band-pass filtering to eliminate the high frequency information carried by the words (e.g. Wood and Terrel 1998b). This reduced the transmission of phonemic information such that the word itself could not be identified; only the prosodic contour of the word remains (Nazzi *et al.* 1998), thus speech rhythm patterns of the word can be identified and compared to the target words' rhythmic pattern without the interference of phonemic cues, thereby offering a stricter way to assess children's sensitivity to rhythm.

When further investigating the design of the newly developed task, it can be said that it ensures strict item randomisation. The task includes 20 items which sound similar (based on the same stress pattern) and 20 items which sound different (based on stemming from two different stress patterns). In the case of children being unsure whether the items presented to them are similar or different and choosing to indicate they are all different (or all similar) the sum of correct answers would be 20, indicating a chance level performance, and that the children responding in this way did not show stress sensitivity. In the case of the DEEdee task, if the children continuously decided that the first DEEdee utterance was the correct answer, this would result in 11 (from a possible 18) correct answers. This would indicate above chance level performance but not necessarily be based on their understanding and sensitivity to speech rhythm.

Furthermore, when the children are presented with the target phrase (e.g. Snow White) they will have to retain this information in memory whilst listening to the two Deedee phrases. Although they would listen to these phrases twice, this appears to be rather memory intensive, especially when progressing to the longer phrases, e.g. *The Gingerbread Man* followed by *dee DEEdeedee DEE* and *dee DEEdee DEEdee* (*The Ugly Duckling*). Compared to the LJT, the children would only hear the stimuli once, and all have the same duration, thus keeping the memory intensity and cognitive demands to a minimum.

It could be argued that exposing the children only once to the stimuli is not enough and could appear to be problematic in other ways, for example in the case of the children not hearing the word fully or the headphones falling off of a child's head. However, during the practice for the LJT, the volume was adjusted to suit each individual child; the headphones were adjusted to fit well and the child was instructed not to move his / her head too much and they were asked to listen very carefully to the items as they could only hear them once. Furthermore, only presenting the children with the stimuli once reduces the overall length of the task and the overall memory load and fatigue for the children. These "steps" may not eliminate problems with the task fully but they are in place to minimise these issues from occurring.

The LJT comprised 40 items, which did not take very long to complete (on average seven minutes) however it appeared that some children (especially the younger ones) found this too long and potentially too repetitive. Therefore a reduction in the amount of stimuli used appears to be necessary to eliminate potential fatigue effects in participants, especially the younger ones.

Examining the internal reliability of both speech rhythm tasks, it was found that neither approached the generally accepted alpha level of minimum .70. The LJT's alpha was worse than the DEEdee tasks' alpha, which introduced the question whether or not these tasks are internally reliable and whether all items are measuring one underlying construct. However, as mentioned previously, the different match/different items included in the LJT warrant that the task should be treated as containing two sub-scales, which, when calculating the alpha for match items and different items separately, yields alphas above 0.7, and thus reaches satisfactory levels.

Based on the current findings it can be said that the newly developed task correlated with the existing speech rhythm measure and also provided better internal reliability, thus the initial expectations of this study were met. Although it has been argued that metrical and lexical stress sensitivity are not part of the same construct (Goodman *et al.* 2010), the Deedee stimuli encompass lexical stress aspects (since lexical stress is a subtype of metrical stress and the stimuli used within this task are rather short thus it can be argued that they also measure lexical stress sensitivity).

Additionally, the LJT showed greater correlations with the PA measure compared to the DEEdee task in this sample, which based on previous findings (e.g. Goswami *et al.* 2002; Holliman *et al.* 2008, 2010a and b) is not surprising. It was argued that the DEEdee stimuli appear to include more phonological cues, therefore it could have been expected that stronger correlations between the DEEdee task and the phonological measure would be found. The phonological awareness measure (Spoonerism task) involves the segmentation of one syllable words at the onset of the word and the replacement of the first sound with another phoneme. Bearing in mind that it has been suggested that sensitivity to stress promotes onset-rime boundary detection (through enhancing of vowel location awareness) and also facilitates phoneme identification in stressed syllables (e.g. Wood *et al*. 2009), the stronger association between the LJT and PA appears to be very likely. The suggestion that children who have better sensitivity to stress are also those children who are more skilled at manipulating phonemes (e.g. Wood and Terrell 1998b) therefore appears supported by these findings. Since sensitivity to stress enhances awareness of vowel occurrences, which promotes onset-rime boundary detection it seems conceivable that children who have better speech rhythm sensitivity would be able to segment words like 'cot' easier at the onset and replace it with a different sound (/g/; to obtain 'got'), as this sensitivity draws their attention to the words beginning, which further enhances segmentation and enables the child to complete the Spoonerism task successfully. Therefore, the association of the LJT and PA is supported by current theory.

Despite the DEEdee stimuli containing more segmental cues, the overall design of this measure might have reduced stronger correlations between it and the PA task from being detected, since good performance on the DEEdee task could have occurred by chance and therefore may not have demonstrated accurately that children who performed well on this task also had higher PA scores. This conclusion is tentative however, since no analyses were conducted to assess statistically whether or not there are clear links between stress sensitivity performance levels and PA scores.

When focusing on the second research question, the prediction was met. That is, children who displayed greater stress sensitivity also showed better reading abilities. Significantly lower scores on the LJT were found for the delayed comprehension group compared to the advanced group. Also, a significant difference between the weak fluency ability group and the good fluency group was found. Difference between the decoding ability groups approached significance. The correlations already indicated significant associations between word reading, reading comprehension and fluency with the new speech rhythm task but further analyses showed that group differences were also present. These findings offer further support for previously found links between speech rhythm sensitivity and decoding (e.g. Holliman *et al.* 2008), comprehension (Whalley and Hansen 2006) and also with reading fluency (Holliman *et al.* 2010b), indicating the successful development of a new speech rhythm task.

Furthermore, exposure to reading may facilitate better stress sensitivity, although the reverse may as well be true, which cannot be established through this concurrent data set. In order to evaluate this further, longitudinal studies are proposed, evaluating reading skills and sensitivity to speech rhythm at two different time points to assess whether reading skills can predict stress sensitivity or vice versa. Only a few such studies have been conducted thus far. Holliman *et al.* (2010a and b) for instance have found that stress sensitivity measured in children aged between five and seven years old was able to predict word reading skills one year later. Additionally, stress sensitivity was able to account for the phrasing component of the fluency measure used. The contributions were found after controlling for age, vocabulary and phonological awareness, indicating a unique contribution of stress sensitivity to these reading skills. This suggests that younger children benefit from being sensitive to stress when they are beginning to build their word reading skills and are not yet able to rely on other reading strategies as successfully.

To expand upon this, other longitudinal studies are required to establish whether suprasegmental aspects might be equally (or more) salient for older children than for younger children, when they are exposed to reading of more multisyllabic words compared to monosyllabic words and encounter more complex texts. Concurrent research has demonstrated associations between literacy skills and prosody in children aged between 8- and 15-years (e.g. Goswami *et al*. 2009) and a link between early young readers (with early superior phonological skills) and greater sensitivity to beats has also been reported (Goswami *et al*. 2002). Therefore it would be beneficial to assess slightly older children than were tested in the current study, with the newly developed task, to explore if similar relations can be found between stress sensitivity and decoding, comprehension and fluency skills. This would provide additional data for validating the Lexical Judgement Task further, as a reliable stress sensitivity measure. Additionally, predictive relationships were not assessed in this pilot, so these analyses are proposed for future studies that are part of this thesis.

The current findings do however support and add to previous research findings which showed that dyslexic children, who are poorer readers, are less sensitive to stress, compared to their age-matched controls (e.g. Goswami *et al.* 2002). This indicates that good speech rhythm sensitivity could be related to better reading skills. The children in this sample were not identified as dyslexic children and the reason for their delayed reading abilities are not clear. It could be hypothesised that the reduced sensitivity to stress is underlying delayed reading development in non-dyslexic children, but this needs to be seen with caution and requires direct testing. To conclude based on the present findings it cannot be determined whether the exposure to reading generates better stress sensitivity or whether better stress sensitivity aids better reading, however it cannot be ignored that a relationship between these skills exists and thus further research is warranted in this area.

3.6 Conclusion

The current study replicated previously reported relationships, as it showed links between stress sensitivity and reading abilities (decoding, comprehension and fluency). This is encouraging, given that a newly developed task was used. This task may offer another way to assess stress sensitivity in an easy to administer and easy to understand way; and has the potential to be used with children from a range of ages. Further studies need to be conducted to evaluate the newly developed task further however and to validate the relationships found with the literacy skills. Additionally, more studies using the same stress sensitivity measure would provide more consistency across studies and allow for the direct comparison of results. An in depth task analysis is proposed next, in conjunction with further testing of children to evaluate whether a revised (and shortened) Lexical Judgment Task would show similar results in relation to children's' reading abilities.

3.7 Task revision

To ensure that the LJT is a good measure of stress sensitivity it was deemed important to reduce the amount of items included in the task so that it would not take too long for children to complete it, which would reduce the potential for fatigue effects to occur. Additionally, this would also make this task more appealing to younger children. In order to identify which items could be removed from the task without harming the internal reliability too much, the children's performance on the Lexical Judgement Task was further analysed for the individual items' difficulty and for the items' ability to discriminate between good and poor performers on the task.

Following Skurnik and Nuttal's (1987) instructions, an item analysis was performed in which each item's facilitatory (F-value) and discriminatory (D-value) indices were calculated. The first step included the ranking of the participant's total scores obtained on the LJT. Following this, the total sum of participants was divided by four to obtain one-quarter (Q) of the participants (in this case n = 17). This allowed for choosing the 25 per cent of participants with the highest and the lowest scores.

For each individual item the number of correct responses of the 17 highest scoring participants was tallied together; the same was done for the 17 lowest scoring participants. The tallies were added together for each item to obtain High scores (H-values) and Low scores (L-values).To calculate the F-index for each task item the H-values were added to the L-values, these scores were then divided by 2 Q (2 x 17 = 34). Suitable F-values should range between 0.25 and 0.75. Scores ranging from 0.10 to 0.24 and from 0.76 to 0.95 are regarded as caution items and should only be used if no suitable items in the acceptable range are present. All other items outside the acceptable and caution range should be removed as they indicate very easy or very difficult items and are not suitable for inclusion.

Following this, the D-values were calculated for each task item. This was completed through subtracting L-values from H-values and dividing the difference by Q. The discrimination value indicates how well each item discriminates between good and poor performers on each item. Depending on the sample size, different D-values are acceptable or advised to be used with caution. In this sample (N = 68) an acceptable D-value would be 0.28 or above. Scores ranging from 0.21 to 0.27 should be used with caution and items with scores below these values should not be used.

Table 3.5 shows the total correct scores for the high quartile and the low quartile, the F- and D-values for each of the 40 items in the Lexical Judgment Task and also the items' match or no match properties. The stress patterns are also shown (SP), indicating to which of the four categories the word pairs belong (stress pattern categorisations are based on the first word in the pair). For an overview of these pattern categories, see Chapter 2.3.

Most F-values were found to be in the acceptable range (0.25 to 0.75), with only three items falling into the “caution” range with an F-value of 0.79 (see items 15, 23 and 29). This indicated that the items were of reasonable difficulty and were not too easy or too difficult for this sample to complete.

Table 3.5 LJT stimuli, individual stress patterns, match properties and item analysis values

SP	Items	Match/No Match	H-value	L-value	F-value	D-value
200	1. Alphabet_Kangaroo	No Match	15	8	.67	.47
200	2. Astronauts_Jellyfish	Match	5	7	.35	-.11
200	3. Factory_Alphabet	Match	11	9	.58	.11
200	4. Suddenly_Introduce	No Match	5	8	.38	-.17
200	5. Vitamin_Sunglasses	No Match	15	8	.67	.41
200	6. Burglary_Vitamin	Match	12	12	.70	0
200	7. Honeycomb_Forever	No Match	13	9	.64	.23
200	8. Jellyfish_Afternoon	No Match	13	8	.61	.29
200	9. Officer_Honeycomb	Match	5	6	.32	-.05
200	10. Pantomime_Suddenly	Match	7	7	.41	0
102	11. Afternoon_Disappear	Match	11	8	.55	.17
102	12. Dissapear_Astronauts	No Match	15	10	.73	.29
102	13. Kangaroo_Mandolin	Match	14	8	.64	.35
102	14. Lemonade_Bricklayer	No Match	13	8	.61	.29
102	15. Magazine_Lemonade	Match	17	10	.79	.41
102	16. Anymore_Bonfire	No Match	10	9	.55	.05
102	17. Introduce_Commotion	No Match	14	9	.67	.29
102	18. Mandolin_Burglary	No Match	6	4	.29	.11
102	19. Overhead_Introduce	Match	15	10	.73	.29
102	20. Siamese_Anymore	Match	13	8	.61	.29
210	21. Grandmother_Sunglasses	Match	13	6	.55	.41
210	22. Caretaker_Bricklayer	Match	9	5	.41	.23
210	23. Grasshopper_Factory	No Match	16	11	.79	.29
210	24. Newspaper_Inspector	No Match	5	7	.35	-.11
210	25. Shopkeeper_Suddenly	No Match	17	8	.73	.52
210	26. Bonfire_Shopkeeper	Match	7	6	.38	.05
210	27. Sunglasses_Burglary	No Match	13	7	.58	.35
210	28. Bricklayer_Jellyfish	No Match	15	10	.73	.29
210	29. Kingfisher_Newspaper	Match	16	11	.79	.29
210	30. Timetable_Grasshopper	Match	14	6	.58	.47
020	31. Bananas_Inspector	Match	4	7	.32	-.17
020	32. Computer_Commotion	Match	11	9	.58	.11
020	33. Remembered_Kangaroo	No Match	13	9	.64	.23
020	34. Umbrella_Timetable	No Match	7	10	.50	-.17
020	35. Amazing_Introduce	No Match	16	7	.67	.52
020	36. Allotment_Umbrella	Match	8	8	.47	0
020	37. Commotion_Honeycomb	No Match	9	4	.38	.29
020	38. Forever_Amazing	Match	16	8	.70	.47
020	39. Inspector_Afternoon	No Match	13	9	.64	.23
020	40. Performance_Remembered	Match	14	11	.73	.17

With regards to the D-values, a wider range of scores was found and these require closer examination. Initially, all items with a D-value below 0.20 were removed but in doing so, the item distribution (regarding a balanced amount of items in each rhythmic pattern and their match/no match propositions) was not equal anymore. However, removal of the low D-value items ensured that the remaining items were those that were able to discriminate between good and poor performers on the task hence are items that are able to identify children with good and poor stress sensitivity levels.

Due to the unbalanced number of items per stress pattern it was decided to remove more items to ensure equal item distribution in each stress category. Looking at the remaining 24 items it was found that they stemmed from different categories as follows: four items in category 200, seven in 102, eight in 210 and five in 020. Based on this item distribution it was debated whether to only include four items from each category to allow for equal distribution. However these most discriminating items did not equate to an equal amount of match/no match stimuli within each rhythmic pattern. Thus the items needed to be examined further to ensure that the most discriminating match and the most discriminating no match items were analysed to be included in an equal amount spread across the stress patterns.

Since the items in the 200 category were the most non discriminating items, it was decided to exclude this rhythm category altogether (as it was not able to differentiate enough between good and poor performers). As these items stemmed from the most dominant stress pattern in the English language (first syllable stressed, see Cutler and Norris 1988) the rhythm of these words may be too habituated or prominent in the children's lexicon, whereas in comparison the words in the other categories are more salient and potentially unexpected. Thus the ability to discriminate between same and different items in these more unusual stress patterns may indicate better underlying speech rhythm sensitivity.

Of the three remaining stress patterns it was decided that these should include the most discriminating four word pairs, with equal amounts of match and no match items. In the 020 category only one of the five word pairs was a match items, thus another match word pair needed to be included. This meant that an item needed to be included which had previously been removed due to a low D-value. The best item to choose was item 40, as it had the highest F-value (0.73) and the highest D-value (0.17). Table 3.6 shows the revised Lexical Judgement Task items (including the stress pattern, SP).

Table 3.6 Revised Lexical Judgement Task items

SP	Item number and name	Match/No Match
102	12. Dissapear_Astronauts	No Match
102	13. Kangaroo_Mandolin	Match
102	14. Lemonade_Bricklayer	No Match
102	15. Magazine_Lemonade	Match
210	21. Grandmother_Sunglasses	Match
210	23. Grasshopper_Factory	No Match
210	25. Shopkeeper_Suddenly	No Match
210	30. Timetable_Grasshopper	Match
020	33. Remembered_Kangaroo	No Match
020	35. Amazing_Introduce	No Match
020	38. Forever_Amazing	Match
020	40. Performance_Remembered	Match

Calculations of Cronbach's alpha based on the same and different items (subscales) yielded similar results as were observed with the 40-items task. Match items' alpha was α 0.65 and different items' alpha was α 0.67 with the shorter version, based on the pilot study sample. However, these findings may differ when assessed across different samples, thus the shortened version needs to be tested further.

As a preliminary assessment, correlations of the revised LJT with the pilot study sample and the measured variables were conducted (see Table 3.7); similar results were found as with the 40-items task (see Table 3.3). No outliers were found in this shortened task and the scores ranged from 2 to 12 across all 69 participants (mean = 7.78, SD = 2.36).

LJT correlated significantly with all variables it previously correlated with; additionally a slight increase in these values can be observed. The previous correlation with word reading was r = .401 whereas it became r = .451; likewise, previously it was r = .400 with reading comprehension whereas now it was r = .489. For fluency it was r = .405 and now it was r = .477. Additionally, the DEEdee task and the shortened LJT also appeared to be more closely associated (before r = .292, p = .016 was found, now it was r = .368, p = .002).

Table 3.7 Zero order correlations between age, vocabulary, IQ, phonological awareness, RAN, literacy skills and revised LJT

	Age	Vocab	IQ	PA	RAN	DEE	LJT	WR	RC
Vocab	.632***								
IQ	.157	.686***							
PA	.451***	.586***	.620***						
RAN	- .636***	-.618***	-.423***	-.653***					
DEE	.343**	.365**	.268*	.371**	-.353**				
LJT	.250*	.311**	.311**	.490***	-.312*	.368**			
WR	.518***	.606***	.603***	.799***	-.781***	.391**	.451***		
RC	.549***	.696***	.609***	.752***	-.676***	.414***	.489***	.858***	
RF	.501***	.563***	.519***	.758***	-.736***	.350**	.477***	.862***	.821***

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

Overall, the reduction in the number of items in the LJT appears to be a good step in ensuring a sound stress sensitivity task being developed. Given that the results remained similar, this further offers support for an underlying link between reading abilities and stress sensitivity. Perhaps the inclusion of the items stemming from a "common" stress pattern (first syllable stressed) created "noise" in the task, which reduced the ability to detect subtle differences in the children's stress sensitivity and may also have reduced the associations between the literacy skills and speech rhythm sensitivity. These findings are however based on the extraction of items from the 40-item task and need to be viewed with caution, thus the task needs to be assessed as a whole before clear conclusions can be drawn.

In reducing the LJT it was anticipated that children would not be affected by fatigue when completing the task, but that enough items are present to assess their stress sensitivity. Therefore another study was conducted, examining some of the children from the pilot study to assess whether they were able to complete the shortened task and whether the performance on the reduced LJT would again yield similar associations with the reading skills. This was followed by the addition of more participants for the examination of further research questions. This is reported in the next chapter.

Chapter 4 – Study 2

Task Validation: Investigating 7- to 9-year-olds' speech rhythm sensitivity and its relation to reading abilities

4.1. Overview

Following the revision of the Lexical Judgement Task, this study aimed to assess children aged 7- to 9-years old with this shorter task to establish its ability to measure stress sensitivity further. Assessing the children's reading abilities, phonological awareness and stress sensitivity showed that the shorter LJT was correlated with word reading, reading comprehension and reading fluency. Although the LJT performance did not differ across reading ability groups, significant variance could be accounted for by stress sensitivity in all three reading skills. These findings offer support for reading theories incorporating suprasegmental phonology (e.g. Wood *et al.* 2009; Zang and McBride-Chang 2010) and the success of the task revision and the findings' implications are discussed in relation to current theoretical views.

4.2. Introduction

The pilot study showed that the newly developed Lexical Judgement Task was correlated with word reading, reading comprehension and reading fluency and also showed associations with an existing speech rhythm task and a measure of phonological awareness. The 40-item task was however regarded as too memory intensive and potentially too long for younger participants, thus a task revision was undertaken. This resulted in a 12-item version of the task, which also correlated with all three reading measures.

These findings were in line with previous research e.g. Goswami *et al.* 2009; Holliman *et al.* 2010b) and provided further support for the investigation of stress sensitivity in relation to reading skills. In order to further assess the shorter LJT measure, more children needed to be assessed. Initially, some children from the pilot study were re-tested, using the 12-item LJT only, to pilot this shortened task as a whole. As these children were previously tested on the whole test battery, this offered an easy way to compare the findings obtained with the 40-items task to the shorter version and also to include these participants in further comparisons with other children. Following this, the study aimed to explore the revised Lexical Judgement Task and its relation to literacy further by assessing more children and addressing the following research questions:

1. Does the shortened Lexical Judgment Task show greater reliability and greater associations with reading skills compared to an existing speech rhythm measure?
2. Are better readers more sensitive to speech rhythm (as measured by the shorter LJT measure) compared to poorer readers?
3. Can stress sensitivity predict unique variance in reading (decoding, comprehension and fluency) after controlling for age, verbal and non verbal IQ, and phonological abilities?

Based on the pilot study findings, correlations between the LJT and the DEEdee task as well as reading skills were expected. After the revision, improved internal reliability of the LJT task was anticipated in comparison to the DEEdee task, which would be indicative of greater consistency across the stimuli used in the LJT. Furthermore, assessing the children's reading abilities and examining their performance in comparison with the stress sensitivity measure allowed the examination of the claim that children who have lower stress sensitivity also display reduced reading skills. For example, Goswami *et al.* (2002) found that dyslexic children showed reduced sensitivity to non-speech rhythm (beats) compared to their age matched non-dyslexic counterparts. Controlling for age, nonverbal IQ and vocabulary also showed that sensitivity to beat detection could account for unique variance (25%) in reading and spelling abilities. Furthermore, Holliman *et al.* (2012) recently showed that chronological-age matched controls performed significantly better on the revised mispronunciations task compared to poor readers; the reading-age matched controls scored higher on this task in comparison to the poor readers but this difference was not significant. Both, speech and non-speech rhythm based measures, have shown that differences between poor readers and good readers as well as age matched controls can be observed. Based on these previous findings, it was predicted that children who perform less well on the reading tasks would also display lower scores on the stress sensitivity measures.

Analysing whether stress sensitivity can predict unique variance in either decoding, comprehension or fluency skills in this study will add to the literature which has indicated that prosodic sensitivity may contribute to decoding (e.g. Holliman *et al.* 2008) and comprehension (Whalley and Hansen 2006) independently of age, IQ, vocabulary and phonological awareness. Research also suggests that prosodic oral reading (reading with expression) can predict later fluency (Miller and Schwanenflugel 2008) after controlling for word reading skills. Being sensitive to stress may help to consolidate phonological processing, which would be indicated through significant associations between phonological awareness and stress sensitivity measures (Wood 2006a); this could be rooted in the ability to detect phonemes in stressed syllables better, which would enable children who are more sensitive to speech rhythm to decode words better phonemically. Alternatively, speech rhythm and decoding associations could also stem from the enhanced ability to detect onset-rime boundaries through the enhanced skill of identifying vowel locations (through stress sensitivity), which would then increase word reading skills (e.g. Goswami *et al*. 2002). The relationship between speech rhythm and comprehension could be grounded in better word reading skills, since the ability to read words more accurately will free up attentional resources for text comprehension; this then leads to better reading fluency (Kuhn and Stahl 2003). Thus assessing these literacy skills alongside the LJT measure and conducting regression analyses is essential to further understand the links between these skills.

4.3. Method

Children aged between 7- and 9-years-old were examined as part of this study on a range of literacy assessments and the revised LJT. All children were assessed individually in one or two sessions on the same measurements. Firstly, the LJT was compared to an existing speech rhythm measure and children's chance level performance was assessed using a binomial test. For the second research question, the children were grouped into poor, typical and advanced readers, based on their standardised word reading and comprehension scores. The children who scored below 85 standardised scores were classed as *poor* readers, those children performing within the normal range (85 to 115 standardised scores) were classed as *typical* readers and children performing above 115 standardised scores were classed as *advanced* readers. Such a categorisation was not possible for the reading fluency ability of the children as the Multidimensional Fluency Scale (MDFS) only provided raw scores. It was suggested that scores of 9 or more are indicative of achieved (good) fluency whereas scores of 8 and below indicate poor fluency (Rasinski 2003). Therefore these scores were used to categorise children into poor fluency (scores of 8 and lower) and good fluency (scores of 9 and above) groups. Differences across reading ability groups on their LJT performance were analysed using ANOVA.

To further investigate the relationships between the literacy skills, cognitive ability, phonological skills and stress sensitivity, correlations were examined and followed by several hierarchical multiple regression analyses to assess further the unique variance that stress sensitivity can account for in each of the three reading skills.

4.3.1. Participants

Twenty-seven children from the pilot study were re-tested on the shortened 12-item Lexical Judgment in order to further assess the reliability and construct validity of the task. The re-tested children were opportunistically sampled from Year 3 (n = 16) and Year 4 (n = 11). Seventeen males and ten females constituted this sub-sample, with an age range of 86 to 110 months (mean 97.44 months, SD = 6.846).

Additionally, 65 children were recruited as participants for this second study. The total sample comprised 92 children, with an age range of 86 to 115 months (mean 98.65 months, SD = 6.97), including 53 males and 39 females. The children were recruited from Years 3 (n = 59) and Year 4 (n = 33) from a primary school in the West Midlands, UK that collaborated with the principal investigator in the pilot study.

4.3.2. Test Battery

The assessments used were divided into two or three separate blocks, which were randomised and the children decided on the order of assessments within each block MANOVA revealed that no significant order effects occurred, $F(468,189) = 1.084$, p = .261.

A detailed overview of the measures used can be found in Chapter 2.5.1. Depending on the children's abilities, either two or three separate sessions were completed with each child. During the first block the children were assessed on word reading and comprehension, fluent reading and phonological awareness. Dependent on the time available and the children's performance, the remaining assessments were all administered in the second block. Where time was limited, rapid automatised naming, the DEEdee speech rhythm sensitivity test and the shortened Lexical Judgment Task Baseline assessment were administered in the second session followed by the IQ task and stress sensitivity as measured by the revised Lexical Judgement Task (LJT experimental condition) in a final session (see Table 4.1 for assessment overview).

Since the number of items in the LJT experimental task was reduced, the baseline task also needed to be shortened. This was completed following a similar procedure as with the experimental task reduction. All items stemming from the first syllable stressed (200) stress pattern were removed, followed by the removal of items in the remaining stress patterns. It was ensured that the items that remained included four items from the same stress pattern and within this categorisation included two same items and two different (no-match) items. These were chosen randomly using the "random sample of cases" function in SPSS (see Appendix 7 for items list).

Table 4.1 Assessment blocks and assessment distribution within blocks used in this study

Block 1	Block 2	Block 3
1. Word reading	**5.** RAN	**8.** IQ
2. Reading comprehension	**6.** DEEdee	**9.** LJT Experimental
3. Fluency	**7.** LJT baseline	
4. Phonological Awareness		

The children's passage reading was audio recorded and later scored for accuracy, phrasing, smoothness and pace (using the MDFS; Rasinski 2003) by the primary researcher and an independent researcher to ensure accurate scoring. Spearman correlations showed significant relationships between the primary researcher's ratings and the independent researcher's ratings of accuracy ($r_s = .821$, $p < .001$), phrasing ($r_s = .699$, $p < .001$), smoothness ($r_s = .860$, $p < .001$) and pace ($r_s = .762$, $p < .001$). Additionally, the total fluency scores were highly correlated ($r_s = .841$, $p < .001$), indicating overall reliable scoring by the primary researcher and thus those scores where used in the subsequent analyses.

4.3.3. General Procedure

The participants for this study were sampled from the same primary school as most of the participants in the first study (see Chapter 3). After consent had been given by their parents the children were asked individually whether they wanted to take part in the study. Some of the children from the Pilot study were approached and asked to retake the Lexical Judgment Task. This enabled reliability and construct validity assessment of the task. The re-test occurred four weeks after the initial assessments and the children were only tested on the shortened LJT. The remaining children from this current sample were assessed individually on two or three separate occasions, on all the assessments, not lasting longer than 30 minutes each.

4.4. Results

Comparison of the shortened Lexical Judgment Task with an existing speech rhythm measure

Initially, the LJT performance of the sub-sample (n = 27) was assessed in relation to their previously obtained scores (when the 12 items were extracted from the longer, original task). Significant differences were observed between the total mean scores, $t(26)$ = - 2.333, p = .028. Figure 4.1 depicts error bars for both mean scores. This difference in scores indicates that the children performed better when they completed the shorter version of the task, which was apparent in the higher mean scores on the 12-item version (mean 8.70, SD = 1.98) compared to the mean scores when the items were extracted from the 40-

items task (mean 7.48, SD = 2.50). A tentative reason for this difference could be explained by the shorter version being less memory intensive and probably having less potential to cause fatigue amongst participants, thus increasing concentration during task completion and yielding better results.

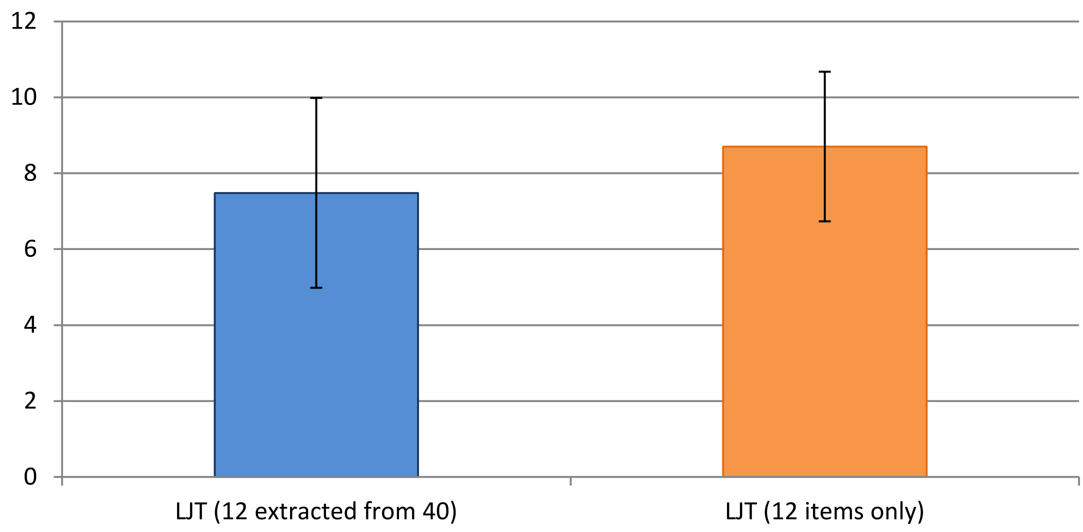

Figure 4.1 Error bars showing mean scores for 12 items only (revised) LJT and for LJT with extracted items from the original, longer, LJT

The performance of the re-tested children on the 12-item LJT was not significantly correlated with the scores from the 12-items when extracted from the longer version, r = 0.279, p = .159. This could be indicative of the task not being reliable over time. Further, when assessing the Cronbach's alpha for the LJT subscales (match and no-match items) a reduction was observed at re-test (match α .37; no-match α .50) compared to initial testing (match α .62; no-match α .65).

Additionally, it was of interest to assess whether the children performed significantly above chance (50% correct) on the 12 items only task and on the comparison task (12 extracted items). Binomial tests indicated that significantly more children performed above chance on the 12 items only LJT than in the comparison Task, when assessed as a whole group. Table 4.2 shows the observed proportion of children performing at chance level (scores of 6 or lower) and above chance level (scores higher than 6).

Table 4.2 Binomial test results of chance level performance analysis

Task	*n*	Scores	OP	*p*
12 items only LJT	4	6 or less	.15	< .001
	23	> 6	.85	
12 extracted items LJT	11	6 or less	.41	.442
	16	> 6	.59	

Note. OP = observed proportions; p = significance level.

This above chance level performance on the shortened task could be due to it being less cognitively demanding and enabling the children to stay focused throughout the whole task; which potentially enhanced the tasks' ability to measure their sensitivity to stress. Despite showing somewhat reduced alpha levels on this task, it appears to be better on the whole than the original 40-item task. The non significant correlation between the 12-items only task and the comparison task may be due to the fact that the items were extracted from the longer LJT, which was too demanding and long, thus extracting items from that task may not be offering good grounds for a direct comparison.

To assess the relationship between stress sensitivity and the literacy assessments, the following analyses were based on the whole sample. Prior to any data analyses the children's scores on the Lexical Judgement Baseline task were examined to establish whether all children had understood the "same-different" principle. Thus it was decided to only include children in the following analyses who scored between 10 and 12 points on this baseline task; one or two errors on this task were acceptable and could be due to response errors, whereas more than two errors were seen as potentially indicative of misunderstanding of the answering principle. Analysis of the LJT baseline data showed that 15 participants had obtained scores lower than 10, and these children were therefore excluded from the subsequent analyses; resulting in a total sample of $N = 77$.

Following this, the remaining variables were checked for normality; this showed that all variables were normally distributed apart from the RAN times, LJT baseline and experimental reaction times (RT's). This was not surprising, since "response-time distributions are not Gaussian (normal) distributions but rather rise rapidly on the left and have a long positive tail on the right" (Wheelan 2008: 475). According to Ulrich and Miller (1994) exclusion of extreme RT's may introduce bias to the analyses because these RT's are actually valid responses and should be included in the analyses. Instead of removing RT's greater than 1 or 2 SD away from the sample mean (e.g. Ratcliff 1993; Wheelan 2008), it was decided to only exclude those values farthest away from the mean by z = +/- 3.29 (Field 2009: 102), to keep the number of excluded reaction times to a minimum and retain statistical power. This procedure resulted in the exclusion of one score per RT variable (which was marked as a missing value), thus the means and correlations for RAN RT and both LJT condition RT's are based on n = 76.

Table 4.3 shows the score distributions, means and standard deviations (in parentheses) for all assessments, including raw and standardised scores as well as the score ranges and maximum possible scores. Cronbach's alpha for all measures (except reaction times) are also included.

The internal consistency reliability coefficient (Cronbach's alpha) for each variable was computed and those were satisfactory (see Table 4.3); however the reliability of the DEEdee task and the revised Lexical Judgment Tasks were very low and required further exploration. The alpha values for the Lexical Judgement Task baseline condition fell far below the acceptable range, but this can be explained by the limited range of scores, due to near ceiling performance. When examining the alpha levels for the original sample (N = 92), prior to the exclusion of children with low scores on the baseline task, the match sub-scales' alpha value was α .67 and the no-match sub-scales' alpha value was α .70. This indicates that reduced variability in the scores could be at the root of the problem for observed low alpha scores in this type of task. The Cronbach's alpha of the experimental LJT and of the DEEdee task will be examined in the following section.

Table 4.3 Summary statistics for all measures used in this study and alpha values

Task	Minimum	Maximum (out of)	Mean (SD)	Cronbach's alpha
Voc[a]	11	40 (56 – 64)	25.23 (5.78)	.77
IQ[b]	65	121	93.49 (11.42)	.86
PA[a]	2	28 (30)	13.96 (6.42)	.87
RAN[c]	54	202	97.82 (30.19)	
DEE[a]	4	16 (18)	10.62 (2.82)	.48
WR[a]	7	50 (70)	30.95 (8.98)	.93
WR[b]	55	129	95.76 (17.15)	
RC[a]	0	34 (50)	11.29 (7.91)	.92
RC[b]	63	132	92.39 (16.34)	
Fluency[a]	4	16 (16)	12.10 (4.05)	.95
LJT base[a]	10	12 (12)	11.70 (.59)	.18 (match)/ .15 (no-match)
LJT base RT[d]	1202	3860	2019.59 (503.46)	
LJTexp[a]	3	12 (12)	8.43 (1.85)	.41 (match)/ .48 (no-match)
LJTexp RT[d]	1232	5701	2475.78 (729.96)	

Note. Voc = Vocabulary; PA = Phonological Awareness; RAN = rapid automatised naming; DEE = DEEdee speech rhythm measure; WR = word reading; RC = reading comprehension; LJT base and LJT exp. = Lexical Judgement Task baseline and experimental condition.
[a]raw scores; [b]standardised scores, [c]RT in seconds; [d]RT in milliseconds.

Internal reliability assessment and associations of speech rhythm sensitivity measures with reading skills

First, focusing on whether the revised LJT shows greater internal reliability compared to the DEEdee task, it can be said that neither task reached a satisfactory level and the LJT appears to be less internally reliable than the DEEdee task (α .31 and α .48 respectively). When assessing the alpha for the same (match items) and the different (no-match) LJT items separately the alpha increased somewhat; match items α .41, no-match items α .48.

As an additional check of the performance of children on the speech rhythm tasks, chance level performance analyses were conducted (using binomial tests). Based on the test probability of 0.5 (50% chance to obtain the correct answer by guessing) it was found that significantly more children performed above chance (scores > 6, *n* = 67) on the Lexical Judgement Task, than at chance level (<= 6, *n* = 10); *p* < .001. In comparison, the performance on the DEEdee task on the other hand did not yield significant above chance performance across participants. Forty-seven children obtained scores higher than 9 and 30 children performed at chance level (scores <= 9); *p* = .068.

These findings may indicate that the LJT is a better task to measure stress sensitivity, since the children appeared to know what they were meant to do when they were completing this task. They also demonstrated above chance (not guessing) performances, which could be argued to be based on stress sensitivity being used.

To assess whether the LJT showed greater associations with reading abilities compared to the DEEdee task, zero order correlations were conducted (see Table 4.4).

Table 4.4 Correlation matrix between reading skills and speech rhythm sensitivity

Variables	1.	2.	3.	4.
1. Word reading				
2. Comprehension	.849***			
3. Fluency	.780***	.809***		
4. Speech Rhythm (DEE)	.377**	.263*	.252*	
5. Speech Rhythm (LJT)	.249*	.284*	.270*	.148

Note: DEE = DEEdee task; LJT = Lexical Judgement Task; all variables based on raw scores.
* p < .05, ** p < .01, *** p < .001.

The Lexical Judgement Task was significantly correlated with word reading (*r* = .249, *p* = .029), reading comprehension (*r* = .284, *p* = .012) and reading fluency (*r* = .270, *p* = .017). This again offers support for the hypothesis that stress sensitivity is associated with reading abilities. In comparison, the DEEdee task correlated with decoding skills (*r* = .377, *p* = .001), comprehension (*r* = .263, *p* = .021), and fluency (*r* = .252, *p* = .027), but not with LJT (r = .148, p = .200). Since the DEEdee task has been used in previous studies as a speech rhythm measure, a correlation between LJT and this existing task would provide an indication for its success in measuring stress rhythm sensitivity; and such a relationship was found in the previous (pilot) study. This was not the case in the current study however. Potential reasons for this will be discussed. The slightly stronger correlation between DEEdee and word reading compared to LJT and word reading does appear perplexing, given the nature of the stimuli in each speech rhythm task. The DEEdee task stimuli are more closely related to measuring metrical stress whereas the LJT items are measuring lexical stress sensitivity. Therefore it was predicted that lexical stress sensitivity would be more strongly correlated with word reading. However, given that both speech rhythm measures show significant relations with all three reading measures indicates associations between these tasks and the reading skills, but it will need to be further examined how these tasks differ in their relationships to these literacy skills.

Sensitivity to speech rhythm across reading ability groups

In order to examine whether poorer readers displayed lower stress sensitivity when compared to better readers, the children needed to be grouped according to their reading skills. This categorisation was based on the obtained standardised scores for word reading and reading comprehension and the raw scores from the fluency assessment (see Section 4.3.2 for grouping details). Table 4.5 shows the sample distribution across the three ability groups for word reading, comprehension and fluency; mean stress sensitivity scores (measured by LJT and the DEEdee task), standard deviations and score ranges are also depicted. Overall the mean LJT scores do not appear to differ across reading skills and ability groups; however to assess these mean scores further several one-way ANOVA were completed.

Table 4.5 Reading ability groups' distribution and speech rhythm sensitivity mean scores

	Ability Levels	*n*	LJT mean	SD	Range	DEEdee mean	SD	Range
WR	Poor (< 85)	21	8.24	1.48	6-12	9.66	2.37	4-14
	Typical (85-115)	46	8.41	2.05	3-11	10.65	2.96	4-16
	Advanced (>115)	10	8.90	1.59	6-11	12.5	2.22	9-16
RC	Poor (< 85)	24	7.96	1.76	3-12	9.75	2.36	4-14
	Typical (85-115)	50	8.62	1.91	3-11	11.02	2.99	4-16
	Advanced (>115)	3	9.00	1.00	8-10	11.00	2.65	8-13
RF	Poor (<9)	17	7.82	1.78	3-10	9.76	2.63	4-14
	Typical (>=9)	60	8.60	1.84	3-12	10.87	2.85	4-16

Note. WR = word reading; RC = reading comprehension; RF = reading fluency.

The word reading ability groups did not differ significantly on their LJT performance, $F(2, 74) = .433$, $p = .650$, nor did the reading comprehension ability groups, $F(2, 74) = 1.198$, $p = .308$ or the fluency ability groups, $F(1, 75) = 2.388$, $p = .127$. These findings are not in line with the original prediction made, that children who perform less well on the reading tasks will also display lower stress sensitivity scores. Nor are these findings in line with the previously found results of the Pilot study (Chapter 3). As a means of comparison the same analyses were conducted with the DEEdee task and the reading ability groups. The comprehension and fluency ability groups did not differ significantly on their performance on the DEEdee task, $F(2, 74) = 1.698$, $p = .190$ and $F(2, 74) = 2.045$, $p = .157$ respectively. The word reading ability groups did differ however, $F(2, 74) = 3.654$, $p = .031$, $\omega^2 = .064$; Games-Howell post hoc analyses indicated that the delayed readers differed significantly from the advanced readers (mean difference -2.83, $p = .011$).

Correlations and regression analyses

Despite the revised Lexical Judgement Task appearing to have low internal reliability and provided no indication of differences between poor, typical or advanced readers, it was of interest to examine whether or not stress sensitivity (as measured with this task) could predict unique variance in reading skills across participants. Initially further correlations were conducted to assess the relationship between the literacy related skills and reading variables prior to the regression analyses (see Table 4.6).

Firstly, focussing on the Lexical Judgement Task, it can be seen that it significantly correlated with the RAN performance (r = - .275, p = .016) but not with age, vocabulary, IQ or phonological awareness, although the correlation with vocabulary was in the expected direction (r = .209, p = .069). This could be indicative of the task not being cognitively demanding or dependent on maturation and that stress sensitivity is a skill independent of phonological awareness.

In contrast, the DEEdee task was significantly correlated with all variables apart from age (r = .001, p = .997) and LJT (r = .148, p = .200). This could indicate that the DEEdee task performance is depending on vocabulary knowledge (r = .370, p = .001) and general ability (r = .411, p < .001) as well as phonological skills (r = .422, p < .001 for PA, and r = -.270, p = .018 for RAN).

Table 4.6 Zero order correlations between age and all test variables used in this study

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Age									
2. Voc	.133								
3. IQ	-.116	.709***							
4. PA	-.017	.328**	.482**						
5. RAN	- .030	-.234*	-.279*	-.548***					
6. DEE	.001	.370**	.411**	.422**	-.270*				
7. LJT	.098	.209†	.018	.159	-.275*	.148			
8. WR	.024	.452***	.487***	.715***	-.787***	.377**	.249*		
9. RC	.104	.507***	.435***	.645***	-.679***	.263*	.284*	.849***	
10. RF	.008	.242*	.207††	.577***	-.684***	.252*	.270*	.780***	.809***

Note: Voc = vocabulary; IQ = verbal and nonverbal intelligence; PA = phonological awareness; RAN = rapid automatised naming (in ms); DEE = stress sensitivity measure (DEEdee); LJT = stress sensitivity measure (Lexical Judgment Task; WR = word reading; RC = reading comprehension; RF = reading fluency. All correlations based on raw scores.
* p < .05, ** p < .01, *** p < .001, †p = .069; ††p = .071.

Further, these correlations may be indicative of a link between stress sensitivity (as measured by LJT) and reading through phonological processing speed (RAN), whereas stress sensitivity (as measured by DEEdee) appears to be linked to reading through phonological awareness and RAN. These claims require further testing however. Therefore, separate partial correlations were conducted, one controlling for PA and the second one controlling for RAN; these can be seen in Table 4.7.

Table 4.7 Partial correlations between all variables after controlling for PA and RAN

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Age	-	.142	-.109	-.005	.032	.150	.036	.010	.110
2. Voc	.149	-	.688***	.239*	.440***	.483***	.104	.324**	.150
3. IQ	-.116	.666***	-	.394***	.437***	.332	-.013	.354**	-.077
4. RAN/PA	-.027	-.073	-.030	-	.542***	.429***	.303**	.328**	-.006
5. WR	.049	.329**	.233*	-.676***	-	.690***	.535***	.263*	.042
6. RC	.159	.409***	.183	-.512***	.728***	-	.636***	.096	.125
7. RF	.048	.068	-.111	-.545***	.655***	.702***	-	.071	.099
8. DEE	.014	.271*	.260*	-.059	.119	-.015	.005	-	.070
9. LJT	.113	.168	-.072	-.236*	.197	.238*	.214†	.088	-

Note: Partial correlations controlling for PA are presented below the diagonal, and partial correlations after controlling for RAN are presented above the diagonal.
$p < .05$, ** $p < .01$, *** $p < .001$, † $p = .065$.

Examining the correlations controlling for phonological awareness shows that speech rhythm (as measured by LJT) is no longer significantly correlated with word reading (r = .197, p = .090) or reading fluency (r = .214, p = .065), but remains significantly correlated with reading comprehension (r = .238, p = .039). Speech rhythm as measured by the DEEdee task on the other hand does not show significant correlations with any of the reading measures. These findings indicate that the relationship between stress sensitivity (measured by LJT) and reading comprehension appears to be independent from phonological awareness.

When examining the associations of the reading skills with both speech rhythm measures after controlling for RAN it can be seen that the LJT does not show significant correlations with any reading skill, whereas the DEEdee measure now shows a significant correlation with word reading (*r* = .263, *p* = .023). These findings suggest that phonological processing speed plays a role in the relationship of stress sensitivity (measured by LJT) and reading skills, whereas it plays a lesser role in the link between word reading and stress sensitivity (as measured by DEEdee). These associations will be examined further in the following regression analyses and will be considered in line with current theoretical views in the discussion.

To assess which variables are able to predict unique variance in word reading, comprehension and fluency, several multiple hierarchical regression analyses were conducted. The focus was placed on the unique variance that can be accounted for by stress sensitivity when predicting each reading skill; independently and after controlling for several predictor variables. Firstly, word reading skills were examined (including the word reading raw scores). Based on the significant correlations found between word reading and both speech rhythm tasks, it was predicted that both would also be able to contribute unique variance to word reading skills.

Initially, two separate regression analyses were conducted to assess the contributions of stress sensitivity, as measured by DEEdee and LJT, to word reading. This showed that LJT was able to contribute unique variance to word reading, $F(1, 75) = 4.954$, $p = .0.029$, $\Delta R^2 = .062$; the DEEdee task was also able to predict unique variance, $F(1, 75) = 12.405$, $p = .001$, $\Delta R^2 = .142$.

Not only is it of interest to assess whether speech rhythm can contribute unique variance to the reading skills after age, verbal and non-verbal IQ and phonological abilities have been controlled for, due to previous studies showing these relations, but also because the partial correlations indicated relationships between the reading skills and speech rhythm that appear to be mediated by PA and RAN.

To further assess the unique contribution of speech rhythm to word reading, this variable (either LJT or DEEdee) was entered into another regression analysis preceded by age and IQ (in separate steps). This showed that stress sensitivity (as measured by LJT) was able to contribute significant unique variance to word reading, $F(1, 73) = 5.657$, $p = .020$, $\Delta R^2 = .054$, after age and IQ were controlled. Age did not contribute significantly to word reading ($p = .834$) whereas IQ did, $F(1, 72) = 23.772$, $p < .001$, $\Delta R^2 = .24$. When DEEdee was entered in the last step it did not account for significant variance in word reading, $F(1, 73) = 3.642$, $p = .060$, $\Delta R^2 = .036$, although it was approaching significance.

Since age did not contribute significantly to word reading in this sample it was omitted from the following regression analyses. Next vocabulary was entered as the first predictor variable, followed by LJT and then by DEE in two separate analyses. This showed that LJT was not able to account for significant variance in word reading ($p = .127$) when vocabulary was included, which accounted for 18.7% of variance in word reading ($p < .001$). When DEEdee was included after vocabulary however it did add 6.7% ($p = .012$) of variance to word reading in addition to vocabulary's contribution. As an additional check vocabulary and PA were controlled prior to entering DEEdee into another analysis. This showed that speech rhythm, as measured by the DEEdee task, was not able to add significant variance to word reading once vocabulary and PA were controlled ($p = .540$).

Next, IQ was entered in Step 1 again, followed by PA in the second step. LJT and DEEdee were both entered in the last step in individual analyses. These showed that neither speech rhythm task could contribute significantly to word reading after IQ and PA were controlled; however LJT's contribution approached significance ($p = .06$). Lastly, IQ (Step 1) and RAN (Step 2) were controlled, followed by LJT and DEEdee (in two individual regression analyses). These analyses showed that neither LJT ($p = .477$) nor

DEEdee (p = .275) could predict word reading after IQ and RAN were controlled. These findings can be seen in Table 4.8.

4.8 Hierarchical multiple regression analyses predicting word reading and comprehension from different variables at different steps

	Word reading			Reading comprehension	
Steps and Variables	**β**	**ΔR²**	**Steps and Variables**	**β**	**ΔR²**
1. IQ	.487**	.237**	1. IQ	.435***	.189***
2. PA	.626**	.301**	2. PA	567***	.247***
3. DEE	.047	.002	3. DEE	-.056	.002
3. LJT	.150	.022†	3. LJT	.197*	.038*
1. IQ	.445***	.198***	1. IQ	.423***	.179***
2. RAN	-.699***	.466***	2. RAN	-.608***	.341***
3. DEE	.079	.005	3. DEE	-.019	.000
3. LJT	.049	.002	3. LJT	.115	.012

Note. $p < .05$, ** $p < .01$, *** $p < .001$, † $p = .060$.

The same regression analyses were conducted to assess speech rhythm's ability to predict reading comprehension (using raw scores). Initially, LJT and DEE were entered into two individual analyses. These showed that LJT was able to significantly predict 8.1% of variance, $F(1, 75) = 6.590$, $p = .012$, and DEEdee was also able to significantly predict 6.9% of variance in reading comprehension, $F(1, 75) = 5.584$, $p = .021$. Next, age and IQ were controlled for, followed by either speech rhythm measure. Age did not significantly contribute to reading comprehension (p = .370) but IQ, $F(1, 74) = 19.056$, $p < .001$, ΔR^2= .203, and LJT did, $F(1, 73) = 6.989$, p =.010, ΔR^2 = .069. DEEdee was not a significant contributor (p = .417).

When vocabulary was the first control variable followed by LJT or DEEdee it was found that vocabulary accounted for 25.7% of variance in comprehension ($p < .001$), whereas LJT (p = .066) or DEEdee (p = .418) was not a significant predictor. However, LJT still contributed 3.8% of unique variance to reading comprehension after IQ and PA were controlled, $F(1, 73) = 5.218$, $p = .025$. Figure 4.2 depicts these findings. DEEdee was again not able to contribute to the model ($p = .579$). Table 4.8 shows the beta and variance values for the comprehension analyses including PA and RAN.

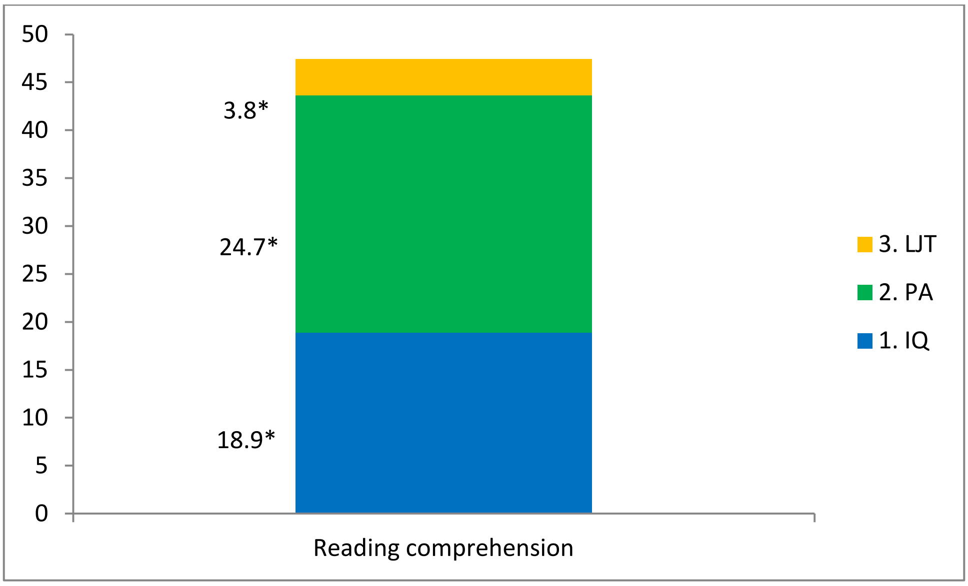

Figure 4.2 Bar chart showing percent of variance (ΔR^2) accounted to IQ, PA and LJT when predicting reading comprehension

The last two regression analyses for reading comprehension included IQ and RAN in the first two Steps. LJT ($p = .174$) and DEEdee ($p = .836$) were both not able to add unique variance to the model. IQ accounted for 17.9% of variance, $F(1, 74) = 16.150$, $p < .001$) and RAN also accounted for an additional 34.1% of variance in reading comprehension, $F(1, 73) = 51.966$, $p < .001$).

Lastly, speech rhythm's contribution to reading fluency was examined. When entered alone, LJT predicted 7.3% of variance, $F(1, 75) = 5.911$, $p = .017$, and DEEdee also accounted for 6.3% of unique variance in reading fluency, $F(1, 75) = 5.082$, $p = .027$. Next, age and IQ were entered in the first two steps followed by LJT or DEEdee. This showed that age and IQ were both not adding significantly to the model, but LJT did, ΔR^2

= .070, *p* = .019. DEEdee's contribution to fluency was not significant (*p* = .111). When vocabulary was entered as a control variable it predicted 5.9% of variance in fluency (*p* = .034) and LJT also accounted for additional 5% (*p* = .044), whereas DEEdee was not adding variance in addition to vocabulary's contribution (*p* = .120).

Because neither age nor IQ were significant in the previous regression and because DEEdee did not add variance in addition to vocabulary it was decided to only include PA prior to the speech rhythm measures in the next regression analyses. This showed that phonological awareness added 33.3% of unique variance, $F(1, 75) = 37.445$, $p < .001$, to the model, whereas DEEdee was unable to contribute significant variance to fluency (*p* = .925). LJT's contribution to reading fluency after PA was accounted for approached significance, $F(1, 74) = 3.811$, $p = .055$, $\Delta R^2 = .033$. Table 4.9 depicts the regression coefficients (beta values) and amount of variance in fluency accountable to PA, RAN, LJT and DEEdee.

Table 4.9 Beta values and amount of variance in reading fluency

	Reading Fluency	
Steps and Variables	**β**	**ΔR^2**
1. PA	.626**	.333***
2. DEE	.010	.000
2. LJT	.150	.033†
1. RAN	-.684***	.468***
2. DEE	.054	.003
2. LJT	.075	.005

Note. $p < .05$, ** $p < .01$, *** $p < .001$, † $p = .055$.

The final two regressions controlled for RAN prior to entering speech rhythm into the regressions. This showed that rapid automatised naming was able to predict 46.8% of unique variance in reading fluency, $F(1, 74) = 65.194$, $p < .001$, whereas neither speech rhythm measure contributed significantly to fluency (DEEdee, $p = .546$; LJT, $p = .399$).

4.5 Discussion

This study set out to investigate the success of the Lexical Judgment Task item reduction and to explore three research questions. In terms of the LJT revision, the results found in this study indicated that the shorter version may be less memory intensive and does not rely heavily on cognitive abilities (as no correlation with IQ was found), thus the task could be completed by a range of children. Additionally, having only 12 items in the task reduced the time it took to complete the assessment, increasing the likelihood of children retaining concentration whilst completing the task and reducing fatigue effects from occurring.

The first research question then focussed on the internal reliability of the LJT and the existing DEEdee task. Both yielded unsatisfactory levels ($\alpha < 0.7$), and the LJT alpha levels also differed when the task was examined as a whole, or split into same and different item sub-scales. This may be accounted for by the fact that the items used do not share much variance, which could be due to the inclusion of items stemming from different stress patterns. Cronbach's alpha is not a good indicator of a test's homogeneity and "it can badly underestimate reliability when the test is not unidimensional" (Miller 1995: 270). However, as Cronbach (1951: 332, 324) has stated "Items with quite low intercorrelations can yield an interpretable scale"; as "the test may be a smooth mixture of items all having low intercorrelations. [...] if the test is long α could be high. Such items are illustrated by very difficult psychophysical discriminations such as a series of near-threshold speech signals to be interpreted; with enough of these items we have a highly satisfactory measuring instrument". This suggests that the reduction of the task may have been counterproductive (in terms of being able to achieve generally acceptable alpha values); however when the Cronbach's alpha is given less attention, several positive aspects of the 12-item LJT can be examined.

Firstly, it is not cognitively demanding or strongly associated with cognitive ability, therefore children with varying levels of verbal and nonverbal skills can complete this task. Secondly, it is not time consuming and children of different ages would have the ability to complete the task quickly. With regards to Cronbach's suggestion that more items could improve the alpha levels, bearing these positive outcomes in mind however, the reduction of items may have yielded lower alpha levels but this "sacrifice" needs to be accepted to ensure the task is designed in a way that is well suited for the use with children.

A further positive aspect of the task concerns the use of low band-pass filtering; this is a good method to reduce segmental phonological cues within the stimuli (e.g. Fisher *et al.* 2007; Wood and Terrell 1998b), thus reducing the problem of measuring aspects of phonology that do not need to be measured (which may be the case in the DEEdee task) when one intends to focus on suprasegmental phonology aspects alone. Additionally, the stimuli included in the LJT are derived from speech, which may be better than using non-speech stimuli, which can be much simpler than speech contrasts (e.g. Mody *et al.* 1997), because some properties that are included in speech cannot be reflected as well in non-speech stimuli (e.g. Rosen and Manganari 2001).

Furthermore, it was of interest to examine whether the LJT task was completed merely through guessing by the children or whether above chance performance occurred, which would indicate that the children did employ a strategy to solve the assessment.

Binomial analysis of the task indicated above chance performances, thus it can tentatively be said that most of the children did use a strategy to complete the task; although not all children may have been aware of this. Based on the LJT stimuli's properties (and perhaps indicated through the non significant correlation between LJT and PA), the use of a segmental phonology-based strategy is unlikely, thus it can be argued that stress sensitivity was used to assist the decisions that were made to choose whether items sounded similar or different. In comparison, the DEEdee task was typically not completed at above chance level, which raises the question of whether the items included in this task were created and presented in a way that was too difficult for children to complete. This appears feasible, since correlations between DEEdee and IQ were found.

To summarise, the reduction in the length of the LJT was essential to enhance other important positive aspects of the task (less cognitively demanding and less time consuming) and by doing so, it still retained its ability to assess stress sensitivity levels in participants. Nevertheless, this claim needs to be viewed with caution, since the reading ability groups did not differ significantly on their LJT performance. Bearing in mind that research has shown differences in poor and good readers and their stress sensitivity (e.g. Goswami *et al.* 2002; Wood 2006b) these differences were expected to be found. A potential reason for this non significant finding may be rooted in the sample itself. The children assessed in this study ranged from 7- to 9-years-old and studies assessing children for their ability to perceive and use prosodic features in their speech have shown that prosodic cues are identified and used from a very young age (e.g. Echols *et al.* 1997; Thiessen and Saffran 2003) but this ability also develops and becomes more refined over time (e.g. Myers and Myers 1983). Wells, Peppé and Goulandris (2004) for example showed that children's ability to produce intonation is mostly established by age 5 years but that the comprehension of intonational differences continues to develop until at least

10 years of age; this may well be the case for perception of varying stress patterns. Being sensitive to stress may be present in very young children, but the participants (especially the oldest ones) in the current sample may have been at a stage in their development where their implicit sensitivity was changing to a more explicit awareness, thus they may have been attempting to make conscious decisions about the stimuli (i.e. trying to make conscious decisions whether the filtered words follow the same rhythmic contour as the clear spoken words) and thus performed less well than they would without explicit effort (e.g. Karmiloff-Smith 1992). Therefore their "true" sensitivity to stress may not be reflected well, and not be in line with their reading abilities.

Although this is only a hypothetical suggestion, since it was not further assessed in the study, it may explain the non significant group differences. Further studies using this stress sensitivity measure therefore need to be conducted with different age ranges to see whether the task is performed less well by children who are younger and also show less developed reading skills or whether this task would be performed much better in older children who are also more advanced in their reading skills (which could potentially then make the LJT a more explicit stress awareness measure).

Focusing on the second part of the first research question, which asked whether greater associations between the LJT and the literacy (related) measures would be found compared to the DEEdee task, some aspects did not meet expectations. Unlike in the pilot study, the LJT did not correlate with DEEdee or PA in this present study. These findings were somewhat surprising as, given the link between segmental and suprasegmental phonology, a correlation between PA and LJT was expected, even if weak. However, a significant correlation between LJT and RAN was identified, which may indicate that the processes involved to access phonological representations rapidly are not only linked to the access of segmental but also suprasegmental information. This finding does provide support for the importance of stress sensitivity in literacy as it is indicative of an indirect link between reading and prosody, via phonological processing speed (Zang and McBride-Chang 2010).

Furthermore, both speech rhythm measures were significantly correlated with the reading measures, however these associations changed when phonological awareness or RAN were controlled in partial correlations. This potentially indicates that the DEEdee task and the LJT are related to literacy skills via different aspects of phonological processing skills, but also shows that speech rhythm sensitivity is a skill involved in the reading development process.

The DEEdee task showed stronger associations with word reading than did the LJT, which was somewhat surprising since the LJT measures stress sensitivity on the word-level compared to the DEEdee task measuring metrical (phrase-level) stress. However, most research conducted so far has only included monosyllabic words in their reading assessments and their speech rhythm measures (e.g. Arciuli and Cupples 2006), which reduces the ability to measure varying lexical stress patterns. The LJT uses multisyllabic words which vary from the dominant strong-weak stress pattern found in English. The variations in stress patterns in the LJT stimuli may not be applicable to the words that were read in the word reading assessment (since most are monosyllabic) thus not producing significant correlations. On the other hand, the comprehension test included a variety of words and phrases (with varying stress patterns) which would have benefitted being read with more prosody. Therefore the application and usefulness of stress sensitivity may be more potent for comprehension and fluency than for word reading in this sample.

Furthermore, the DEEdee task may be influenced by segmental phonology and thus be correlated to word reading more due to its close relationship with phonological awareness. Thus children who are able to decode the words more phonemically may be those children that also employed a more segmental strategy when completing the DEEdee task, resulting in the significant correlation found between the DEEdee task and word reading. This is also supported by the partial correlation (controlling for RAN) which showed that the relationship between word reading and DEEdee persisted; when PA was controlled however this association was no longer significant.

The third research question was concerned with the unique variance that can be accounted for by stress sensitivity when predicting the reading skills. Individually, stress sensitivity, measured by either the LJT or the Deedee task, was able to predict unique variance in word reading, reading comprehension and reading fluency. When age and IQ were controlled the LJT was still able to contribute significant unique variance to word reading, whereas the DEEdee task's contribution only approached significance. Since age did not contribute to the model it was excluded from the other analyses. LJT scores were not able to add significant variance in addition to vocabulary's contribution to word reading, whereas DEEdee scores did, indicating that stress sensitivity's contribution to word reading (as measured by LJT) is mediated by vocabulary. On the other hand DEEdee did not appear to be mediated by vocabulary, however once PA was also included in addition to vocabulary knowledge the DEEdee measure did not add unique variance anymore, thus the DEEdee task's association with word reading appear to be via phonological awareness.

When IQ and PA were controlled for, the LJT's contribution to word reading approached significance, whereas the DEEdee task did not. This offers partial support for the claim that stress sensitivity can account for word reading skills independently of phonological awareness (e.g. Holliman *et al.* 2008) but it also indicates that this may be dependent on the measure used to assess stress sensitivity. In contrast to this, when IQ and

RAN were accounted for neither stress sensitivity measure could contribute uniquely to word reading. This shows that rapid processing of, or access to phonological representations may be closely linked to suprasegmental phonology and acts as a route over which prosody can influence word reading skills.

A similar pattern was found for reading comprehension. Stress sensitivity (as measured by the LJT) was able to account for significant unique variance in this skill, independently of age, IQ, and phonological awareness but not after RAN was accounted for. On the other hand, the DEEdee task was only able to account for significant variance in reading comprehension when no other skills were controlled. Thus these results highlight the need to develop theory models for the reading skills separately, as it seems that prosodic sensitivity is implicated in these skills, but perhaps via different pathways. Lastly, when examining reading fluency, again both stress sensitivity measures accounted for unique variance when assessed individually; but only LJT was a significant predictor after age and IQ were taken into consideration. When IQ and PA were controlled, LJT's contribution approached significance. Again, after RAN was controlled neither prosodic measure could contribute significant variance to the model.

As had previously been suggested, the complexity of the text used to assess fluency may be important for the ability to accurately measure a child's use of prosody when reading aloud (Miller and Schwanenflugel 2008). The passage used to assess children's fluency in this study was not very complex as it was seen as more important to be able to test more children (including those with less accurate decoding skills), thus this may have introduced the artefact of not being able to accurately measure the children's prosodic rendering of text. Thus the link between stress sensitivity and its ability to predict the children's fluency may be reduced, since the fluent reading of some children could have been more mediocre as they still had to rely to some degree on their phonemic decoding skills to read the passage accurately.

4.6 Conclusion

In sum, the present investigation yielded some interesting results. Not only does the Lexical Judgement Task appear to be a good measure suitable to be used with a range of children (based on age and general ability) but it also appears to indicate underlying relationships between prosody and literacy. This further offers support for theories of reading development that are concerned with suprasegmental aspects of phonology (e.g. Wood *et al.* 2009; Zang and McBride-Chang 2010). However, to further analyse how the relationships between stress sensitivity and literacy behave, further studies are need. Therefore another research study is proposed which examines the reading skills, phonological processing skills and stress sensitivity in somewhat older children to investigate whether the observed associations in this present study could also be found in older children or whether the relationships change. This would also allow for the Lexical Judgement Task to be tested with a different sample; which would provide further data to show the usefulness of this task in assessing stress sensitivity. Due to the issues demonstrated with the DEEdee task items, it was decided not to use this measure further to assess speech rhythm sensitivity.

Chapter 5 – Study 3

9- to 11-year-olds' speech rhythm sensitivity and its associations with reading skills

5.1 Overview

This study set out to expand upon the previous studies by assessing children aged between 9 and 11 years, to investigate whether speech rhythm sensitivity was more closely related to reading skills in an older sample, since greater reading demands may also require additional skills. Against expectations no significant correlations were found between stress sensitivity and reading or phonological processing skills. Differences between poor, typical and advanced readers (based on their standardised decoding, comprehension or fluency scores) on the LJT task were not found either. Additionally, stress sensitivity was not able to account for unique variance in reading skills. These findings do not support current theoretical views and it is proposed that further, longitudinal, assessments should be carried out before dismissing stress sensitivity's role in the development of reading skills in this age range.

5.2 Introduction

This study follows on from the previous study to further investigate the relationship of stress sensitivity with reading skills in another population. As has been found in the literature, children of different ages demonstrate different levels of awareness and ability to use prosodic features in their speech. Atkinson-King (1973), for example, found that 4-year-old children were able to use contrastive stress to indicate specific things they wanted and that by around 11 years of age children were able to use the correct stress for compound words, when they were presented out of context in pictures (e.g. "highchair" versus "high chair"). Wells, Peppé and Goulandris (2004) further showed that by 5-years-old, children are mostly able to produce different intonations when speaking but the ability to comprehend aspects of intonation is still developing until age 11 years. It was also found that this comprehension ability was correlated with receptive as well as expressive language development. Thus a developmental trajectory in the ability to use prosody, including correct stress emphasis and intonation, in spoken language is apparent. Thus it can be hypothesised that the use of prosody in reading may also follow an age-related trajectory.

Research has indicated that prosody plays an important role in reading, but the exact processes that underlie this role are still uncertain. Holliman *et al.* (2008), for example, showed that in 5- to 6-year-olds sensitivity to stress could predict word reading, after age, vocabulary and phonological processing were controlled, and Whalley and Hansen (2006) found that prosodic skills in 8- to 10-year-old children directly contributed to reading comprehension. Further, Cowie *et al.* (2002), who also assessed 8- to 10-year-old children on fluent and expressive reading of texts, found that expressive readers showed greater variations in pitch and that fluent readers read faster and employed fewer pauses between sentences. High expressiveness correlated strongly with high fluency whereas high fluency did not necessarily involve reading with expression. Thus, fluent readers who used prosody showed better rendering of written passages. The literature has highlighted that fluent (prosodic) reading may be a key feature in reading comprehension, and not merely fluent reading in the form of automaticity and accuracy of word reading (e.g. Kuhn and Stahl 2003, Miller and Schwanenflugel 2008). When presented with more complex texts, the application of prosody is predictive of comprehension, beyond rate-based measures of fluency (e.g. Benjamin and Schwanenflugel 2010). It has been suggested that reading prosody increases, rather than reduces, when more difficult texts are read – even in younger readers who may struggle with the difficult texts.

Benjamin and Schwanenflugel (2010) stated that the achievement of fast and accurate reading is related to the development of prosody, as children who can read fast and accurately have additional cognitive resources available (Koriat *et al.* 2002), which can be used for text comprehension. Thus prosody enhances comprehension, and it was found that children with good comprehension skills also displayed greater prosody in general. The participants in this study were on average 8 years and 2 months old so it was hypothesised that even older children, like those in the present study, who had greater fluency would also display higher prosody levels (in this case higher scores on the stress sensitivity measure), since they have had more experience with literacy.

In the current study aspects of expressiveness and fluency were not specifically investigated (instead reading rate was used) but it may be the case that children who are faster readers will also display greater stress sensitivity, although it may be dependent on the difficulty of the texts, as has been suggested by Benjamin and Schwaneflugel's (2010) findings (that prosody employed in easy texts could not predict comprehension skills beyond reading rate, but that prosody expressed in renderings of difficult text added unique variance to comprehension skills additionally to the variance contributed by reading rate).

These research findings together raise the question of whether prosodic skills are used differently at varying points of reading development. Once children have established a sight word lexicon and are able to use grapheme-phoneme conversions successfully, it may be the case that children are more prosodically aware and able to produce a more speech-like rendering of written scripts. Based on this, it was therefore decided that children in the last two years of primary school (Years 5 and 6) should be assessed to establish whether they display greater sensitivity to stress as opposed to children tested in the previous study (see Chapter 4). Stress sensitivity may show a greater association with reading in this age group and this examination would allow for a comparison with the younger children tested thus far. Research generally has focused on pre-readers or beginning readers, or adults when examining stress sensitivity so there is limited literature on children in late primary school ages who should be skilled readers, thus the current study would add to the literature by examining somewhat older children further, who have not yet been studied extensively.

A more recent study by Fraser, Goswami and Conti-Ramsden (2010) demonstrated that sensitivity to rise time changes (non-speech rhythm) was significantly related to reading ability; this was shown in children aged 9 to 11 years (equivalent to children in the proposed Year groups for this study). They examined 64 children, of which 16 had developmental dyslexia (specific reading disability – SRD), 14 had specific language impairments (SLI), 21 had both, SRD and SLI, and 13 were age matched controls (CA). They were assessed on phonological skills (such as rhyme and phoneme awareness and phonological short-term memory – PSTM), auditory processing skills (rise time processing) and non-phonological language skills (vocabulary, sentence processing and grammatical morphology) to examine whether they displayed similarities in their development. It was found that the SLI children had difficulties with phonological and non-phonological skills but did not display as substantial impairments with auditory processing as the SRD children, who also had impairments with phonological awareness tasks. Overall, overlap between the SRD and SLI groups of children was found on all three assessed areas.

In terms of the relationship of the measured variables with reading and language skills, strong relationships between auditory processing and reading were found, but PA and PSTM were the only significant predictors of reading ($\beta = 0.624$, $p < .001$ and $\beta = 0.357$, $p = .004$, respectively). Vocabulary ($\beta = 0.410$, $p = .002$) and recalling sentences (β

= 0.392, *p* = .001) were the only significant predictors for language skills. These findings suggest that phonological awareness operates as a mediator for the found relationship of auditory processing and reading and that the relationships between PA, phonological short-term memory and grammatical morphology stem from associations with lexical memory. These findings are in line with previous studies which suggest that SRD and SLI children display similarities in terms of phonological skills but differences in terms of non-phonological language skills (e.g. Bishop and Snowling 2004). Additionally, it was suggested that basic auditory processing skills may be similar between SRD and SLI children (e.g. Corriveau, Pasquini and Goswami 2007) but could indicate differences in developmental paths when other factors such as language are considered (e.g. Muneaux *et al.* 2004; Surányi *et al.* 2009). This study utilised a non-speech rhythm measure, which was associated with reading skills but it was suggested that this relationship may be mediated by phonological awareness skills. No study to date has assessed the association of lexical stress sensitivity (speech rhythm) and reading skills in a sample of children aged between 9 and 11 years, therefore, in order to confidently theorise about the associations between speech rhythm sensitivity and reading, studies using speech-based stimuli are needed. This is especially important since Holliman *et al.* (2010a) observed that, although being related, non-speech and speech rhythm contribute independently to reading skills.

Although the children sampled for this current study did not have SLI or SRD as the children assessed by Fraser *et al.*'s (2010), it was important to review this study here, since not many researchers have examined children's rhythmic sensitivity within this age group before. In order to understand the association of stress sensitivity with reading (related) skills, two specific research questions were addressed by this study. The first one was concerned with differences in reading abilities and stress sensitivity:

1. Are better readers, aged 9 to 11 years, more sensitive to speech rhythm compared to poorer readers?

In the previous study no significant differences between poor, typical and advanced readers on the stress sensitivity task were found, but this may be due to somewhat limited reading skills overall in the younger sample. Thus it was predicted that those children who were better readers would show greater LJT scores than their less skilled counterparts in an older sample, since poorer readers may not have developed prosodic skills to a sufficiently high level to benefit the processing of written language. As was previously stated in the literature review (Chapter 1), children are sensitive to prosodic features in speech from a very young age (e.g. Jusczyk and Aslin 1995); however, their sensitivity to and comprehension of prosodic features in oral language continues to develop throughout childhood (e.g. Wells and Peppé 2003). It therefore may be that the extent to which sensitivity to speech rhythm aids reading skills also develops over time and becomes more refined or specific in older children; younger, early readers may demonstrate a greater need to rehearse this skill in order to use it to benefit from it with respect to their literacy skills.

The second research question was concerned with stress sensitivity's ability to predict reading skills, as has been found in the literature before (e.g. Richardson *et al.* 2004; Holliman *et al*. 2008):

2. Can stress sensitivity predict unique variance in reading (decoding, comprehension and fluency) after controlling for age, IQ and phonological processing skills?

It was predicted that stress sensitivity would be able to account for variance in reading skills, even after control variables were accounted for, since the use of more advanced strategies for reading may be needed in older children. Thus phonological awareness may not be as important in this slightly older sample, compared to younger children.

5.3 Method

This study examined primary school children in Years 5 and 6 on a range of literacy assessments. These assessments were presented to each individual child in one session in a randomised fashion (see Section 5.3.3). For recruitment details and ethical considerations see Chapter 2.4

To assess whether poorer readers also displayed lower LJT scores, the children were grouped into poor, typical and advanced readers, based on their standardised reading accuracy, reading rate and reading comprehension scores. These groups were created by categorising children with standardised scores of 84 or lower as *poor* readers, children with scores between 85 and 115 as *typical* readers, and children with scores of 116 and above as *advanced* readers. Differences were analysed using ANOVA.

To further investigate the relationships between literacy skills, cognitive ability, phonological skills and stress sensitivity, correlations were examined and followed by multiple regression analyses to assess further the unique variance that can be accounted to stress sensitivity for each of the three reading skills.

5.3.1 Participants

For this study 56 children were recruited from the same primary school as those children in the previous two studies. Thirty two children attended Year 5 and 24 children attended Year 6 during the time of the study. Of these children, 31 were female and 25 were male. The ages ranged from 117 to 142 months, with a mean age of 128.73 months (SD = 7.08).

All participants performed well (10 or more points) on the Lexical Judgement Task baseline condition (inclusion criteria). Analyses of normality indicated that the scores for all variables (apart from LJT baseline) were normally distributed. Due to only two participants scoring 10 points on the LJT baseline condition (and most children scoring 11 or 12), these two values appeared to be outliers. However, these scores were not excluded, since they were within the inclusion criteria, thus the sample size of 56 remained.

5.3.2 Test Battery

A detailed overview of the measures used can be found in Chapter 2.5.2.

The assessments were administered to each child individually, in one session. The order of assessments was not systematically randomised for each child, as the children were allowed to choose the order in which they wanted to do the tests in order to maintain rapport and the children's engagement with the assessment process; the assessments used are listed in Table 5.1. The test order was noted for each child however and a MANOVA showed that no significant order effects were present, $F(336, 104) = 1.024$, $p = .452$.

Table 5.1 Assessment battery used within this study

Assessments
1. Reading (decoding, comprehension and fluency)
2. Rapid automatised naming
3. Phonological Awareness
4. Stress sensitivity
5. Verbal and non-verbal IQ

5.3.3 General Procedure

After the study had been explained to each child verbally to ensure they knew what was expected from them, they were asked to sign a 'consent' (assent) form prior to any assessments being completed. The children were then assessed individually in one session, not lasting longer than 40 minutes.

5.4 Results

Initial data screening for normality was performed, to ensure the data did not include outliers and that the assumptions for later ANOVA analyses were met. No outliers were found therefore parametric analyses were conducted. The score ranges, mean scores and standard deviations for the assessed variables can be seen in Table 5.2. Raw scores were used for vocabulary, Spoonerisms and both Lexical Judgement Tasks, RAN times are in seconds and the IQ and reading measures are shown as standardised scores. The Cronbach's alpha coefficients are also shown (where applicable) in the table.

The standardised mean reading scores and IQ score were below the standardised mean (100) but within normal range. One reason for these lower performances can be (tentatively) accounted for by the socio-economic background of the children in this sample, who came from somewhat deprived families.

Table 5.2 Score ranges, mean scores (SD) and Cronbach's alpha for all assessments

Measures	Minimum	Maximum	Mean scores (SD)	α
Word reading	70	112	88.14 (10.59)	-
Fluency	70	130	93.09 (14.73)	-
Comprehension	70	121	94.54 (12.25)	-
Vocabulary (64)	20	49	32.09 (6.77)	.767
IQ	65	119	87.34 (11.99)	.871
Spoonerism (30)	3	28	18.05 (6.01)	.857
RAN times	40	132	71.61 (20.74)	-
LJT baseline (12)	10	12	11.86 (0.44)	.48 (match); .33 (no-match)
LJT experimental (12)	6	12	9.54 (1.63)	-.13 (match); .21 (no-match)

Note: Maximum scores for each measure, where applicable, are depicted in parentheses. Spoonerism = phonological awareness measure.

As can be seen in Table 5.2, the reliability coefficients for the Lexical Judgement Task are low. Therefore as an additional assessment the children's performance on this task was assessed in terms of chance level performance. Binomial tests showed that only three children scored less than 50% correctly on this task, indicating that the sample as a whole performed significantly ($p < .001$) above chance.

In order to assess the relationships between the measured skills, Pearson correlations were conducted. These can be seen in Table 5.3; standardised scores were used for the reading measures and the IQ variable, other variables used raw scores and RAN is based on reaction times (in seconds).

Table 5.3 Correlations between age, literacy-related skills, reading and stress sensitivity

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8**
1. Age								
2. Vocab	-.018							
3. IQ	-.281*	.730***						
4. PA	-.170	.520***	.479***					
5. RAN	-.311*	-.455***	-.392***	-.458***				
6. WR	-.211	.580***	.484***	.635***	-.534***			
7. RF	-.186	.674***	.568***	.580***	-.642***	.792***		
8. RC	-.371**	.670***	.618***	.502***	-.244	.551***	.629***	
9. LJT	-.085	.164	.174	.172	-.007	-.006	.100	.227

Note. Vocab = vocabulary; PA = phonological awareness; RAN = rapid automatised naming; WR = word reading; RF = reading fluency; RC = reading comprehension; LJT = stress sensitivity.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Phonological awareness correlated significantly with word reading ($r = .635$, $p < .001$), fluency ($r = .580$, $p < .001$) and reading comprehension ($r = .502$, $p < .001$). RAN also correlated with word reading ($r = -.534$, $p < .001$) and fluency ($r = -.642$, $p < .001$) but did not reach significance with comprehension, $r = -.244$, $p = .070$. Speech rhythm sensitivity however was not significantly associated with age or any of the measured skills; the correlation with reading comprehension was the closest to being significant, $r = .227$, $p = .093$. These non significant findings were against expectations; it appears that stress sensitivity in 9- to 11-year-olds is not an important reading-related skill. Due to these non significant findings no regression analyses were conducted and the second research question was not examined.

The relationship between poor and good readers and their performance on the LJT was examined next. Based on the children's word reading (WR), fluency (RF) and reading comprehension (RC) scores, they were grouped as poor, typical and advanced readers for each reading skill. The sample distribution can be seen in Table 5.4, including the grouping criteria based on standardised scores and the stress sensitivity mean scores obtained by each group.

Table 5.4 Poor, typical and advanced readers across reading skills and mean LJT scores

Ability Group	Word reading		Fluency		Comprehension	
	n	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)
Poor (< 85)	20	9.45 (0.366)	18	9.44 (1.916)	13	9.46 (1.808)
Typical (85 to 115)	36	9.58 (0.274)	35	9.543 (1.421)	40	9.40 (1.532)
Advanced (> 115)	-	-	3	10.00 (2.646)	3	11.67 (0.577)

Note: SD = standard deviation (shown in parentheses).

A slightly higher mean score is apparent in the advanced comprehension group compared to the other mean scores obtained. Thus, ANOVA analyses were conducted to examine whether significant differences between the observed scores existed. No significant differences were found between poor and typical readers (based on word reading) on their LJT performance, $F(1, 54) = .085$, $p = .772$. Neither were significant differences observed between reading fluency ability groups on LJT performance, $F(2, 53) = .146$, $p = .865$. However, a near significant difference was obtained between the reading comprehension groups' LJT performance, $F(2, 53) = 2.908$, $p = .063$. Since only three children were able to be classed as advanced comprehenders, this non significant finding may be due to the unequal and small sample size. Although overall no significant difference was obtained, it can be speculated that the more advanced a child is in their comprehension skill, the better their stress sensitivity is, or vice versa (but this claim needs to be viewed with caution, since the advanced group only consisted of three children).

5.5 Discussion

This study set out to investigate two research questions to further evaluate the relationship of speech rhythm to reading skills in intermediate readers.

This study found:

- No significant correlations between word reading, fluency and comprehension with stress sensitivity.

- No significant differences between poor, typical and advanced readers on word reading, fluency and reading comprehension skills, although reading comprehension ability groups' performance on LJT did approach significance.

The lack of significant correlations between stress sensitivity and reading skills was against expectations and is not in line with the literature. It could be hypothesised that stress sensitivity is not an essential, reading-related skill in children aged between 9 to 11 years. However such a strong claim would go against those studies which did find associations between speech rhythm and reading in children of similar ages (e.g. Fraser *et al.* 2010; Whalley and Hansen 2006). Perhaps the reasons for the non significant associations found in this study lie elsewhere.

The small sample size (N = 56) could have limited the ability to detect associations between reading skills and speech rhythm and the small group sizes across the reading comprehension and reading fluency ability groups could have also made it more difficult to detect significant differences. A marginally significant main effect was found when the reading comprehension ability groups were examined, therefore, in terms of comprehension skills it can be, tentatively, said that the obtained results are in line with previous findings (e.g. Goswami *et al.* 2002; Richardson *et al.* 2004); better comprehenders displayed greater stress sensitivity.

So far the assessments of children from different age groups on the (lexical) stress sensitivity measure have shown that not all children's stress sensitivity is equally related to reading skills (see Chapters 3 and 4). The children assessed in this study did not show significant relationships between stress sensitivity and any reading (related skills), whereas the children assessed in Studies 1 and 2 showed significant correlations between stress sensitivity and reading skills. The Study 2 children's LJT performance was also significantly associated with RAN, whereas the Study 1 children's stress sensitivity was correlated with all test variables. The main difference that can be observed between these samples is their age. The Study 1 sample assessed 5- to 9-year-old children, whereas Study 2 assessed 7- to 9- year-olds. Adding the present findings of 9- to 11-year-olds, an overall decrease of stress sensitivity's association with reading skills can be observed. The non significant associations between PA, RAN and vocabulary and stress sensitivity found in this study are not in line with current theory models (e.g. Wood *et al.* 2009; Zang and McBride-Chang 2010). It was proposed that speech rhythm sensitivity would be involved with reading skills via these skills, and finding no associations at all indicates that, at least in children aged between 9 and 11 years, stress sensitivity is no longer important (or linked to PA, RAN, vocabulary and reading skills). Therefore different models may need to be considered, which are developed specifically for word reading, reading comprehension and fluency skills as well as tailored more specifically for narrower age ranges.

When the Lexical Judgement Task was examined, it did not show very good reliability with this sample, which suggests that the measure may not be suitable for use with children of these ages however, and thus did not reveal significant associations with the reading measures. It may be that the children were trying to use explicit strategies to complete the task, which could have prevented their actual sensitivity being measured. That is, Karmiloff-Smith (1992) highlighted in her *representational redescription model* (RR model) how children develop from implicit to explicit knowledge, which could demonstrate itself in a reduction of performance (a u-shaped pattern of development). Success on a task without insight or knowledge regarding how the child answered the question or made the decision about their answer is seen as indicative of implicit knowledge, whereas explicit knowledge can initially be demonstrated though over-application of rules and theories, which results in errors (thus poorer performance). Following this, the child transitions into full explicit awareness, that could be demonstrated by the child through verbalisation of their strategies used to form their decision or answers. The sample's overall mean performance on the LJT was significantly above chance so it can be said that the children were not guessing the answers. It cannot be ascertained however whether this above chance performance was also indicative of the children using explicit (speech rhythm) strategies; this would require further testing whilst at the same time collecting data on the children's verbal self-reports of how they were completing the task.

Another tentative reason for the non significant associations could also be due to the children relying more on skills other than on stress sensitivity; morphological awareness may be a more vital skill for children in the higher primary grades, which has been shown to be closely associated with children's reading (Clin *et al.* 2009). The written materials that children are exposed to in Years 5 and 6 are more complex and syntactically varied and may therefore require different knowledge and skills, which are not directly provided by speech rhythm sensitivity.

At this point it is difficult to conclude which of these suggestions may the “right one” and it seems important to conduct further assessments first. A longitudinal study is proposed to assess whether the lack of association between speech rhythm and reading skills observed here would persist when the children are re-tested. Miller and Schwanenflugel (2008) have suggested that prosodic skills need to be assessed over time, and may not show effects when measured concurrently. Therefore a specific conclusion about the relationship between speech rhythm and reading skills in this sample cannot be made at this point in the thesis.

5.6 Conclusion

No apparent relationships between speech rhythm and reading skills were found in this study. The reasons for this are unclear at present and will be examined more closely after conducting a longitudinal study. The longitudinal assessment will also include the children from the previous study in order to compare a larger group of children. Prior to presenting the longitudinal study however it is of interest to present a study conducted with 4- to 7-year-old children, which was carried out to further examine stress sensitivity’s association with literacy skills in a younger sample.

Chapter 6 – Study 4

Speech rhythm sensitivity's link with early reading and phonological processing skills in 4- to 7-year-olds

6.1 Overview

Four- to seven-year-old children were examined on a range of literacy and literacy-related measures, as well as assessed on their stress sensitivity using the Lexical Judgement Task. It was found that stress sensitivity showed associations with all examined measures, but significant relationships only remained between stress sensitivity and nonword reading skills after age and vocabulary were controlled. No differences between pre-readers' and beginning readers' stress sensitivity in relation to reading skills were found. Overall, the findings further add support to the theoretical models implicating stress sensitivity as an important aspect of reading attainment but further examinations are required to disentangle the age-related trajectory of stress sensitivity's development.

6.2 Introduction

Several research studies have been conducted with children in the early primary years and overall it has been found that young, early readers display sensitivity to stress and that this sensitivity is related to emergent written language skills. Wood (2006b) for example, assessed 4- to 7-year-old children in a cross-sectional study and found that, although no age group differences were obtained in their first experiment, overall the 4- to 5-year-olds performed significantly worse on a stress manipulation condition of the mispronunciations task used, compared to conditions in which vowel identity was manipulated. The nature of the changes in the words appeared to be crucial, not merely the number of changes that were introduced in the stimuli. As a result another study was conducted to assess the stress manipulation condition. For this, 5- to 7-year-old children were assessed, which showed that the 7-year-old children were significantly better at completing the mispronunciations task compared to the 5-year-olds. Reading, spelling, rhyme detection, nonword reading and letter-sound knowledge were all found to be predicted by stress sensitivity, and the unique contribution of stress sensitivity remained significant for spelling and rhyme detection after age was taken into account. In this study stress sensitivity appeared to be the strongest predictor of spelling ability, as this was also predictable by stress sensitivity after vocabulary and phonological awareness were controlled. These findings possibly indicate that early rhyme awareness and spelling skills are boosted by stress sensitivity, which later on may enhance reading skills. Although there was room for improvement on the stress manipulation task, it was concluded that maturation appears to play less of a role in this skill's development.

Holliman *et al.* (2008) also assessed 5- and 6-year-old children, using the revised mispronunciations task and found significant relationships between stress sensitivity and word reading, nonword reading, vocabulary knowledge, and age as well as with rhyme and phoneme awareness. After controlling for age, vocabulary and phonological awareness, stress sensitivity was still able to account for unique variance in reading attainment. Although phonological awareness and stress sensitivity were associated, both still contributed independently to reading skills. This study therefore supported but also extended Wood's (2006b) findings and provided support for a direct contribution of stress sensitivity to reading in this age group, independently from PA.

These studies used speech-based stimuli within their speech rhythm assessments and provided interesting results linking suprasegmental phonological sensitivity to segmental phonology and early reading skills. In a study using non-speech stimuli

Corriveau, Goswami and Thomson (2010) also found relationship between rise time sensitivity and phonological awareness. Their findings across 3-,4-, 5- and 6-year-olds indicated that phonological awareness and letter-sound knowledge increased across these age groups and that rise time sensitivity was also significantly greater in the 5- and 6- year-olds compared to the two younger age groups. Correlations revealed significant associations between rise time and phonological awareness skills and with letter-sound knowledge across groups. However, after age was controlled rise time was no longer significantly correlated with syllable segmentation skills and letter-sound knowledge. Regression analyses revealed that rise time was a significant unique predictor of rhyme awareness, alliteration and sound isolation skills, after age and nonverbal IQ (and intensity and frequency discrimination skills) were taken into account. This cross-sectional study supported the hypothesis that auditory processing skills are implicated in early pre-reading skills. In a further, small-scale longitudinal analysis they also found that children's phonological awareness skills (except alliteration skills) increased over time (between ages 4;5. and 5;5) as well as their rise time sensitivity and frequency discrimination skills. The strongest association was found between rhyme awareness and rise time sensitivity, which could predict rhyme awareness over time, after IQ was controlled. Adding to Holliman *et al.*'s (2008) and Wood's (2006) findings, this study further highlighted that early pre-reading skills also showed associations with auditory processing skills, which were able to predict phonological awareness. This study further offered support for the theoretical viewpoint that sensitivity to rhythm is implicated in reading skill development, however not directly, but through its contribution to phonological awareness, and especially rhyme awareness. Although associations between non-speech rhythm and early phonological awareness were demonstrated in this study, it is difficult to make inferences about the relationship between *speech rhythm* sensitivity and phonological awareness based on these findings. However, they are informative in that they indicate that some auditory processing abilities are associated with early reading-related skills, and rise time is hypothesised to underpin skills such as speech rhythm sensitivity.

Another study that assessed young children (mean age 5;7 years) was conducted by Goodman *et al.* (2010), which further showed that stress sensitivity (using an adapted version of Wood's, 2006b, mispronunciations task) was strongly associated with PA and early reading skills. They also assessed children's ability to identify compound nouns (Wells and Peppé 2003), which did not contribute significantly to reading but was associated with phoneme deletion however. Overall, stress sensitivity (on the lexical level, as measured with the mispronunciations task) may enable children to pay attention to stressed syllables within words, which then further enhances phoneme identification in those stressed syllables and subsequently aids reading development indirectly. This was further supported by Goodman *et al.*'s findings that stress sensitivity was not able to contribute to reading after IQ and PA were controlled.

These studies highlight the potential involvement of stress sensitivity in early reading development, which was mostly found to occur via phonological awareness development. Although similar findings were obtained across these studies when different rhythmic sensitivity measures were used, it is difficult to integrate these findings into theoretical models because of the very different assessments used. That is, the findings could be artefacts of the assessments used and creating models based on these observations could introduce misinterpretations of the relationships. Therefore it is important to validate the observed associations with a single stress sensitivity measure which is not affected by some of the assessment issued highlighted in Chapter 2 with respect to the existing measures; namely the Lexical Judgement Task. This would enable a better understanding whether stress sensitivity contributes to reading skills independently or via PA. This further allows for the assessment of the tasks' functionality with a younger population. It would also be interesting to assess whether differences are evident between pre-readers' stress sensitivity compared to children who are early readers as it may be the case that stress sensitivity initially aids phonological skills in pre-readers but then supports reading directly once the children have acquired early reading skills. Therefore this study set out to investigate the following research questions:

1. Is stress sensitivity, as assessed by the LJT, associated with early word reading and literacy related skills in 4- to 7-year-olds?
2. Can performance on the LJT predict reading or phonological processing skills in this young sample?
3. Does performance on the LJT show different relations with literacy skills in pre-readers compared to beginning readers?

Based on the research evidence presented so far it was predicted that a link between reading, phonological skills and stress sensitivity would be found in this sample and that stress sensitivity would also be able to account for unique variance in reading skills. Since the literature is somewhat divided about whether stress sensitivity can contribute directly to reading (Holliman *et al.* 2008) or enhances reading skills via phonological awareness skills (Corriveau *et al.* 2010; Goodman *et al*. 2010), it was important to assess this further. This may also depend on the phonological awareness measures used, and closer associations with rhyme awareness may be found rather than with phoneme awareness (Wood 2006b), therefore both these phonological awareness tasks were included in this study.

6.3 Method

It was of interest to investigate whether stress sensitivity showed associations with reading measures and literacy-related skills in this sample, which was analysed with zero-order and partial correlations. Additionally, to assess the unique contribution of stress sensitivity to literacy skills several multiple hierarchical regression analyses were conducted. Lastly, in order to determine a child's reading skill level, the single word reading test was used (BAS II) as a grouping criterion. Successful reading of two or more words was used to indicate that children had acquired some early reading skills and those children who failed to read any words accurately (or only read one correctly) were therefore classified as pre-readers. To evaluate potential differences in the relationship between pre-readers' and early (beginning) readers' stress sensitivity with reading related skills, partial correlations were computed. An ANOVA was also carried out to determine whether the groups differed in their stress sensitivity.

6.3.1 Participants

Reception, Year 1 and Year 2 children from a primary school in the West Midlands took part in this study and were assessed individually in a semi-quiet area of the school. The children's parents were informed about the study via an information letter distributed by the class teachers and asked to opt-out if they did not want their child to be approached for recruitment. No parent withdrew their consent, and all children in Reception class, Year 1 and Year 2 classes were asked to participate.

In total, 132 children were assessed; if any child appeared very nervous, uncomfortable or easily distracted at the start of the assessment he or she was reminded that they did not have to complete the tests and could return to class if they wanted. Five children declined to participate at the start of the study and five other children completed a few assessments before withdrawing. All other children were happy to complete the entire test battery. However, the Lexical Judgement Task baseline condition was again used as an inclusion criterion; only children who obtained 10 or more correct answers on this task were included in the subsequent analyses.

Exclusion due to incomplete assessments and low LJT scores resulted in a final sample of 112 children (comprising 62 boys and 50 girls). Testing procedures and analyses are based on this final sample. Thirty two of these children attended reception class (mean age 58 months, SD = 3.48), forty-four were in Year 1 (mean age 69 months, SD = 3.74) and the remaining 36 children attended Year 2 at the time of the study (mean age 80 months, SD = 3.91). Overall, the age of the participants ranged from 53 to 88 months, with a mean age of 69 months (SD = 9.57).

Some children were unable to complete the rapid object or rapid colour naming tasks (or both) and therefore no total RAN times were calculated for those children and these participants' scores were marked as missing values. This resulted in the RAN times mean scores being based on n = 104.

6.3.2 Test Battery

All the children were assessed on the stress sensitivity measure used in the previous studies, the Lexical Judgment Task. They were also asked to read as many words as they could from the British Ability Scales (BAS II) word list and from the PhAB nonword lists. To assess phonological awareness the children completed the Rhyme and Alliteration subtests from the PhAB. The CTOPP rapid automatised naming colour and object subtests were administered to test the children's phonological processing speed and the British

Vocabulary Picture Scales (BPVS III) measure was administered to assess the children's receptive vocabulary skills. A detailed overview of these assessments can be found in Chapter 2.5.3. All children were tested on the Lexical Judgement Task first, and then given the choice which other "game" they wanted to play next. This was done in order to engage the children more during the assessments; the order of assessments was noted. All children completed the whole test battery in one session, not lasting longer than 30 minutes. To check for order effects MANOVA was conducted and revealed no significant effect, F (202, 4) = 0.526, p = .888, so it can be concluded that although no systematic randomisation (or counterbalancing) was employed, no test order effects were apparent.

6.3.3 Procedure

Each child was asked individually whether they wanted to take part in this study and were informed that they would be playing some word games and asked to read but that they did not have to do the tests if they did not want to. The first assessment was the Lexical Judgment Baseline Task, which was used as an inclusion criterion. Due to the young age of most children, special attention was given to the children's ability to make "same-different" judgements. The children were asked whether they knew what *similar*, *same* and *different* meant, and were given some examples ("When I say *blue and blue*, does that sound the same or different" vs. "When I say *chair and table*, does that sound the same or different?" As well as an example with sounds, "When I make these sounds, do they sound the same or different?", e.g. *beep-beep* vs. *beep-beep-beep*. Following this, the practice LJT baseline items were completed to familiarise the children with the corresponding buttons on the laptop; the children were also asked whether they wanted to press the buttons or whether they wanted the experimenter to press them for them after they gave a verbal response. All children decided to respond themselves and did not seem to have issues with that.

Following the LJT baseline task the children completed the LJT experimental version and all the other assessments in a random fashion, as the children decided which "game" they wanted to complete next.

6.4 Results

Prior to any analyses the data were checked for normality; one child had obtained a very high vocabulary raw score (131) which was further than 3 SD from the mean and therefore that participant's raw and standardised vocabulary scores were marked as missing values and excluded from the analyses. No other outliers were found.

Table 6.1 shows the distribution of the scores obtained on all assessments (including maximum possible scores), means and standard deviations. Due to the young age of some participants (less than 5-years-old) standardisation of the word reading scores was not possible for 22 of the participants; therefore the raw scores were used for word reading in subsequent analyses to include all participants. The Lexical Judgement Task baseline condition had been used as an inclusion criterion measure, therefore all children included in this sample scored 10 or more on this task (mean 11.705, SD = .595).

The word reading standardised scores (mean 101.69) indicated average (100) performance across the whole sample, whereas the vocabulary scores were marginally lower (mean 90.58) than the standardised mean.

Table 6.1 Score ranges, mean scores and Cronbach's alpha for all assessments

	Score Ranges		Mean	SD	α
	Min	Max			
BAS[a] / 90	0	76	16.77	12.93	.98
BAS[b]	71	145	101.69	15.63	-
N-word[a] / 20	0	20	6.64	5.51	.94
RAN[c]	109	416	216.72	71.32	-
Rhyme[a] / 21	0	19	6.15	5.06	.91
Alliteration[a] / 10	0	10	4.29	3.59	.91
Vocab[a] / 168	29	106	72.47	15.05	.95
Vocab[b]	70	117	90.58	10.25	-
LJT[a] / 12	2	12	6.786	1.768	.62 (match) .66 (no match)

Note. BAS = word reading; N-word = nonword reading; RAN = rapid automatised naming; Rhyme = rhyme awareness task; Alliteration = phoneme awareness task; Vocab = receptive vocabulary measure; LJT = stress sensitivity measure.
[a]raw scores; [b]standardised scores; [c] reaction times in seconds.

Stress sensitivity's association with early word reading and literacy related skills

In order to investigate the first research question, initially zero order correlations were conducted to assess the associations between speech rhythm sensitivity and the variables of interest. The correlation matrix can be seen in Table 6.2. The analysis was based on the variables' raw scores; RAN was measured in reaction times in seconds.

Table 6.2 Correlation matrix between age, literacy skills and speech rhythm sensitivity

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**
1. Age							
2. Vocab	.567***						
3. BAS	.645***	.422***					
4. N-Word	.623***	.426***	.896***				
5. Rhyme	.509***	.452***	.626***	.614***			
6. Alliteration	.628***	.519***	.711***	.733***	.614***		
7. RAN	-.493***	-.357***	-.493***	-.494***	-.491***	-.560***	
8. LJT	.264**	.209*	.267**	.327***	.304**	.272**	-.262**
	.005	.028	.004	.000	.001	.004	.007

Note. Vocab = vocabulary measure; BAS = word reading; N-word = nonword reading; Rhyme = rhyme awareness; Alliteration = phoneme awareness; RAN = rapid automatised naming; LJT = stress sensitivity measure (showing exact significance levels).
* p <.05, ** p <.01, *** p < .001.

Across the whole sample it can be seen that all variables showed significant relationships with one another. Since age and vocabulary were also strongly correlated with all measures and to further assess the relationship that stress sensitivity in particular has with the reading and literacy related skills, partial correlations were conducted, controlling for age and controlling for age and vocabulary; these can be seen in Table 6.3.

When age was partialled out stress sensitivity showed a significant association with nonword reading (*pr* = .217, *p* = .029) and a marginally reliable association with rhyme awareness (*pr* = 182, *p* = .068).

Table 6.3 Partial correlation matrix between all variables, controlling for age and for age and vocabulary

	1.	2.	3.	4.	5.	6.	7.
1. Vocab	-						
2. BAS	.041	-	.805***	.497***	.593***	-.307**	.121
3. N-Word	.052	.806***	-	.462***	.609***	-.283**	.214*
4. Rhyme	.237*	.492***	.461***	-	.400***	-.328**	.172
5. Alliteration	.261**	.583***	.601***	.437***	-	-.382***	.129
6. RAN	-.099	-.309**	-.287**	-.340**	-.392***	-	-.154
7. LJT	.061	.123	.217*	.182†	.137	-.159	-

Note. Correlations controlling for age and vocabulary are shown above the diagonal; correlations controlling for age only are depicted below the diagonal. Vocab = vocabulary measure; BAS = word reading; N-word = nonword reading; Rhyme = rhyme awareness; Alliteration = phoneme awareness; RAN = rapid automatised naming; LJT = stress sensitivity measure (showing exact significance levels).
* *p* <.05, ** *p* <.01, *** *p* < .001, † *p* = .068.

Vocabulary knowledge was only significantly correlated with rhyme awareness (*pr* = .237, *p* = .017) and phoneme awareness (*pr* = .261, *p* = .008) and the phonological awareness skills as well as RAN still showed significant associations with word and nonword reading. When age as well as vocabulary were controlled the significant correlation between stress sensitivity and nonword reading remained (*pr* = .214, *p* = .031).

As age appears to be mediating the previously observed relationships between stress sensitivity and the reading and phonological awareness skills, apart from the association with nonword reading, it was of interest to assess whether the correlation between stress sensitivity and nonword reading would remain significant after phonological awareness skills were also controlled. Given that nonword reading skills demonstrate the ability to decode letter strings through direct grapheme-phoneme conversions, another partial correlation matrix was created, controlling for age and rhyme awareness as well as for age and phoneme awareness, to assess whether PA skills also play a role in the observed association between stress sensitivity and nonword reading. These partial correlations are depicted in Table 6.4.

Bearing in mind that stress sensitivity was significantly correlated with both phonological awareness measures and with word reading and nonword reading skills (as well as with RAN and vocabulary), the partial correlations show that these relationships diminish once age and either PA measure are controlled for.

The found association between stress sensitivity and nonword reading after age alone was controlled (and also after age and vocabulary were controlled) also disappeared once phonological awareness measures were controlled. These findings indicate that the observed link between nonword reading and stress sensitivity is mediated by aspects of age and phonological awareness.

Table 6.4 Partial correlations between reading, literacy related variables and LJT

	1.	**2.**	**3.**	**4.**	**5.**	**6.**
1. Vocabulary	-	-.089	-.067	.180	-.020	.019
		.375	.509	.071	.840	.854
2. Word reading	-.142	-	.749***	.470***	-.173	.040
	.157		.000	.000	.083	.695
3. Nonword reading	-.136	.701***	-	.500***	-.155	.153
	.175	.000		.000	.121	.127
4. Rhyme / Alliteration	.141	.324**	.275**	-	-.288**	.066
	.159	.001	.005		.003	.515
5. RAN	.004	-.108	-.069	-.204*	-	-.105
	.972	.284	.493	.040		.296
6. LJT	.026	.053	.170	.136	-.115	-

Note. Vocabulary = BPVS III; Word reading = BAS.
* p <.05, ** p <.01, *** p < .001

Interestingly, the association between stress sensitivity and either PA measure were also non significant once age was controlled. Given that a large age range was included in this sample it appears that individual age (or Year) groups should be assessed for their stress sensitivity and literacy skills to directly compare the impact that age (or maturation) has on the development of stress sensitivity and its relationship with phonological awareness and reading skills.

These correlational analyses indicated relationships between stress sensitivity, phonological processing skills and reading skills, which were not surprising based on the literature to date. However, these relationships need to be investigated further as they appear to be due to maturation effects and mediated by phonological awareness skills.

Predicting reading and phonological processing skills in young children

It was of interest to assess whether stress sensitivity could account for unique variance in word reading, nonword reading and/or phonological processing skills after age and the stated literacy related skills have been controlled for. Therefore, several multiple regression analyses were conducted to answer this second research question. The data were checked whether they met the assumptions for regression analyses. This was found to be satisfactory.

The first sets of regressions investigated the unique contribution of stress sensitivity to word reading. On its own stress sensitivity contributed 7.1% of unique variance to word reading, ΔF (1, 110) = 8.466, p = .004, β = .267; however, stress sensitivity's contribution was non significant (p = .168) once age was accounted for in Step 1 (ΔF (1, 110) = 78.326, p < .001, ΔR^2 = .416). Since age was strongly implicated in the relationship between stress sensitivity and reading, no further regressions were conducted controlling for age and other variables.

Next, nonword reading was assessed as the outcome variable. Stress sensitivity was able to contribute 10.7% of unique variance to this skill, ΔF (1, 110) = 13.162, $p < .001$. Since the partial correlation indicated a significant association between LJT and nonword reading after age was controlled it was expected that stress sensitivity would also be able to account for unique variance in nonword reading after age was taken in to account, this was indeed found. LJT added additional 2.8% of variance to nonword reading skills (ΔF (1, 109) = 5.303, $p = .023$) after age was controlled (ΔF (1, 110) = 69.750, $p < .001$, ΔR^2 = .388). Following this, age was controlled in the first Step and vocabulary in the second to assess whether stress sensitivity could still account for variance in nonword reading. It was found that vocabulary did not explain significant variance in nonword reading ($p = .119$) but stress sensitivity still accounted for 2.7% (β = .196, $p = .031$). Since vocabulary did not contribute to nonword reading it was not included as a control variable in the subsequent analyses. Table 6.5 shows the percentage of variance in nonword reading accounted by stress sensitivity after age and either reading, RAN, rhyme awareness or phoneme awareness were controlled.

Table 6.5 Predicting nonword reading

Variable	β	ΔR^2
1. Age	.623***	.388***
2. Reading	.846***	.418***
3. LJT	.088*	.007*
2. Rhyme	.400***	.119***
3. LJT	.106	.010
2. Alliteration	.564***	.193***
3. LJT	.113	.012
1. Age	.664***	.441***
2. RAN	-.219**	.036**
3. LJT	.142	.018

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

Stress sensitivity was able to contribute 0.7% of significant unique variance to nonword reading after age and word reading skills ($p < .001$) were controlled. It was not able to account for significant variance in nonword reading after rhyme or alliterations were controlled ($p = .137$ and $p = .083$ respectively) and was marginally non significant after age and RAN were accounted for ($p = .061$). Although stress sensitivity's contribution to reading (BAS) was not significant after age was controlled, it is conceivable that its small contribution to nonword reading (after age and vocabulary were controlled) subsequently also contributes to decoding skills of real words, but that this contribution was via phonological processing skills.

Next, stress sensitivity's contribution to phonological processing speed was assessed. This showed that individually, LJT could account for 6.9% of unique variance in this skill, ΔF (1, 102) = 7.523, $p = .007$. After age was controlled in the first Step (which accounted for 24.3% percent, ΔF (1, 102) = 32.810, $p < .001$, LJT did not add significant variance to the model, $p = .122$. No other regressions were conducted for phonological processing speed.

Another important aspect to consider is the role that stress sensitivity plays in rhyme and phoneme awareness. For this, separate multiple regressions were conducted again, first for phoneme awareness. Similarly as was found for RAN and word reading, LJT was able to contribute significant variance when entered alone (ΔF (1, 110) = 8.785, $p = .004$, $\Delta R^2 = .074$) but not after age was controlled ($p = .139$), which was significant (ΔF (1, 110) = 71.711, $p < .001$, $\Delta R^2 = .395$). When rhyme awareness was the outcome variable stress sensitivity accounted for 9.2% of unique variance when entered alone (ΔF (1, 110) = 11.184, $p < .001$) and also predicted 3.1% of variance ($\beta = .182$, $p = .032$) after it was entered into the model preceded by age, which also accounted for 25.9% ($\beta = .509$, $p < .001$). These findings indicate that maturation plays a part in stress sensitivity's relationship with phoneme awareness but not with rhyme awareness (or with nonword reading as was shown in the earlier analyses).

When age and vocabulary were entered as the first two predictors of rhyme awareness stress sensitivity still accounted for 2.6% of variance, p = .047. Table 6.6 depicts the beta values and R^2 change for the regression analyses controlling for age and vocabulary in the first two steps followed by reading, nonword reading, phoneme awareness or RAN prior to entering stress sensitivity. The findings indicated that stress sensitivity could predict rhyme awareness independently from age and vocabulary but not once nonword reading or reading skills, phoneme awareness or RAN were also accounted for. In sum, these results further support the notion that stress sensitivity plays a role in literacy attainment. However, once age was controlled it could not account for significant unique variance in word reading, RAN or phoneme awareness, thus indicating that maturation is implicated in stress sensitivity's association with these skills.

Table 6.6 Multiple regression analyses predicting rhyme awareness

Steps and Independent Variables	β	ΔR^2
1. Age	.496***	.246***
2. Vocabulary	.252*	.043*
3. LJT	.167*	.026*
3. Word reading	.484***	.140***
4. LJT	.120	.013
3. Nonword reading	.452***	.127***
4. LJT	.094	.008
3. Alliteration	.445***	.114***
4. LJT	.125	.014
1. Age	.491***	.241***
2. Vocabulary	.248*	.043*
3. RAN	-.325**	.077**
4. LJT	.110	.011

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

Nevertheless, for nonword reading and rhyme awareness LJT could add unique variance over and above age and vocabulary and it also predicted some variance in nonword reading after age and word reading were accounted for. These findings will be examined further in the discussion.

Since the current sample comprised children who were beginning readers as well as children who were not able to read and were therefore classed as pre-readers, it may well be the case that the relationship between stress sensitivity and literacy skills differs between these two groups of children. The next analyses aimed to investigate this further.

Stress sensitivity's relation with literacy skills in pre-readers and beginning readers

In order to answer this third research question, all children were grouped as either pre-readers or beginners. This was done on the basis of the BAS II word reading scores. Children who scored zero or one (were able to read none or one word correctly) on the BAS II reading test were classed as pre-readers. Whereas all children who scored more than two correct were grouped as beginning readers. This categorisation resulted in 23 children being in the *pre-reader group* and 89 children comprising the *beginner group*. Descriptives for each group can be seen in Table 6.7.

Since the groups vary in size, independent t-tests were conducted to assess whether the participants differed significantly on age and vocabulary knowledge (using raw scores).

Table 6.7 Descriptive statistics across pre-readers and beginners groups

		Minimum	Maximum	Mean (SD)
Age	Pre-readers (*n* 23)	53.00	74.00	59.96 (5.82)
	Beginners (*n* 89)	55.00	88.00	72.04 (8.76)
Vocabulary	Pre-readers (*n* 23)	29.00	83.00	57.35 (15.15)
	Beginners (*n* 88)	45.00	106.00	76.42 (12.34)
BAS	Pre-readers (*n* 23)	.00	1.00	.26 (.45)
	Beginners (*n* 89)	2.00	76.00	21.03 (17.77)
Nonword	Pre-readers (*n* 23)	.00	5.00	.48 (1.34)
	Beginners(*n* 89)	.00	20.00	8.24 (5.03)
RAN	Pre-readers (*n* 20)	158.00	416.00	265.70 (65.06)
	Beginners (*n* 84)	109.00	372.00	205.06 (68.03)
Rhyme	Pre-readers (*n* 23)	.00	7.00	2.13 (2.65)
	Beginners (*n* 89)	.00	19.00	7.19 (5.02)
Alliteration	Pre-readers (*n* 23)	.00	4.00	.87 (1.09)
	Beginners (*n* 89)	.00	10.00	5.17 (3.49)
LJT	Pre-readers (*n* 23)	2.00	8.00	6.00 (1.62)
	Beginners (*n* 89)	2.00	12.00	6.99 (1.75)

The analysis showed that *Levene's equality of variance* was not met for the age analysis (F = 6.90, p = .010) and therefore the statistics are reported based on unequal variances, t(50.924) = - 7.193, p < .001, which indicated that the two groups did differ significantly on age. When the groups' vocabulary scores were compared, *Levene's test* was non significant (F = 2.367, p = .127) and the t-test showed that the groups also did differ significantly on their vocabulary knowledge, t(109) = - 6.287, p < .001. Subsequent analyses therefore controlled for age and vocabulary to minimise the impact the observed differences may have.

To assess whether stress sensitivity was associated differently with reading (related) skills across the two groups, partial correlations were conducted between all variables of interest. These can be seen in Table 6.8.

Table 6.8 Partial correlations between stress sensitivity, reading and reading related skills across pre-readers and beginning readers groups, controlling for age and vocabulary

	1.	2.	3.	4.	5.	6.
1. BAS	-	-	-	-	-	-
2. N-Word	.806***	-	.265	.526*	.277	.180
3. Rhyme	.502***	.465***	-	.459	-.155	.126
4. Alliteration	.563***	.572***	.379***	-	-.208	.218
5. RAN	-.351**	-.338**	-.349**	-.416***		.004
6. LJT	.105	.205	.166	.097	-.181	-

Note. Correlations controlling for age and vocabulary for the pre-readers are depicted above the diagonal, and correlations for the beginning readers are depicted below the diagonal. BAS (word reading) correlations were not computed with the pre-readers.
* p <.05, ** p <.01, *** p < .001.

Examining the pre-readers' correlations with stress sensitivity it was found that LJT performance did not correlate significantly with any reading or reading-related skills. Similarly, in the beginning readers group, no significant correlations were found, although the correlation between nonword reading and stress sensitivity was approaching significance (pr = .205, p = .067). Due to the small sample size in the pre-reader group these findings have to be viewed with caution, however it appears that stress sensitivity's association with early (pre-) reading skills is mediated by age and vocabulary knowledge; at least in this sample.

Lastly, it was assessed whether the groups differed on their LJT performance and whether the groups performed significantly above chance, as an additional check for the task's suitability to be used with young children. An ANOVA was conducted to assess the group differences on the LJT performance. Homogeneity of variance was met (p = .322) and the analysis showed that the groups did differ significantly (F = 5.974, p = .016, ω^2 = .043), with the pre-readers scoring 6 on average (SD = 1.62) and the beginning readers scoring 6.99 on average (SD = 1.75). However, this significant finding may be an artefact due to the different sample sizes. Additionally, binomial tests indicated that neither group performed significantly above chance on the stress sensitivity task (see Table 6.9).

Table 6.9 Pre-readers and beginners chance level performance on LJT

Group	Scores	*n*	Observed proportion	Sig.
Pre-readers	<= 6	14	.61	.405
	> 6	9	.39	
Beginning readers	<= 6	41	.46	.525
	> 6	48	.54	

Note: Sig. = significance level, * p <.05, ** p <.01, *** p < .001.

This overall chance performance on the stress sensitivity measure potentially indicated that the children were guessing and did not understand the task or that their lack of stress sensitivity did not enable them to perform better on this measure. Overall, when the whole sample was assessed it was found that 67% of the children (n = 75) performed at chance level on this task, whereas only 37 children performed above chance (mean 8.76, SD = 0.98).

6.5 Discussion

This study set out to investigate the relationship of stress sensitivity to reading and literacy related skills in 4- to 7-year-old children and whether stress sensitivity could also account for unique variance in these skills. Pearson correlations showed that stress sensitivity was significantly associated with reading and phonological processing skills, which is in line with the literature (e.g. Goswami *et al*. 2002; Holliman *et al.* 2008; Wood 2006). Partial correlation analyses indicated however that the observed relationships may be mediated by age. Once age was controlled, stress sensitivity only remained significantly associated with nonword reading skills; this association also remained once age and vocabulary skills were controlled. Regression analyses further showed that LJT was able to predict unique variance in nonword reading after age and vocabulary were controlled, but not after other predictors were also included in the analyses. Further regression analyses indicated that stress sensitivity was not able to account for unique variance in word reading, phoneme awareness or RAN when age was accounted for, indicating that maturation plays a key part in the development of these skills. However, stress sensitivity was directly associated with rhyme awareness (and nonword reading), independently from age and vocabulary knowledge. These findings highlight the need to assess groups of children across various ages to further examine how stress sensitivity is linked to these reading (related) skills.

When phoneme awareness was assessed as the outcome variable, LJT was not able to add unique variance once age was controlled. This may appear contradictory, since the awareness of sounds is implicated in the ability to map phonemes to graphemes in nonword reading. Nevertheless, stress sensitivity is an underlying, implicit ability, whereas phoneme awareness is an indication of conscious, explicit, knowledge of phonemes. Therefore different cognitive processes are underlying the ability to successfully complete either task and may thus contribute to nonword reading (and subsequently to decoding skills) in different ways. When rhyme awareness was assessed as the outcome variable, stress sensitivity was also able to account for unique variance after age and vocabulary were controlled. This further indicates that stress sensitivity may aid rhyme awareness (e.g. Goswami 2003; Wood *et al*. 2009), which in turn facilitates word reading skills and offers support for Wood *et al.*'s (2009) as well as Zang and McBride's (2010) phonological awareness pathways in their proposed models.

In terms of different associations of stress sensitivity with pre-readers and beginning readers it can be said that stress sensitivity does not appear to be associated differently with literacy skills across the two reading groups. In fact, no significant correlations were found with reading skills or phonological processing skills in either group once age and vocabulary were controlled. When the sample was assessed as one however, significant correlations with nonword reading were still obtained. It could be argued that, since stress sensitivity is an implicit and subconscious skill, which is moderated by age, larger samples are required to detect the underlying relationships that stress sensitivity has with reading skills. Therefore, assessing two reading groups that differ in size and are somewhat small may reduce statistical power and therefore these findings need to be viewed and interpreted with caution. However, since no associations between stress sensitivity, reading and phonological processing skills were found once age and vocabulary were controlled it could be argued that these findings support the vocabulary pathway proposed by Wood *et al.*, which highlighted the importance of speech rhythm in facilitating vocabulary knowledge, which then aids reading skills.

Additionally, due to the samples' young age it is arguable that the children found the stress sensitivity task too demanding or were unsure of what was asked from them. The performance across both reading groups was statistically not above chance, which would support this view. Alternatively, the chance level performance may indicate that the children simply did not have adequate stress sensitivity. However, when the reading groups' score ranges on the LJT were examined it was found that the beginning readers displayed higher scores compared to the pre-readers, which may be indicative of greater sensitivity to stress in those children with higher reading abilities. This however requires further examination. As was proposed earlier, an analysis examining children from different age (or Year) groups is needed to assess their varying stress sensitivity levels in line with their (increasing) reading skills and literacy-related skills to systematically assess their cross-sectional, age related trajectory of stress sensitivity. In conclusion, it appears that the LJT may not be suitable for the use with children as young as those assessed in this study, however the proposed age-specific analyses would further indicate whether the observed chance level performance on this task was perhaps due to children of a specific age. This would provide additional information with regards to the suitability of the LJT with certain age groups.

6.6 Conclusion

This study offered some additional support for stress sensitivity's involvement in reading attainment in young children, and the findings suggested that this relationship is not a direct one, but rather moderated by age and phonological awareness skills. It could be argued that the LJT is not suitable for the use with young children, since overall chance level performance was observed. However the findings are viewed with caution due to this, as well as due to unequal sample sizes, thus the reported results are viewed as indications of potential underlying associations irrespective of the suitability of the task for young samples for now; it was proposed to examine more groups of different ages for their stress sensitivity and reading skills in the future. Next, the longitudinal study proposed in Chapter 5 will be examined in the following chapter. This may aid the understanding of stress sensitivity's development over time in slightly older children.

Chapter 7 – Study 5

Longitudinal Investigation: Relationships between speech rhythm sensitivity, morphological awareness, reading and phonological processing skills over time

7.1 Overview

This study assessed whether stress sensitivity was able to predict later reading skills in two cohorts of children. It was found that stress sensitivity was able to account for significant variance in reading comprehension and in the phrasing component of reading fluency in Year 4 and 5 children. Once vocabulary, IQ, PA or RAN were accounted for however no direct, longitudinal contribution was accountable to stress sensitivity. No significant associations between stress sensitivity and reading (related) skills were found in the second (Year 6) cohort, either longitudinally or concurrently. When the concurrent skills were examined at re-test in the younger sample, stress sensitivity could account for unique variance in the development of reading comprehension and phrasing, beyond the associations of vocabulary, PA, RAN and morphological awareness with these reading skills. Implications of these findings are discussed further.

7.2 Introduction

Longitudinal studies provide a good indication of children's development over time in the assessed skills. They also enable the identification of which skills may precede others and how they interact and influence each other over time. With regards to the development of prosodic skills not many such studies have been conducted. Miller and Schwanenflugel (2008) for instance assessed 92 children over three school years on prosodic text reading and examined the relationships between general fluent reading and comprehension skills with reading prosody.

The longitudinal analyses revealed that Grade 1 children who included fewer pauses during reading also demonstrated better, more adult-like intonation in second grade. More fluent children (those with higher reading rate and accuracy scores) were able to produce more speech-like renderings of texts and it was found that the use of pauses during reading was also associated with word reading skills. A link between the number of these pauses and children’s later intonation contour production skills was also found. Children’s reading fluency in Grade 3 was predicted by Grade 1 and 2’s word reading skills and early adult-like intonation patterns were also found to be predictive of later fluency, even after controlling for early word reading skills. This consequently indicated that good intonation was predictive of prosodic renderings and later fluent reading abilities.

Furthermore, early adult-like intonation and amount of pauses used were also able to predict comprehension skills in Grade 3. This finding added to previous studies (e.g. Schwanenflugel *et al.* (2006) which did not find an association between pauses and comprehension skills and suggested that this relationship may only be detectable over time. It was also suggested that good word decoding skills and fluency could aid children in that they insert more pausal intrusions to ensure better text comprehension. It would be of interest to assess this relationship further by examining children’s general stress sensitivity, measured as a separate ability, rather than as part of fluent reading assessed by a productive speech rhythm measure (as was used by Miller and Schwanenflugel 2008) to test whether it could also predict later comprehension skills. Such a study was conducted by Holliman *et al.* (2010b), who used a receptive speech rhythm sensitivity measure.

They conducted a follow-up investigation to an earlier study (Holliman *et al.* 2010a) and tested 69 of the previously assessed children one year later. The children were in Years 1 to 3 at the time of re-testing and had a mean age of 7 years and 7 months. At both time points speech rhythm, rhyme and phoneme deletion, word reading and reading fluency were assessed. Fluency was not scored or included at Time 1 to avoid experimenter bias due to knowledge of children's fluency skills when scoring took place at Time 2. The phrasing, smoothness and pace of children's fluent reading were assessed (Zutell and Rasinski 1991) for later analyses. Reading comprehension was also tested at Time 2. The speech rhythm measure that was used was the revised mispronunciations task (Holliman *et al.* 2010a).

The relationship of speech rhythm to phonological awareness (at both times) and vocabulary was assessed, as well as speech rhythm sensitivity's predictive power of word reading, reading comprehension and reading fluency at Time 2. All variables were found to be significantly correlated with speech rhythm sensitivity at Time 2 and further regression analyses also revealed that speech rhythm was able to account for significant unique variance in word reading skills over and above age, vocabulary and PA. Speech rhythm was marginally reliable in predicting comprehension skills (p = .057). However children's phrasing was significantly predicted by speech rhythm measured at Time 1, after age, vocabulary and PA were controlled.

As Miller and Schwanenflugel (2006) previously stated, different aspects of prosodic fluent reading may be related differently to reading comprehension. Holliman *et al.* (2010b) did not measure prosody as an aspect of fluency per se but as a separate construct using a receptive speech rhythm sensitivity measure. Therefore it was interesting to see that measuring speech rhythm sensitivity as a separate ability also yielded significant relationships with reading skills over time (although this was only marginal in the case of comprehension skills in this study).

Corriveau, Goswami and Thomson (2010) also conducted a longitudinal (and cross-sectional) study, assessing preschool and kindergarten children's rise time sensitivity (non-speech rhythm) and its relation with early pre-reading skills. They assessed the children on a rise time task and a frequency discrimination task, as well as on phonological awareness and literacy skills. The cross-sectional analyses revealed differences between all age groups (3-, 4-, 5- and 6-year-olds) on the psychometric tests, indicating significant increases in phonological awareness and letter-sound knowledge across each age group. Significant differences between rise time and intensity measures were also found between the 3- and 4-year-olds compared to the 5- and 6-year-olds.

Longitudinal analyses of twenty-five children (aged between 4;5 and 5;5 years) over three time points showed significant increases in rhyme awareness, syllable segmentation, sound isolation, letter sound knowledge, rise time discrimination and frequency discrimination between Time 1 and Time 3. Regression analyses revealed that rise time discrimination was predictive of rhyme awareness, after individual differences in rise time sensitivity over time were controlled as well as after individual differences in IQ were taken into consideration. Phoneme awareness and sound isolation abilities were also predicted by earlier rise time sensitivity, which further offers support for the implication of auditory processing abilities in phonological awareness development. Due to the young age of the participants the predictive power of non-speech rhythm sensitivity to reading skills was not assessed. It can however be hypothesised that rhythmic sensitivity would also be able to predict early reading skills (as was found by Holliman *et al*. 2010b).

In summary, Holliman *et al*.'s speech rhythm measure was able to predict later word reading and phrasing ability, independently from age, vocabulary and PA. Reading comprehension was predicted marginally. Furthermore, Corriveau *et al*. found that the non-speech rhythm measure was able to account for unique variance in children's rhyme awareness, phoneme awareness and sound isolation abilities over time, after individual differences in rise time sensitivity and IQ were controlled. Taking these findings together it can be said that non-speech rhythm appears to be implicated in children's early phonological awareness development, whereas speech rhythm sensitivity also contributes something unique to word reading and phrasing independently of its association with PA.

The longitudinal assessment conducted by Corriveau *et al.* (2010) was based on a rather limited sample (*N* = 25) and requires replication to be more generalisable. Furthermore, early word reading skills were not measured due to the age of the participants, but perhaps nonword reading skills could have been assessed; this would have been insightful in terms of early non-speech rhythm's contribution to early reading skills, which perhaps would be similar to the involvement observed in children of similar ages, when speech rhythm based measures were used (e.g. Wood 2006b). In terms of Miller and Schwanenflugel's (2008) longitudinal assessment, they analysed prosodic renderings of text as an intricate aspect of fluency, but did not control for vocabulary or phonological awareness. This would have enabled a closer comparison with other studies that have controlled for these skills and also facilitated our understanding of prosody's role with reading fluency once vocabulary and phonological awareness were accounted for.

In order to expand upon these observed longitudinal relationships between (speech) rhythm sensitivity and literacy, additional longitudinal studies are required to consolidate these findings further. Utilising the same stress sensitivity task that now has been used across a range of ages would allow for clearer understanding of stress sensitivity's role in the development of reading skills over time. Therefore, to gain additional insight into the development of children's prosodic skills and their reading development it was of interest to re-assess children to conduct a longitudinal examination of their skills and abilities. Children previously tested in Study 2 and 3 (see Chapters 4 and 5) were re-assessed. Note, that the children in Study 2 displayed stress sensitivity which was associated with word reading, reading comprehension and fluency skills. The children assessed as part of Study 3 did not show that stress sensitivity was a skill associated with their reading abilities, however. Several reasons for this were proposed and this study aims to explore these further.

It was speculated that it may be that stress sensitivity's contribution to reading skills in children older than 9-years-old, is only apparent over time (Miller and Schwanenflugel 2008), thus a longitudinal study is required to test this claim. Although others have found some supporting evidence for speech rhythm's contribution to reading comprehension in children of similar ages as have been assessed in Study 3 (e.g. Miller and Schwanenflugel 2006; Whalley and Hansen 2006), they did not control for morphological awareness for example, which has been suggested to play an increasingly important role in older children's reading skills (e.g. Roman, Kirby, Parilla *et al.* 2009). It may be feasible that children older than 9 years of age do not display stress sensitivity as a reading-related skill anymore, when assessed by the LJT, perhaps because their morphological awareness (MA) is increasingly important. For example, as Clin *et al*. (2009) have found, MA and prosodic sensitivity were both implicated in 8-13 year olds reading skills. They tested Grade 3 (mean age 104 months, SD = 4.25), Grade 5 (mean age 127 months, SD = 3.3) and Grade 7 (mean age 150 months, SD = 3.4) children and assessed whether morphological derivations (which differed in phonological complexity) were equally difficult to produce or whether those derivations requiring stress changes were most difficult. Additionally, they tested whether morphological awareness and prosodic sensitivity could predict concurrent reading skills in this sample.

To measure prosodic sensitivity Clin *et al.* used an adaptation of Wood and Terrell's (1998b) sentence matching task as well as the DEEdee task (Whalley and Hansen 2006). Morphological awareness was assessed with a measure adapted from Carlisle (1988, 2000), in which children had to produce derived word forms from a stem to complete a sentence. Four different categories of derivations were included; no change (e.g. *appear – appearance*), phonemic change (e.g. *elect – election*), stress change (e.g. *human – humanity*) and phonemic and stress change (e.g. *electric – electricity*). Several reading measures were also included (such as reading accuracy, sight word recognition and comprehension), which were combined to produce a reading composite score. Nonverbal IQ, general language competence and PA were also assessed.

It was found that children's performance on the morphological derivation task varied, dependent on derivation types and Grade. The no change and phonemic change items were performed at 79 and 81% accuracy, respectively, whereas the phonemic and stress change items were completed at 60% accuracy. The stress shift items were performed worse, at 51% accuracy. Thus suprasegmental phonological shifts were more difficult for the children compared to segmental phonological changes. Although all children displayed greater difficulty with the stress change items, the younger children (Grade 3) displayed the most difficulties, which suggests that sensitivity to stress changes in derivations is an ability that increases with age, but also that stress changes form an integral part of morphological derivations, which may be completed more easily by children with greater sensitivity to stress.

To assess the concurrent relationships between prosodic sensitivity and morphological awareness with reading ability composite scores were created. Both stress sensitivity measures used were combined to form a prosodic sensitivity composite. Age, non-verbal IQ, general language ability, working memory and PA were used as control measures (in Step 1) followed by prosody and MA in Step 2 and 3. This showed that stress sensitivity could account for 3% of variance in reading skills and MA accounted for 6% of variance. When MA was entered in Step 2 and stress sensitivity was entered in Step 3 it was found that MA significantly contributed 7% of variance to reading ability followed by prosodic sensitivity accounting for a further 2%. Therefore, morphological awareness and prosodic sensitivity added unique variance to reading ability over and above the control measures; although it was found that MA was contributing much more compared to any other variable.

To further test whether children's ability to make stress-neutral or stress-shifting derivations was implicated in their reading skills, the no change and phonemic change derivation items were combined to make a stress-neutral MA variable and the items involving stress changes were combined to a stress-shifting MA composite. The same regression model was used as before, but included these two MA variables; this analysis showed that stress-shifting morphological awareness was the strongest predictor of reading ability, over and above the control variables and prosodic sensitivity; stress-neutral MA did not add significant variance to this model.

This study showed that children found stress-shifting morphological derivations more challenging than stress-neutral derivations, which is consistent with earlier studies (e.g. Jarmulowicz, Taran and Hay 2007), which showed that Grade 1 children performed better on derivations with stress-neutral endings (e.g. *–tion*). A developmental trend was also apparent, suggesting that children in Grade 5 experienced rapid growth in the understanding of suffixes which involved stress changes (e.g. Jarmulowicz 2006). Furthermore, the predictive power of MA and stress sensitivity to reading skills beyond phonological awareness demonstrated the importance of these skills, which may not be surprising when one considers the complexity of multisyllabic words. These include affixes and suffixes that drive phonological changes in morphological roots and require correct stress assignment and vowel reductions that operate across syllables, thus indicating that suprasegmental phonology skills are also essential for reading.

The role of morphology in children's reading has been well documented (Carlisle 1995, 2000; Nagy, Berninger and Abbott 2006; Jarmulowicz *et al.* 2008; Tong *et al.* 2011). Morphological awareness was found to predict vocabulary (e.g. Carlisle 2007), and spelling (e.g. Deacon, Kirby and Bell-Casselman 2009) and also comprehension skills, although vocabulary knowledge was also found to be a confounding variable strongly related to comprehension and MA (e.g. Kuo and Anderson 2006). That is, Deacon *et al*. found that MA can predict vocabulary, whereas Kuo and Anderson found that MA could predict reading but so could vocabulary. Vocabulary and MA were closely related so vocabulary may have been mediating MA's contribution to reading skills.

Studies examining the role of morphology in reading skills further demonstrated that dyslexics were able to produce derived words, but given their phonological impairments, they may rely more on semantic rather than phonological information to achieve this (Casalis, Colé and Sopo 2004). Furthermore, MA was also found to contribute to reading comprehension and pseudoword reading after controlling for verbal and non-verbal intelligence, PA and reading abilities (Deacon and Kirby 2004). Foorman, Petscher and Bishop (2012) also found that MA was able to predict reading comprehension over and above spelling, text reading efficiency and prior reading comprehension in Grade 3 to

10 students. However, it cannot be ascertained whether vocabulary knowledge was implicated in this relationship as it was not measured.

Duncan, Casalis and Colé (2009) showed that French and English speaking 8- year-old children demonstrated similar levels of sensitivity to morphologically-related words, but that the English children performed worse on a real word derivation production tasks. In comparison, both groups of children had difficulties with the production of novel derivations from nonword roots. Overall, a slower developmental rate of metamorphological development was observed in the English speaking children compared to the French children, even when receptive vocabulary skills and age were equivalent across both language groups. It was suggested that this could be influenced by lexical stress differences across both languages; since final syllable stress placement is rare in English and could therefore de-emphasise suffixes and reduce their salience in English speaking children (e.g. Cutler and Clifton 1984), which subsequently could prolong the acquisition of English speaking children's knowledge of stress-shifting suffixes compared to stress-neutral suffixes (e.g. Carlisle 2000; Mahony, Singson and Mann 2000). This opens the question whether English speaking children who demonstrate greater sensitivity to stress would also demonstrate overall greater morphological awareness and thus be able to complete morphological stress-shifting derivations more easily compared to children with reduced sensitivity to stress.

Overall, these studies demonstrated that MA plays an important part in reading skills however it is unclear how speech rhythm, and especially stress sensitivity, is related to morphological awareness as it has not yet been extensively assessed in comparison with MA. Clin *et al.* (2009) suggested that morphological awareness was a key component in children's reading abilities, which accounted for the greatest variance in reading (compared to stress sensitivity and other control factors). However this study assessed skills concurrently and therefore it cannot be gauged whether stress sensitivity may have had a greater impact on reading over time, as suggested by Miller and Schwanenflugel (2008).

Studies assessing how morphological awareness and stress sensitivity influence reading development are limited to those reviewed above and are therefore sparse and it is of interest to further assess how these skills relate to word reading, reading comprehension and fluency skills in intermediate readers. To further investigate the association between stress sensitivity and reading skills and to expand upon the limited research work in this area the following research questions were explored in the present study:

1. Can stress sensitivity predict reading skills and morphological awareness over time?

2. Which literacy components can predict stress sensitivity over time?

3. Does stress sensitivity account for unique variance in morphological awareness and reading skills concurrently?

7.3 Method

This longitudinal study re-assessed children from Years 4, 5 and 6 who were assessed 4 to 12 months previously (mean 7.2 months, SD = 2.3 months). That is, Time 1 testing occurred during autumn/winter and early spring school terms for the Study 2 sample and during spring/summer term for the Study 3 sample. Re-testing took place after the school summer holidays in the autumn/winter term for all children. The Study 2 cohort and Study 3 cohort were analysed separately so that there was greater consistency in the time elapsed between Time 1 and Time 2 (i.e. mean 8 months for Study 2 children, and mean 5 months for Study 3 children).

The Study 2 sample's fluency was measured using the Multidimensional Fluency Scale (MDFS, Rasinski 2003) whereas the Study 3's fluency was based on reading rate; therefore those children's passage reading was re-analysed using the MDFS, so that Time 1 fluency scores were comparable. At Time 2 all children received the same assessments (see Section 7.3.2). To explore relationships between skills at Time 1 and Time 2 zero order correlations were carried out as well as several hierarchical multiple regression analyses.

7.3.1 Participants

Overall, Seventy-seven children were available at Time 2 for re-test from the original 133 participants across both study samples. The high attrition rate across both cohorts (58%) was due to children being absent from school during re-test, having moved away from the school's catchment area or moving onto secondary school, and were thus unavailable for re-test. ANOVA were conducted to assess whether the children who were unavailable for re-test differed from those that took part in the Time 2 testing. For the Study 2 sample it was found that the re-tested children (n = 47) scored significantly lower on vocabulary, reading comprehension and reading fluency compared to the not re-tested children (n = 30), and they scored significantly higher on phonological awareness than the attrition group. In terms of the Study 3 sample, the re-tested children (n = 30) were significantly younger than those that were unavailable for re-test (n = 26) but they performed significantly better on the reading comprehension and word reading tasks.

The children were grouped into either *Cohort A* or *Cohort B*; Cohort A (*n* = 47) comprised the Study 2 sample whereas Cohort B (*n* = 30) comprised the previous Study 3 children. It was deemed important to assess children by sub-samples to enable more direct comparison to the previously conducted studies and also to account for different time spans between testing points. Table 7.1 provides an overview of the age ranges and mean ages (and standard deviations) across cohorts, as well as the overall age at both testing points and the mean time gap across cohorts.

Table 7.1 Age ranges and mean ages across cohorts at both testing points (with mean differences between T1 and T2)

Time 1 Cohort	Age range (months)	Mean age *(SD)*	Time difference (months)	Time 2 Cohort	Age range (months)	Mean age *(SD)*
A	86 – 115	98.94 (6.62)	8.60 (1.94)	A	97 – 121	107.53 (6.38)
B	117 – 129	123.53 (3.62)	5.13 (0.43)	B	123 – 134	128.67 (3.58)
All	86 – 129	108.52 (13.32)	7.30 (2.3)	All	97 – 134	115.77 (11.71)

As an inclusion criterion, only children who were able to successfully complete the LJT baseline condition (scores of 10 or more) were included in the analyses. At Time 1 as well as at Time 2 all children were able to reach the criterion; Time 1 LJT baseline mean score was 11.67 (SD = 0.62) and at Time 2 the mean was 11.79 (SD = 0.41) across the whole sample.

7.3.2 Test Battery

All children were assessed on reading skills using the YARC Form B (Snowling, Stothard, Clarke *et al*. 2011). They were re-tested on the Lexical Judgement Task and additionally completed a morphological awareness test (Duncan *et al*. 2009), comprising real and nonword roots within a sentence that needed to be completed with (non) lexical derivations (see Chapter 2.5.4 for details).

Standardised scores were used for comparisons of word reading and comprehension skills. For the word reading Time 1 scores, the Study 2 sample's WRAT word reading scores were used and the Study 3 sample's YARC passage reading accuracy scores were used. At Time 2 all children's standardised passage accuracy scores were used.

The WRAT sentence comprehension scores from the Study 2 sample and the Study 3 sample's YARC passage reading comprehension scores were used at Time 1. Although both measures assessed reading comprehension in a different format it was deemed acceptable to compare both tests' standardised scores. Both samples completed the same IQ and phonological processing tests at Time 1 and were therefore directly comparable. Likewise, all children completed the same stress sensitivity measure at both testing points.

Since different fluency measures were used at Time 1, the Study 3 sample's reading recordings needed to be analysed for phrasing, smoothness and pace according to the MDFS (the accuracy aspect was omitted in this analysis to focus solely on prosodic aspects of fluent reading; this resulted in a maximum score of 12 instead of 16). At Time 2 all children completed the YARC and the passage reading recordings were also analysed according to the MDFS. These scores were then used as the fluency variables for Time 1 and Time 2.

Spearman correlations showed significant relationships between the primary researcher's ratings and an independent researcher's ratings of phrasing (r_s = .614, p < .001), smoothness (r_s = .793, p < .001) and pace (r_s = .765, p < .001) and total fluency scores (r_s = .696, p < .001) at Time 1. At Time 2, these ratings were also significantly correlated; phrasing (r_s = .781, p < .001), smoothness (r_s = .590, p = .006), pace (r_s = .862, p < .001) and total fluency scores (r_s = .804, p < .001). Overall, these associations indicated reliable scoring by the primary researcher and thus those scores were used in the subsequent analyses.

7.3.3 Procedure

All children who had previously taken part in Study 2 and 3 were approached again and asked whether they wanted to take part in this study. Verbal assent was obtained and the children were informed that they would be assessed on a reading task, a computer-based task and a new word game. Each child was tested individually in the school's library in one session not lasting longer than 30 minutes. All children were assessed on the LJT task first, and then either completed the YARC or the MA task next. Half of the children subsequently were tested on the LJT, YARC and the MA, the other half of the children were assessed on LJT, MA and then YARC. Potential task order effects were assessed (MANOVA) and found to be non significant, $F(5, 70) = 0.371$, $p = .867$.

7.4 Results

Data were checked for normality and two outliers (z scores greater than +/- 3.29) were detected within the RAN variable in Cohort A; these were marked as missing and excluded from later analyses, resulting in the RAN times being based on $n = 45$. All other variables were normally distributed. Table 7.2 depicts the mean scores (and standard deviations) as well as the Cronbach's alpha (where computable) for both time points across cohorts.

Table 7.2 Mean scores and alpha values for Time 1 and 2 measures across both cohorts

Cohort A			Cohort B		
Time 1	**Mean (SD)**	**α**	**Time 1**	**Mean (SD)**	**α**
Vocab / 56 - 64	24.43 (6.49)	.81	Vocab / 64	32.40 (6.95)	.81
IQ	93.47 (12.66)	.88	IQ	89.37 (12.39)	.88
PA / 30	14.25 (7.10)	.87	PA / 30	19.23 (5.26)	.82
RAN	96.24 (26.28)		RAN	74.43 (21.23)	
WR	93.55 (18.08)		WR	95.77 (13.84)	
RC	89.53 (17.22)		RC	97.97 (12.40)	
RF / 12	8.13 (3.26)		RF / 12	7.77 (1.98)	
Phrasing /4	2.64 (1.11)		Phrasing / 4	2.50 (0.78)	
Smoothness / 4	2.85 (1.18)		Smoothness / 4	2.80 (0.89)	
Pace / 4	2.64 (1.17)		Pace / 4	2.48 (0.63)	
LJT / 12	8.42 (1.75)	.17 (match) .59 (no-match)	LJT / 12	9.63 (1.69)	.03 (match) .27 (no-match)
Time 2			**Time 2**		
WR	88.91 (11.02)		WR	88.23 (9.54)	
RC	93.36 (12.72)		RC	103.80 (13.57)	
RF / 12	6.87 (2.31)		RF / 12	8.63 (2.01)	
Phrasing / 4	2.11 (0.91)		Phrasing / 4	2.93 (0.83)	
Smoothness / 4	2.51 (0.86)		Smoothness / 4	3.03 (0.72)	
Pace / 4	2.25 (0.76)		Pace / 4	2.67 (0.76)	
MA / 36	18.15 (6.84)	.88	MA / 36	24.40 (4.72)	.80
LJT / 12	9.02 (2.27)	.65 (match) .62 (no-match)	LJT / 12	9.53 (1.55)	-.27 (match) .16 (no-match)

Note: Vocab – vocabulary raw scores, IQ – verbal and nonverbal IQ standard scores; PA – phonological awareness raw scores; RAN – rapid automatised naming reaction times in seconds; WR – word reading standard scores; RC – reading comprehension standard scores; RF – reading fluency (at both time points sum of phrasing, smoothness and pace scores based on MDFS); MA – morphological awareness raw scores; LJT – stress sensitivity task.

Regression analyses predicting reading skills and morphological awareness over time

Initially, the data were analysed to see whether relationships between stress sensitivity and the literacy-related variables (at Time 1) and the reading and MA variables at Time 2 could be observed. These zero order correlations are depicted in Table 7.3. For comparison, the correlations between these variables across the whole sample can be found in Appendix 8.

Cohort A's stress sensitivity at Time 1 was found to correlated with reading comprehension (r = .331, p = .023), the phrasing component of fluency (r = .310, p = .034) and morphological awareness (r = .377, p = .009) at Time 2. It also correlated with itself over time (r = .380, p = .008); this small to moderate correlation was rather surprising and will be explored further in the discussion. The variables that correlated with stress sensitivity over time were also found to correlate with vocabulary, IQ and PA. Reading comprehension and phrasing were also significantly associated with RAN, but morphological awareness was not (p = .08). Thus in separate regression analyses vocabulary, IQ, PA, and RAN were used as controls in addition to stress sensitivity when predicting comprehension and phrasing. When morphological awareness was the outcome variable vocabulary, IQ and PA were used as the predictor variables.

In terms of Cohort B's stress sensitivity at Time 1 it was found that it only correlated with itself at Time 2 (r = .407, p = .026). Therefore no further regressions were conducted for Cohort B.

Table 7.3 Correlations between stress sensitivity and T1 control variables and T2 literacy variables and morphology across both cohorts

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Age	-	-.087	-.327	-.172	-.327	-.243	.007	-.096	.113	.150	-.153	.281	-.098	.083
2. Vocab	.180	-	.684***	.548**	-.464**	.042	.631***	.698***	.570**	.557**	.543**	.386*	.383*	.105
3. IQ	-.118	.725***	-	.387*	-.388*	-.072	.414*	.529**	.261	.221	.402*	.069	.230	.112
4. PA	.029	.450**	.599***	-	-.361^{+}	.176	.644***	.543**	.576**	.558**	.609***	.340	.506**	.048
5. RAN	.062	-.317*	-.295*	-.623***	-	.167	-.661***	-.340	-.633***	-.532**	-.523**	-.601***	-.037	-.255
6. LJT	.109	.304*	.061	.204	-.394**	-	.018	.096	.000	-.067	.096	-.018	.322	.407*
7. WR	-.341*	.231	.503***	.617***	-.613***	.204	-	.592**	.752***	.670***	.638***	.655***	.326	.201
8. RC	-.154	.369*	.542***	.672***	-.603***	.331*	.679***	-	.655***	.631***	.588**	.489**	.258	.050
9. RF	-.009	.411**	.450**	.681***	-.719***	.266††	.682***	.714***	-	.898***	.821***	.891***	.122	.132
10. Phrase.	-.089	.439**	.480**	.695***	-.667***	.310*	.706***	.763***	.943***	-	.584**	.733***	.140	.029
11. Smooth.	-.009	.374**	.426**	.668***	-.723***	.171	.610***	.659***	.924***	.845***	-	.591**	.220	.108
12. Pace	.089	.297*	.308*	.476**	-.540***	.241	.531***	.506**	.856***	.706***	.659***	-	-.039	.216
13. MA	.111	.570***	.444**	.450**	-.264	.377**	.294*	.501***	.298*	.393**	.209	.196	-	.206
14. LJT	.250	.250	.291*	.161	-.019	.380**	.177	.320*	.175	.324*	.061	.072	.278†	-

Note. T1 = Time 1; T2 = Time 2. T2 Variables shaded in grey. Cohort A correlations are shown below the diagonal and the Cohort B correlations are depicted above the diagonal.

Vocab = vocabulary; PA = phonological awareness; RAN = rapid automatised naming; LJT = stress sensitivity; WR = word reading; RC = reading comprehension; RF = reading fluency total; Phrase = phrasing (fluency component); Smooth. = smoothness (fluency component); Pace = fluency component; MA = morphological awareness.

$^{*}p < .05$, $^{**}p < .01$; $^{***}p < .001$; $^{+}p = .05$, $^{\dagger}p = .058$, $^{\dagger\dagger}p = .071$.

Initially, stress sensitivity was entered as the sole predictor of reading comprehension at Time 2; this showed that it was able to account for 11% of variance in comprehension skills over time (β = .331, p = .023). When vocabulary was included as the first control variable it was found that it could predict 13.6% of variance in reading comprehension (p = .011) whereas stress sensitivity no longer added significant variance (p = .098). Similarly, when RAN or PA were entered as control variables in separate regression analyses, stress sensitivity again was unable to contribute significantly to comprehension (p = .299 and p = .072 respectively). However, when IQ was entered individually as the first control variable stress sensitivity still contributed significant variance to reading comprehension (p = .015, ΔR^2 = .089). Since LJT did not add unique variance to reading comprehension once vocabulary was entered into the model as the first predictor, it was of interest to examine whether it could predict comprehension when IQ and PA were controlled and when IQ and RAN were also accounted for (in separate analyses) to determine that the contribution of PA and RAN were not mediated by cognitive ability. These results can be seen in Table 7.4.

When IQ and PA were accounted for, stress sensitivity still added 4.5% of unique variance to reading comprehension (p = .049), thus it can be said that some of the variance accounted for by PA was mediated by IQ; once this association was taken into account, stress sensitivity was able to add additional variance to comprehension skills, independently from IQ and PA. When IQ and RAN were entered in the first two steps before including stress sensitivity however, it did not add unique variance to reading comprehension any more (p = .180).

The same regression analyses models were computed to predict phrasing abilities at Time 2; the outcomes can also be seen in Table 7.4. Individually, stress sensitivity predicted 9.6% of variance in phrasing over time (p = .034, β = .310). After vocabulary, PA or RAN were controlled for, stress sensitivity was unable to add unique variance to phrasing anymore (*p* = .169, *p* = .110 and *p* = .536 respectively). When IQ was the first predictor however, stress sensitivity still accounted for 7.9% of variance in phrasing (*p* = .030) beyond the 23% accounted by IQ (*p* = .001). It seems that stress sensitivity was not able to add unique variance to phrasing beyond IQ, PA and RAN's contribution, when these predictors were accounted for in two separate analyses.

Table 7.4 Regression analyses predicting Cohort A's comprehension and phrasing over time

	Comprehension		Phrasing	
Steps and Independent Variables	**β**	**ΔR^2**	**β**	**ΔR^2**
1. Vocabulary	.369*	.136*	.439**	.193**
2. LJT	.241	.053	.194	.034
1. PA	.672***	.451***	.695***	.483***
2. LJT	.203	.039	.176	.030
1. RAN	-.603***	.363***	-.667***	.445***
2. LJT	.139	.016	.078	.005
1. IQ	.542***	.294***	.480**	.230**
2. LJT	.299*	.089*	.282*	.079*
1. IQ	.542***	.294***	.480**	.230**
2. PA	.541***	.188***	.636***	.259***
3. LJT	.218*	.045*	.183	.032
1. IQ	.507***	.257***	.448**	.201**
2. RAN	-.497***	.225***	-.586***	.313***
3. LJT	.164	.023	.096	.008

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

When stress sensitivity's predictive power of morphological awareness over time was assessed it was found that it accounted for 14.2 % of variance in MA (β = .377, *p* = .009) but when vocabulary was included as the first control variable stress sensitivity did not contribute significantly to morphological awareness anymore (*p* = .081); vocabulary however accounted for 32.4% of variance in MA (β = .570, $p < .001$). When PA was included in the analyses as the first control variable, it accounted for 20.3% of variance in

MA (β = .450, p = .001) and stress sensitivity also added 8.5% of variance (β = .297, p = .027).

Next, vocabulary and PA were entered into the first two steps followed by stress sensitivity. It was found that stress sensitivity was not able to contribute to MA once vocabulary and PA were controlled, p = .100. Vocabulary was the only significant predictor, accounting for 32.4% of variance in morphology over time, PA was not significantly contribution to the model (p = .076, ΔR^2 = .047). When IQ was the first control variable it accounted for 19.7% of variance in MA (p = .002, β = .444) and stress sensitivity added a further 12.3% of variance to morphology (p = .007, β = .351); when PA was included as the second predictor after IQ, it did not contribute significantly to the model (p = .084) but stress sensitivity did, $F(1, 43) = 6.265$, p = .016, ΔR^2 = .095. The beta values and R^2 change values for the regression analyses controlling for vocabulary and PA and for IQ and PA prior to stress sensitivity are depicted in Table 7.5.

Table 7.5 Variance in Cohort A's morphological awareness

	Morphological awareness	
Steps and IV's	**β**	**ΔR^2**
1. Voc	.570***	.324***
2. PA	.243	.047
3. LJT	.208	.039
1. IQ	.444**	.197**
2. PA	.288	.053
3. LJT	.316*	.095*

Note. IV = independent variables.
*p < .05, **p < .01; ***p < .001.

Predicting stress sensitivity over time

It was of interest to assess whether any of the Time 1 reading abilities were significantly correlated with stress sensitivity at Time 2 (in both cohorts) and would also be able to account for unique variance in this ability over time, to further ascertain whether stress sensitivity was a skill facilitated by reading related skills or through general ability. Cohort A's reading comprehension and phrasing abilities were found to significantly correlate with stress sensitivity at Time 2 (r = .328, p = .024 and r = .348, p = .017 respectively). The correlation matrix depicted in Table 7.3 already showed that IQ was significantly correlated with stress sensitivity at Time 2 (r = .291, p = .047) so this variable was also included as a predictor variable.

Several regression analyses were conducted including IQ, comprehension and phrasing as the sole predictor, followed by the same analyses but also accounting for stress sensitivity from Time 1 as the auto-regressor. Analyses outcomes can be seen in Table 7.6. IQ (p = .047), comprehension (p = .024) and phrasing (p = .017) could all account for variance in stress sensitivity over time when entered alone into the models, however these associations disappeared once the auto-regressor was included; IQ's contribution did however approach significance (p = .051).

Table 7.6 Predicting Cohort A's stress sensitivity over time

	Time 2 Stress sensitivity	
Steps and IVs	**β**	**ΔR^2**
1. IQ	.291*	.085*
1. RC	.328*	.108*
1. Phrasing	.348	.121*
1. LJT T1	.380**	.144**
2. IQ	.268†	.072†
2. RC	.222	.043
2. Phrasing	.253	.058

Note. T1 = Time 1. RC = reading comprehension.
*p < .05, **p < .01, ***p < .001.

Since no variables were significantly correlated with stress sensitivity at Time 2 in Cohort B, no regression analyses were conducted for this sub-sample.

Predicting morphological awareness and reading skills concurrently at Time 2

Lastly it was of interest to assess whether stress sensitivity could account for variance in morphological awareness and in reading skills concurrently. Since Cohorts A and B did not display significant correlations between stress sensitivity and morphological awareness concurrently (r = .278, p = .058 and r = .206, p = .275) no regression analyses were conducted to predict MA with stress sensitivity. Cohort A's correlation was approaching significance thus it can be argued that a larger sample may have shown significant associations between these skills; this would required further testing however.

In terms of the reading skills, stress sensitivity at T2 was found to correlate significantly with T2 comprehension (r = .320, p = .028) and with T2 phrasing (r = .324, p = .027) in cohort A. Since comprehension and phrasing also correlated significantly with vocabulary, IQ, PA, RAN and MA (see Table 7.3) these skills were used as control variables (in separate analyses). Table 7.7 depicts all regression analyses outcomes.

Initially, comprehension was examined and vocabulary, PA and RAN were accounted for before entering stress sensitivity into the model. This showed that vocabulary (p = .011), PA (p < .001) and RAN (p = .028) combined accounted for 48.7% of variance in reading comprehension and that stress sensitivity was still able to predict a further 9.2% (p = .005). When IQ was entered as the first predictor instead of vocabulary, stress sensitivity still accounted for 7.4% of variance in reading comprehension in addition to these control variables. As IQ (β = .507) had a stronger association with comprehension than vocabulary (β = .375) this variable was used in the following regression which included morphological awareness in the fourth step before including stress sensitivity in the final step. This showed that stress sensitivity was able to account for 5.7% of variance in comprehension (p = .023) once MA was also controlled, which did not contribute significantly to the model (p = .122).

Next, phrasing abilities were examined. When vocabulary, PA and RAN were entered as the control variables, which combined accounted for 57.3% of variance, stress sensitivity still added 7.2% of variance to phrasing (p = .007) over and above these control factors. It also contributed 7.4% of variance (p = .007) when IQ, PA and RAN were controlled and in addition stress sensitivity added 7.1% of variance to phrasing when morphology was also accounted for.

Table 7.7 Predicting comprehension and phrasing concurrently from stress sensitivity after controlling for vocabulary, IQ, PA, RAN and MA (in separate analyses)

	Comprehension T2		Phrasing T2	
Steps and IVs	**β**	**ΔR^2**	**β**	**ΔR^2**
1. Vocab	.375*	.140*	.446**	.199**
2. PA	.600***	.283***	.595***	.278***
3. RAN	-.325**	.064**	-.397**	.096**
4. LJT	.321**	.092**	.283**	.072**
1. IQ	.507***	.257***	.448**	.201**
2. PA	.528**	.186**	.622***	.259***
3. RAN	-.353**	.076**	-.417**	.106**
4. LJT	.291**	.074**	.291**	.074**
4. MA	.192	.028	.069	.004
5. LJT	.263*	.057*	.293**	.071**

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

Overall, these findings suggested that stress sensitivity is associated with reading comprehension and phrasing, independently from vocabulary, IQ, phonological awareness, RAN and morphological awareness when assessed concurrently. This was in contrast to the findings obtained when assessing stress sensitivity's contribution to comprehension and phrasing over time. This will now be explored further.

7.5 Discussion

This study set out to examine the relationship between speech rhythm sensitivity and reading (related) skills concurrently and over time.

The sample was divided into two cohorts (A and B), which represented children that were previously tested as part of Study 2 and 3. The children from Cohort B did not display significant associations between stress sensitivity and reading skills over time or during the second testing point and therefore no regression analyses were conducted with this sub-sample. These findings were similar to those obtained previously in Study 3. In that study the children were aged between 9;9 and 11;10 years (mean 10;9 years) and did not display associations between stress sensitivity and reading skills. Thus, the current findings provided some support for the notion that stress sensitivity is not an important, literacy related skill, in children aged above 9;9 years, at least not in this sample when tested with the LJT. Others however have found that speech rhythm sensitivity was related to reading skills in samples of similar ages (e.g. Clin *et al.* 2009; Miller and Schwanenflugel 2006, Whalley and Hansen 2006). It may be that measuring prosodic reading components, such as pitch, demonstrates stronger associations with reading comprehension in children aged around 9-years of age (Miller and Schwanenflugel 2006), or that children's metrical stress sensitivity (assessed with the DEEdee task) is more closely related to reading comprehension (Clin *et al.* 2009; Whalley and Hansen 2006). As has been reported previously (see Chapter 4) issues with the DEEdee task were identified, therefore this measure was not used anymore. Thus, the children in Study 3 and in this current study were not assessed with that measure. It cannot be ruled out whether stronger associations between speech rhythm and reading skills could have been observed in Cohort B, if the DEEdee task had been used. The non significant findings between stress sensitivity and reading skills in Cohort B however may indicate that lexical stress sensitivity in particular is not as essential in older children's reading as it may be in younger children, adding some tentative support for the notion that metrical and lexical stress should be assessed as separate constructs (e.g. Goodman *et al.* 2010).

Furthermore, the results obtained from Cohort A (comprising children from the earlier Study 2) showed that stress sensitivity did not add significant unique variance to reading comprehension and the phrasing component of fluency over time, when vocabulary, phonological awareness or RAN were added as control factors. However, it was able to predict comprehension over time when IQ was the control variable and stress sensitivity also reached significance (p = .049) when IQ and PA were accounted for. These findings indicate that stress sensitivity can account for unique, independent variance in reading comprehension over time but that it mainly contributes to comprehension via vocabulary, RAN and also PA. When phrasing abilities were examined stress sensitivity was able to account for unique variance in phrasing independently and when IQ was controlled, but it did not reach significance when either of the other control variables were included in the analyses. These findings demonstrated that stress sensitivity perhaps contributes to reading skills differently over time and that theory should incorporate different paths for stress sensitivity's contribution to word reading, reading comprehension and fluency.

These findings also suggested that earlier stress sensitivity (when the children were aged between 7;2 and 9;7 years, mean age 8;2 years) does not play an important, independent role in children's comprehension or phrasing abilities, when the children are on average aged 8;11 years (ranging from 8;1 to 10;1 years). Although this is contradictory to longitudinal studies that have found associations of stress sensitivity with reading skills independently from age, vocabulary and PA over time (e.g. Holliman *et al.* 2010b; Miller and Schwanenflugel 2008), it may just be indicative of stress sensitivity being subsumed in these control variables in the present study and therefore does impact upon reading skills indirectly via vocabulary and phonological processing speed. Additionally, these longitudinal findings may indicate that stress sensitivity is not able to account for growth in reading skills in children of these ages. Thus at some point in development stress sensitivity perhaps ceases to be an important, independent, reading-related skill.

However, contradictory to this claim, when the concurrent data from cohort A's re-test was examined stress sensitivity was able to contribute to comprehension and the phrasing component of fluency, independently from vocabulary, IQ, PA and RAN, and in addition, independently from morphological awareness. This therefore does not support the notion that stress sensitivity ceases to be an independent factor in children's reading skills. It is conceivable however that the youngest children in the Time 2 sample were perhaps facilitating these found associations and therefore it cannot be concluded at this point whether stress sensitivity really does continue to be implicated in reading comprehension and phrasing abilities in children aged above nine years. This requires further examination of specific age groups, which also need to be larger than the samples assessed in this study, which were not very large and may have reduced statistical power.

Furthermore, the obtained results were also contra to Clin *et al.*'s (2009) findings, which showed that sensitivity to stress and morphological awareness were both implicated in children's reading abilities, with MA accounting for greater variance in reading skills in addition to stress sensitivity's contribution. When one considers that the children tested in Clin *et al.*'s study were aged between 9 and 13 years, it may explain the present findings however. Before morphological awareness reaches a point in a child's development where it is an important and necessary skill (perhaps from age 9 years), stress sensitivity plays the key role in children's reading comprehension and fluency and thus can account for independent variance in reading skills, whereas MA does not contribute beyond vocabulary, PA and RAN. Therefore it is proposed that, although stress sensitivity does precede morphological awareness, it is an integral aspect of MA, but that morphological awareness may also play a greater role in children's later reading skills, which is beyond its association with stress. Further exploration of these associations is beyond the scope of this thesis however.

In terms of facilitating the understanding of stress sensitivity in line with theoretical models, the data are mixed. On the one hand the longitudinal data did provide some evidence for an association of stress sensitivity with reading skills that is mediated by vocabulary, phonological awareness and phonological processing speed (Wood *et al.* 2009; Zang and McBride-Chang 2010) since stress sensitivity did not add variance to comprehension and fluency beyond these factors. On the other hand, stress sensitivity was also able to account for unique, independent variance in reading skills beyond the control variables and thus provides support for a direct contribution of stress sensitivity to reading, which is also not mediated by morphological awareness, therefore providing evidence opposing the morphological pathway proposed by Wood, Wade-Woolley and Holliman (2009). These mixed associations therefore do not enable an easier understanding of where in the developmental model stress sensitivity should be placed.

Furthermore, it is argued however that the findings obtained in this study further offer support for the notion that stress sensitivity is implicated in the development of reading skills, rather than being a result of literacy exposure or schooling perhaps. Although earlier IQ, reading comprehension and phrasing abilities were found to account for significant variance in stress sensitivity over time, these associations did not survive once stress sensitivity from Time 1 was included as the auto-regressor, thus showing that lexical stress is not a result of literacy per se. However, given that stress sensitivity itself was only moderately correlated with itself and only accounted for 14.4% of variance in itself over time, it cannot be the case that most of stress sensitivity's variance was already accounted for. Additionally, this small amount of variance in later stress sensitivity accounted for by earlier stress sensitivity is perplexing, indicating that stress sensitivity can only predict a small amount of growth in itself. Furthermore, IQ was only marginally non significant in predicting stress sensitivity over time after the auto-regressor was included, which may be indicative of a change from stress sensitivity to stress awareness over time. This explanation is very tentative however as it requires further testing, which was beyond the scope of this thesis. Nevertheless, it does highlight the need for additional investigations to assess stress sensitivity's development and its role in reading skills further. At this point, no clear answer for stress sensitivity's small association with itself over time is conceivable; however it may be indicative of other factors impacting upon stress sensitivity over time. Thinking back to the proposed relationship between stress sensitivity and morphological awareness, it could also be that morphological awareness plays a role in stress sensitivity's development longitudinally, however due to the non significant associations between these two skills (and because MA was not assessed at Time 1) this claim could not be pursued further but clearly further research is needed.

A final aspect that needs to be briefly examined concerns the observed variability across reliability coefficients of the Lexical Judgment Task. When Cronbach's alpha was computed for cohort A at Time 1 it was very low for the match items subscale (α .17) and mediocre for the no-match items (α .059). At Time 2 both values increased however (α .065 for match, and α .062 for no-match items). In comparison, the cohort B's Time 1 value for match items was α .03 and for no-match items it was α .27. Neither of which are acceptable. These scores did not improve over time, rather they got worse (match items α -.27 and no-match items α .16). No clear explanation for this occurrence is present at current, however it is suggested that these varying alpha values are linked with the sample sizes and the children's ages, and perhaps also linked to a change in implicit versus explicit awareness of stress sensitivity.

Cohort A was marginally bigger than cohort B and displayed greater reliability; they were also younger which may be adding further to the claim that older children do not display stress sensitivity as much as younger children perhaps do. It could also be indicative of a change from sensitivity to stress to a more explicit, stress awareness in cohort B (this does not however explain the very low alpha value observed in the match items sub-scale of the LJT in Cohort A). Overall, it is warranted that this should be explored further in the future.

7.6 Conclusion

In sum, this study assessed the longitudinal and concurrent associations of stress sensitivity with reading skills and found that there is reason to believe that stress sensitivity is related to reading abilities, but perhaps differently across different age groups. No longitudinal associations of stress sensitivity with reading skills were observed that went beyond the relations that vocabulary, IQ, PA and RAN have with reading skills, however this does not indicate that stress sensitivity is not a unique contributor to reading when assessed concurrently.

Chapter 8 – General Discussion

The primary aim of this thesis was to assess whether the newly developed stress sensitivity task was able to measure stress sensitivity better, and more reliably, than an existing task. Overall, this was found to be the case. A second aim was to assess whether the LJT would show associations with children's reading abilities and literacy-related skills, across a range of different age groups. Stress sensitivity was found to be significantly associated with reading skills and reading-related skills, but differences in these associations across age groups were observed. Lastly, the third aim of this thesis was to test whether speech rhythm sensitivity could predict variance in the different components involved in children's reading skill development, concurrently and over time. Although stress sensitivity was not able to predict significant growth in reading comprehension and phrasing once vocabulary, PA and RAN were controlled, it was able to account for unique variance in these skills when assessed concurrently. Each research question will now be explored in more depth, beginning with the evaluation of the Lexical Judgement Task, followed by an examination of the research findings across all studies.

8.1 Lexical Judgement Task evaluation

In order to provide a clearer picture of the associations between rhythmic sensitivity and reading it has been demonstrated that there is a need for a new measure of speech rhythm sensitivity. Some researchers have used non-speech rhythm measures (e.g. Goswami *et al.* 2002; Leong *et al.* 2011; Pasquini *et al.* 2007; Richardson *et al.* 2004; Thomson *et al.* 2006), whereas others assessed rhythmic sensitivity using speech-based stimuli (e.g. Clin *et al.* 2009; Holliman *et al.* 2008, 2010a and b; Kitzen, 2001; Mundy and

Carroll 2012; Wood 2006b; Wood and Terrell 1998b). Again others assessed prosody as part of fluent rendering of text (e.g. Benjamin and Schwanenflugel 2010; Miller and Schwanenflugel 2006, 2008; Schwanenflugel *et. al.* 2004, 2006). Consequently, to systematically measure speech rhythm sensitivity, the need for a simple, easy to use speech rhythm assessment that can be used with a range of children, which is not contaminated by segmental phonology cues, is high. Such a task was developed – namely the Lexical Judgement Task (LJT). Throughout the studies, the usefulness of this task was assessed.

It was of interest to assess whether the LJT was correlated with the DEEdee task, a widely used speech rhythm measure (e.g. Clin *et al.* 2009; Goswami *et al.* 2009; Holliman *et al.* 2012; Kitzen 2001; Mundy and Carroll 2012; Whalley and Hansen 2006), and whether these measures had satisfactory reliability coefficients. The alpha value of the DEEdee task has been reported by Goswami *et al.* (α .45) and Holliman *et al.* (α .37), which were comparable to the coefficients obtained in Studies 1 and 2 (α .47 and .48 respectively), but all fell below the widely accepted .7 mark. Thus it was important to compare the LJT alpha values to the DEEdee values.

The LJT comprised two sets of stimuli, some which were similar based on stress contour and some which were different. Therefore two alpha values were calculated for LJT throughout; in the Pilot study these were satisfactory (α .76 for match items and α .78 for no-match items). The initial research question was whether the LJT would display greater reliability compared to the DEEdee task, so based on these findings it can be said that this was found to be the case. Furthermore, it was assessed whether the new stress sensitivity measure would also display associations with children's reading skills. As was summarised in the previous section, such correlations were obtained across all studies; although these associations did vary depending on the assessed sample. However, overall the LJT can be seen as having been successful in measuring stress sensitivity, displaying satisfactory reliability coefficients and also showing associations with reading and literacy related skills.

The LJT also correlated with the DEEdee task in the Pilot study but was not correlated with the DEEdee task in the second study, and the reasons for this may lie in the idea that the LJT is an assessment of lexical stress and the DEEdee task can be seen as a measure of metrical stress. Originally this was not seen as a potential difficulty as lexical stress is a component of metrical stress and so there should be significant overlap between the two tasks. However, Goodman *et al.* (2010) compared metrical and lexical stress and proposed that these are separate constructs and that metrical stress may be more important for more advanced reading skills whereas lexical stress may be more important in earlier reading skills. This view was partially supported by the current findings as the LJT was more strongly associated with word reading skills in the youngest sample. However, it was also consistently associated with comprehension skills (up until the age of 9 years). In the Pilot study, which also included children aged between five and six years, significant associations were found between performance on the LJT and all reading measures. Furthermore, metrical stress (i.e. the DEEdee task) appeared to be more strongly associated with word reading skills than lexical stress (LJT) was and this could be due to the fact that metrical stress includes aspects of lexical stress, so it cannot be said that either stress sensitivity is more closely related to advanced skills than the other. Although metrical and lexical stress could be seen as separate constructs, they also share some commonalities, as they were found to correlate similarly with reading skills when assessed in the same study. For example, Whalley and Hansen (2006) found relationships between the DEEdee task and reading comprehension in their sample of 8- to 10-year-olds and the LJT also displayed significant relationships with reading comprehension when children of similar ages were assessed. Furthermore, metrical stress includes aspects of lexical stress, as both are based on syllable strength and metrical stress encompasses longer segments than lexical stress does (Slowiaczek *et al*. 2006). Therefore it was predicted that these tasks would correlate highly, as this was not found, it is argued that this was due to the tasks themselves. That is, the DEEdee task may not be a pure metrical stress sensitivity assessment as it appears to be contaminated by segmental phonology cues and also encompasses lexical stress. Furthermore, it was correlated with IQ, which indicates that the task was cognitively demanding, and additionally it is argued that this measure perhaps assesses prosodic awareness rather than prosodic sensitivity.

Bearing in mind that the original LJT comprised 40 items in total, it underwent an item reduction in order to shorten the task so that children (especially younger ones) would not experience fatigue effects (see Chapter 4) when completing the task. Overall the revision of the task was deemed successful; however, a reduction in the alpha values was also observed (α .41 for match items and α .48 for no-match items). Three different stress patterns were included within the stimuli set and it is argued that the items were not unidimensional, which could be a reason for the observed reduction in alpha values, as Cronbach's alpha underestimates the reliability of a task when it is not unidimensional (Miller 1995), or when too few items are included .

To further evaluate the LJT it was of interest to compare the reliability coefficients across all study samples, since differences were observed. Table 8.1 depicts the alpha values obtained across studies, including samples sizes, children's age ranges, LJT score ranges, means and standard deviations (SD).

Table 8.1 Cronbach's alpha reliability coefficients obtained from each study sample

Sample	*n*	Age range (years)	LJT range	Mean (SD)	Alpha match items	Alpha no-match items
Study 1 / 40	69	5;2 – 9;4	15 – 31	23.15 (3.30)	.76	.78
Study 2 / 12	77	7;2 – 9;7	3 – 12	8.43 (1.85)	.41	.48
Study 3 / 12	56	9;9 – 11;10	6 – 12	9.54 (1.63)	-.13	.21
Study 4 / 12	112	4;5 – 7;4	2 – 12	6.79 (1.77)	.62	.66
Study 5 / 12 T1 cohort A	47	7;2 – 9;7	3 – 11	8.42 (1.75)	.17	.59
T1 cohort B	30	9;9 – 10;9	6 – 12	9.63 (1.69)	.03	.27
T2 cohort A	47	8;1 – 10;1	3 – 12	9.02 (2.27)	.65	.62
T2 cohort B	30	10;3 – 11;2	5 – 12	9.53 (1.55)	-.27	.16
T1 whole sample	77	7;2 – 10;9	3 – 12	8.89 (1.82)	.22	.52
T2 whole sample	77	8;1 – 11;2	3 – 12	9.22 (2.02)	.49	.52

Neither study, which used the 12-items LJT, provided alpha values in excess of the generally acceptable .7 mark. However, the task's success as a stress sensitivity measure should not be merely placed on the coefficient values; this will be further discussed shortly. The alpha values were very similar across match and no-match items in Studies 1, 2, 4 and at Time 2 when cohort A or the whole Time 2 sample were examined in Study 5. This demonstrates that both types of stimuli, either same or different stress contours, yielded similar reliability coefficients in most studies. However, the alpha values were overall rather low, which could be seen as problematic. It appears that perhaps the sample sizes as well as the children's ages were implicated in these differing coefficients. To further assess this, the children from all studies that completed the 12-item LJT were grouped into Year groups to calculate the alpha coefficients for the task across these groups; this can be seen in Table 8.2.

Table 8.2 LJT score ranges, mean scores and alpha coefficients across Year groups

Year Group (*n)*	LJT range	Mean scores (SD)	Alpha match items	Alpha no-match items
Reception (33)	2 – 9	6.22 (1.47)	.78	.77
Year 1 (49)	3 – 11	6.66 (1.69)	.53	.58
Year 2 (40)	2 – 12	7.44 (1.92)	.53	.47
Year 3 (50)	3 – 11	8.22 (1.92)	.51	.43
Year 4 (27)	5 – 12	8.81 (1.66)	.13	.47
Year 5 (32)	6 – 12	9.66 (1.66)	.05	.22
Year 6 (24)	6 – 12	9.37 (1.61)	-.43	.21

Interestingly, grouping children by Year groups demonstrates a gradual increase in mean scores from Reception to Year 5, with a slight decrease in Year 6, whereas the alpha values appear to be decreasing continuously, with the highest coefficients observable in the youngest Year group and the lowest coefficients in the oldest Year group. The mean score distributions are also depicted in Figure 8.1.

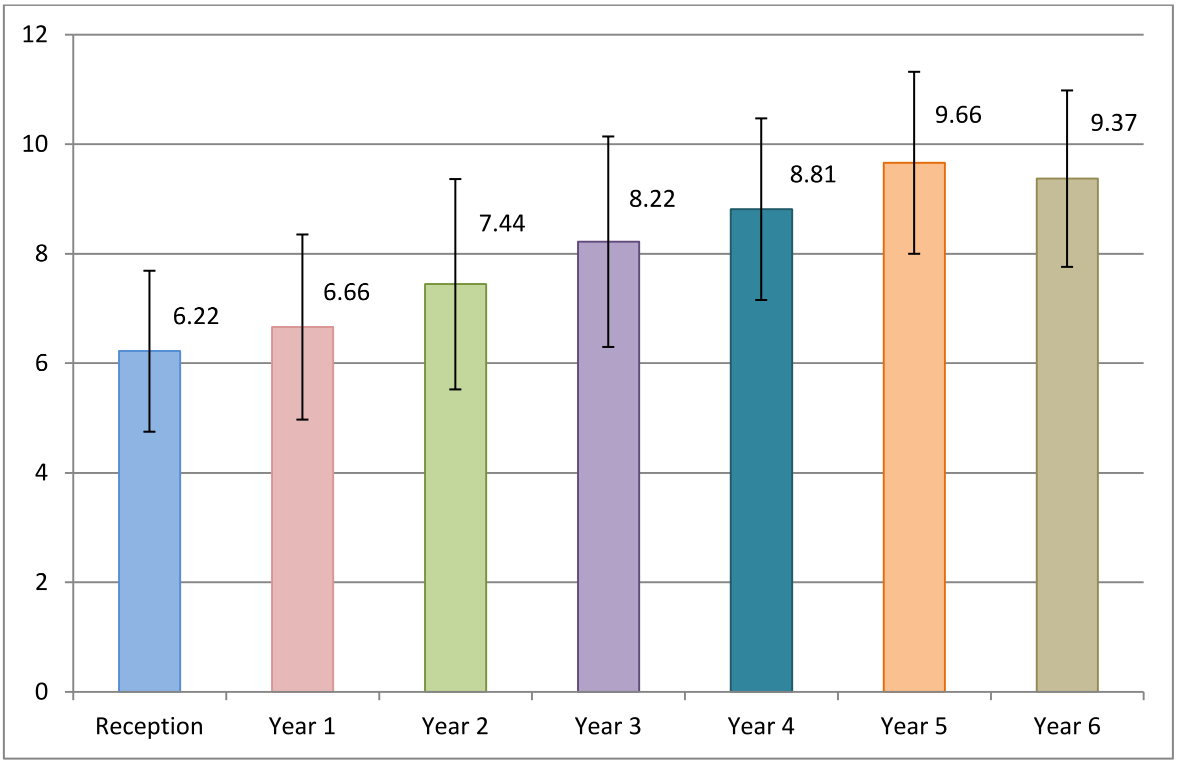

Figure 8.1 Error Bars depicting Lexical Judgement Task mean scores across Year groups

The increase in LJT scores and the simultaneous decrease in alpha coefficients may be indicative of a change from stress sensitivity to stress awareness, as discussed in Chapter 5. This is supported somewhat by the finding that the 12-item LJT was not significantly correlated with IQ until it was measured at Time 2 in Study 5, which suggests that at this point the children are processing the items in the task in a way that is more cognitively demanding, consistent with a change towards an explicit awareness of stress (although this association was not found in the Cohort B sample). This tentative claim clearly requires further testing. Nevertheless this cautious exploration of different Year groups and their LJT performance further highlights the importance of assessing different groups of children (from the same Year or age group) to gain a better understanding of the developmental trajectory of stress sensitivity.

Overall, in terms of internal reliability, neither the DEEdee task nor the LJT reached acceptable levels. However, as has been previously discussed (see Chapter 4), the success of the LJT as a speech rhythm measure should not be solely placed on Cronbach's alpha since this has been shown to be variable, dependent on the multidimensionality of the stimuli as well as dependent on the amount of items included within a task (Cronbach 1951).

The LJT was easily understood and happily completed by the participants whereas the DEEdee task at times seemed to confuse the children as they were not sure what they were meant to do. Therefore, from an observational point of view the LJT appears to be a good measure. Additionally, the task did not appear to be very memory intensive or cognitively demanding, so could be used with a range of children. Furthermore, using filtering procedures to remove (or reduce) segmental information carried by the words enabled a clearer distinction between this task and phonological awareness tasks. Other tasks using speech-based stimuli perhaps still provide phonemic cues (as was argued to be the case with the DEEdee task) and may therefore be more closely related to PA rather than speech rhythm sensitivity per se.

In addition to this, studies have found associations between non-speech stimuli-based tasks and children's reading and phonological awareness (e.g. Corriveau *et al.* 2010; Goswami *et al.* 2002; Huss *et al.* 2011) thus it is interesting to observe that the LJT yielded similar results to these studies. It is unclear how reliable these non-speech (rise time) tasks were however, as the coefficients have not been reported, but the obtained results are widely regarded as informative and essential for the further understanding of rhythmic sensitivity's involvement in children's reading skill development.

Additionally, the LJT was created with the intention to measure only one aspect of prosody, namely (lexical) stress to assess whether this component can test children's sensitivity to rhythm. The included items may have had slightly different durations and intensities when they were recorded. Although every care was taken to pronounce all words in a neutral and equal way, differences could have still been present. This subsequently could have introduced some slight differences when the words were filtered, since the peak (beat, energy) of some vowels might be stronger in some words compared to others therefore the filtering may have reduced segmental phonological cues in some words, and removed it more in others. Nevertheless, the task taps into suprasegmental phonology aspects and does not measure segmental phonology.

Another aspect of the task worth exploring further is that of chance level performance on the LJT across samples, as it was noticed that not all children performed above the 50% chance level cut-off in all studies. Table 8.3 illustrates the participant distribution for chance level and above chance level performances and shows the mean scores obtained on the LJT by these groups.

Table 8.3 LJT chance performance across all samples

Sample	Chance	*n*	Mean (SD)
Study 1 / 40	Chance	16	19 (1.32)
	Above chance	52	24.42 (2.59)
Study 2 / 12	Chance	10	5.1 (1.29)
	Above chance	67	8.92 (1.33)
Study 3 / 12	Chance	3	6.00 (0)
	Above chance	53	9.73 (1.43)
Study 4 / 12	Chance	55	5.38 (1.04)
	Above chance	57	8.14 (1.16)
Study 5 / 12			
T1 cohort A	Chance	6	5.33 (1.21)
	Above chance	41	8.88 (1.31)
T1 cohort B	Chance	2	6.00 (0)
	Above chance	28	9.89 (1.42)
T2 cohort A	Chance	7	4.71 (1.11)
	Above chance	40	9.77 (1.104)
T2 cohort B	Chance	1	5.00 (0)
	Above chance	29	9.67 (1.31)
T1 whole sample	Chance	8	5.5 (1.07)
	Above chance	69	9.29 (1.43)
T2 whole sample	Chance	8	4.75 (1.03)
	Above chance	69	9.74 (1.36)

Few children performed below chance level across these studies, apart from the Study 4 children (which were aged between 4- and 7-years), who appeared to be equally distributed in terms of chance or above chance performance. Observations of these distributions indicate that as the children got older fewer were performing at chance. Interestingly, when the whole sample of Study 5 was examined those children performing on chance level at Time 1 performed even worse at Time 2. Furthermore, those children performing above chance demonstrated increasingly higher scores with increasing age. The associations between chance level performance and implicit/explicit knowledge in terms of stress sensitivity are not very clear at this moment, however, this cautious exploration may be indicating important, underlying relationships between these components and require further investigation.

8.2 The relationship between stress sensitivity and reading skills

Speech rhythm sensitivity has been found to be associated with different literacy-related skills across studies. Some found associations between rhythmic sensitivity and reading skills beyond phonological awareness (e.g. Goswami *et al.* 2002; Holliman *et al.* 2008; Mundy and Carroll 2012) whereas it was also found that speech rhythm enhanced rhyme and phoneme awareness, which consequently facilitated reading (e.g. Wood and Terrell 1998b). Vocabulary knowledge was suggested to link speech perception skills and reading (Walley, 1993), thus associations of speech rhythm sensitivity with vocabulary knowledge have also been proposed (Wood *et al.* 2009), but were not always found (e.g. Wood and Terrell 1998b), or vocabulary was not controlled to assess this directly (e.g. Clin *et al.* 2009; Whalley and Hansen 2006). Furthermore, it was argued that basic auditory processing precedes speech perception abilities developmentally (Kuhl 2004) thus deficits in basic auditory processing must underlie later segmental and suprasegmental speech perception deficits (e.g. Amitay, Ahissar and Nelken 2002; Goswami 2011), which subsequently present themselves in reading impairments. However, not all children who display reading deficits also demonstrate problems with auditory or rhythmic skills (Ramus and Ahissar 2012).

In addition, a vast range of samples have been examined, ranging from pre-school children (e.g. Corriveau *et al.* 2010; De Bree *et al.* 2006; Goodman *et al.* 2010; Leppänen *et al.* 2010), over to primary school aged children (e.g. Fraser *et al.* 2010; Holliman *et al.* 2012; Schwanenflugel *et al.* 2006; Thomson and Goswami 2008) to secondary school aged children and adults (e.g. Ashby 2006b; Clin *et al.* 2009; Leong *et al.* 2011; Pasquini *et al.* 2007; Williams and Wood 2012). Evidence for the importance of speech rhythm in reading development has also been noted across different languages, (e.g. Gutiérrez-Palma and Palma Reyes 2007; Muneaux *et al.* 2004; Poelmans *et al.* 2011; Protopapas *et al.* 2006) providing some evidence for a language-universal implication of rhythmic sensitivity with reading (e.g. Goswami *et al.* 2011); however this view has not been consistently supported yet (Georgiou *et al.* 2010; Hämäläinen *et al.* 2009; Surányi *et al.* 2009). Additionally, few longitudinal studies have been conducted to further provide empirical evidence for speech rhythm sensitivity's implication in the development of children's literacy skills over time (e.g. Corriveau *et al.* 2010; Goswami *et al.* 2012; Holliman *et al.* 2010b; Miller and Schwanenflugel 2008).

To provide a better understanding of the literature, the second research question of this thesis was concerned with stress sensitivity's associations with reading skills and literacy-related components, utilising the same speech rhythm measure. In order to explore these associations further, the obtained findings from this thesis in relation to this research question are summarised below.

Study 1

- Children aged between 5;2 and 9;4 years displayed stress sensitivity, which was correlated with age, vocabulary, IQ, PA, RAN, word reading, reading comprehension and fluency skills.
- No significant group differences on LJT performance by decoding ability groups were found.
- Significant differences between comprehension and fluency ability reading groups were found in terms of their stress sensitivity; the delayed comprehension group displayed lower stress sensitivity scores compared to the advanced group and the poor fluency group also scored lower on LJT than the good fluency group.

Study 2

- Assessment of 7;2- to 9;7-year-olds also revealed significant correlations between stress sensitivity and all three reading skills as well as with RAN, but not with PA.
- Partial correlations (controlling for PA) showed that stress sensitivity remained significantly correlated with reading comprehension but not with word reading or fluency skills, when RAN was controlled no significant associations between stress sensitivity and reading remained.
- No reading ability group differences were found in terms of LJT scores

Study 3

- Assessment of children aged between 9;9 and 11;10 years revealed no significant associations between stress sensitivity and the reading measures or reading-related skills (thus no regression analyses were conducted).
- No significant reading ability group differences were observed in terms of LJT performance, although the comprehension groups did approach to be significantly different.

Study 4

- This study assessed 4;5- to 7;4-year-olds and revealed significant correlations between stress sensitivity and age, receptive vocabulary, nonword reading, word reading, RAN and PA.
- When age was controlled, stress sensitivity was still significantly correlated with nonword reading and approached significance with rhyme awareness; when age and vocabulary knowledge were controlled the correlation with nonword reading remained

significant. Once rhyme or phoneme awareness was partialled out, stress sensitivity was no longer associated with nonword reading.

Study 5

- The sample was divided into Cohort A and B to assess the children that have been previously tested in Studies 2 (Cohort A) and 3 (Cohort B) separately, in order to keep the time between testing points comparable between children in the same cohort.
- The Time 1 (T1) Cohort A, which was aged between 7;2 and 9;7 years, showed significant associations between stress sensitivity and vocabulary and RAN at T1, and also with reading comprehension and phrasing abilities at Time 2 (T2).
- At T2, the Cohort A was aged between 8;1 and 10;1 years, and their T2 stress sensitivity was also significantly correlated with T2 reading comprehension and phrasing, and marginally significantly correlated with morphological awareness.
- Cohort B, which was aged between 9;9 and 10;9 years at T1 and between 10;3 and 11;2 years at T2 did not display significant correlations between stress sensitivity and any reading (related) skills, thus no further analyses were conducted with this cohort.

These findings were collated and are presented in Table 8.4 to summarise the different associations that were found between stress sensitivity and the various assessments used across studies. Overall, stress sensitivity was significantly correlated with all variables across a range of ages, however when smaller age ranges were assessed (for instance in Study 2 and 3) stress sensitivity no longer correlated with vocabulary (Study 2 and 3) nor did it correlate with RAN (Study 3) or PA (both studies). However, when the data from a smaller sample of the Study 2 children were analysed again (Cohort

A at Time 1 in Study 5) significant associations between vocabulary and stress sensitivity were found again. Over time this association diminished and instead stress sensitivity was correlated with IQ. As noted earlier, this may indicate that the children's earlier stress sensitivity changed by the end of the study and had become an explicit awareness of stress.

Furthermore, associations between stress sensitivity and variables of interest perhaps need to be examined with more specific age groups (or Year groups) to detangle the exact relationships. Inclusion of a breadth of different age groups could potentially highlight (or hide) associations that are facilitated by children of specific ages and not necessarily reflect the "true" underlying relations. It seems that stress sensitivity was consistently related to reading comprehension (apart from when the older children in Study 3 and Study 5 were examined). Word reading and overall reading fluency were not found to correlate with stress sensitivity when the assessed samples were older than 9;7 years. The strongest associations of stress sensitivity and word reading were found in the youngest samples, thus indicating that early word reading skills are influenced by aspects of speech rhythm sensitivity. When fluency's individual components were examined significant correlations with phrasing were also found in the Cohort A of Study 5, when those children were aged up to 10;2 years. Nevertheless, it cannot be concluded from this correlation summary whether stress sensitivity's associations change depending on the age of the tested samples; further analyses with larger samples with similar ages are required to ascertain this claim.

Table 8.4 Correlation overview between stress sensitivity, age and literacy (related) measures across all empirical studies conducted in this thesis

Age ranges	**Measures across all research studies**														
	Age	Voc	IQ	Rhyme	Phoneme	Spoon	RAN	Nword	WR	RC	RF	Phrasing	Smooth.	Pace	MA
5.2 to 9.4 year olds (Pilot)	✓	✓	✓	-	-	✓	✓	-	✓	✓	✓	✓	✓	✓	-
4.5 to 7.4 year olds (S4)	✓	✓	-	✓	✓	-	✓	✓	✓	-	-	-	-	-	-
7.2 to 9.7 year olds (S2)	X	X	X	-	-	X	✓	-	✓	✓	✓	✓	✓	✓	
9.9 to 11.10 year olds (S3)	X	X	X	-	-	X	X	-	X	X	X	-	-	-	-
7.2 to 9.7 year olds (cohort A) T1															
LJT + T1 variables	X	✓	X	-	-	X	✓		-	-	-	-	-	-	-
T1 LJT + T2 variables	X	-	-	-	-	-	-	-	X	✓	X	✓	X	X	X
8.1 to 10.1 year olds (cohort A) T2															
LJT and T1 variables	X	X	✓	-	-	X	X	-	-	-	-	-	-	-	-
T2 LJT + T2 variables	X	-	-	-	-	-	-	-	X	✓	X	✓	X	X	X
9.9 to 11.2 year olds (cohort B at T1 and T2)															
both T1 + T2 LJT and variables	X	X	X	-	-	X	X	-	X	X	X	X	X	X	X

Note. Dash (-) = not assessed in study (or at time point); for Study 5 time points are indicated (T1 = Time 1 and T2 = Time 2). Pilot = 40-item LJT measure. Voc = vocabulary; Rhyme, Phoneme and Spoon = phonological awareness measures; RAN = rapid phonological processing; Nword = nonword reading measure; WR = word reading tasks; RC = reading comprehension tasks; RF = fluency scores; Phrasing = phrasing fluency component; Smooth. = smoothness fluency component; Pace = pace fluency component; MA = morphological awareness.
X = non significant correlation, $p > .05$; ✓ = significant correlation, $p < .05$.

Next, the regression analyses outcomes will be summarised before exploring stress sensitivity's predictive power over time.

Study 2

- Stress sensitivity was able to account for unique variance in all three reading skills over and above age and IQ, but could not predict word reading once vocabulary, PA or RAN was accounted for.
- Stress sensitivity also accounted for unique variance in reading comprehension after PA was controlled, but not beyond vocabulary's or RAN's contribution to comprehension. For reading fluency, stress sensitivity's contribution approached significance when PA was controlled, but was not significant when RAN was accounted for. It was however able to contribute to fluency when only vocabulary was the control factor

Study 4

- Regression analyses showed that stress sensitivity could account for variance in word reading, RAN and phoneme awareness; however these associations did not remain once age was controlled for.
- Stress sensitivity further accounted for unique variance in nonword reading and rhyme awareness beyond age and vocabulary knowledge, and also significantly predicted nonword reading beyond age and early word reading skills.
- When pre-readers and beginning readers were examined, stress sensitivity was not significantly correlated with any variable; however its association with beginning

readers' nonword reading skills approached significance and it was significantly associated with the beginning readers' age.

Study 5

- Cohort A's stress sensitivity at T1 was found to account for significant variance in reading comprehension and phrasing ability over time, independently and after IQ was controlled. When PA, RAN and vocabulary were entered as control variables, stress sensitivity could not add unique variance to reading comprehension or phrasing. However, when IQ and PA were controlled, stress sensitivity added unique variance to children's later reading comprehension skills.

- When the T2 data was examined concurrently it was found that stress sensitivity was able to account for unique variance in reading comprehension and phrasing after vocabulary, PA, RAN and MA were all accounted for; the same was found when IQ was included in the model instead of vocabulary knowledge.
- As an additional check, T1 variables that correlated with stress sensitivity at T2 were examined for their predictive power of stress sensitivity over time. IQ, reading comprehension and phrasing individually could predict stress sensitivity, but once the auto-regressor was included in the analyses, these associations became non significant.

Overall, stress sensitivity was not able to predict reading development over time once vocabulary, PA and RAN were accounted for individually, but it predicted word reading over and above IQ and PA longitudinally; it also showed unique contributions to comprehension and phrasing concurrently at Time 2. Individually, and after IQ and PA were controlled, stress sensitivity could predict reading comprehension over time. However when vocabulary, PA and RAN were the control variables the predictive power of stress sensitivity was removed. Controlling for the cognitive demands that are required when completing the phonological awareness task indicated that stress sensitivity was a unique predictor of comprehension; highlighting that it is important to account for those skills that are associated with reading skills and with one another to better understand the associations of each skill with comprehension. Although path analyses would be more suitable to further assess these associations, this was not possible due to the small sample sizes. Additionally, the time range between testing points may not have been large enough to clearly detect longitudinal effects of stress sensitivity.

The research study outcomes further emphasised that stress sensitivity is associated with children's reading skills and with phonological awareness, although the later is more apparent in younger samples. In terms of the longitudinal assessment, perhaps some measurement errors were present that prevented the longitudinal associations from being observed more strongly. The Study 5 sample was split into two cohorts to examine the previous Study 2 and 3 samples separately, which controlled for the time difference between testing points slightly. Nevertheless, since these cohorts differed in age as well, this may have added a further confounding factor.

In sum, perhaps stress sensitivity was not able to account for significant variance in growths of comprehension and phrasing, however it was able to account for variance when tested concurrently, The research conducted offered further support for the association of speech rhythm sensitivity with reading skills, if not as systematic as was anticipated, the assessment of different age groups highlighted that it is essential to assess children across different ages, as it appears that maturation does play part in the development of speech rhythm and subsequently may facilitate reading skills differently at different points in the development.

8.3 Theoretical Models

The reviewed literature provided empirical evidence for a link of prosody to reading skills (e.g. De Bree *et al.* 2006; Goswami *et al*. 2002; Goswami *et al.* 2009; Holliman *et al*. 2008, 2010a and b; Huss *et al.* 2011; Leong *et al.* 2011; Miller and Schwanenflugel 2008; Schwanenflugel *et al*. 2004; Thomson *et al.* 2006; Thomson and Goswami 2008; Whalley and Hansen 2006; Williams and Wood 2012; Wood 2006a and b; Wood and Terrell 1998b), yet the evidence for proposed theoretical models (Wood *et al.* 2009; Zang and McBride-Chang 2010) is still mixed, arguably due to the diversity in assessments and methodological approaches adopted by empirical work in this area. It has been argued that this mixed pattern of findings and mixed methodological approaches pose difficulties in the development of one, clear model for reading development that incorporates speech rhythm or general auditory processing skills (e.g. Goswami 2011; Wood *et al.* 2009; Zang and McBride 2010) and reduces the ability to clearly demonstrate how speech rhythm sensitivity in particular is related to literacy skills. Based on the obtained findings in the present studies, which also examined a range of age groups but utilised the same stress sensitivity measure across all samples, the following models were proposed.

Stress sensitivity and word reading

The research findings from all studies in this thesis produced the word reading model depicted in Figure 8.2.

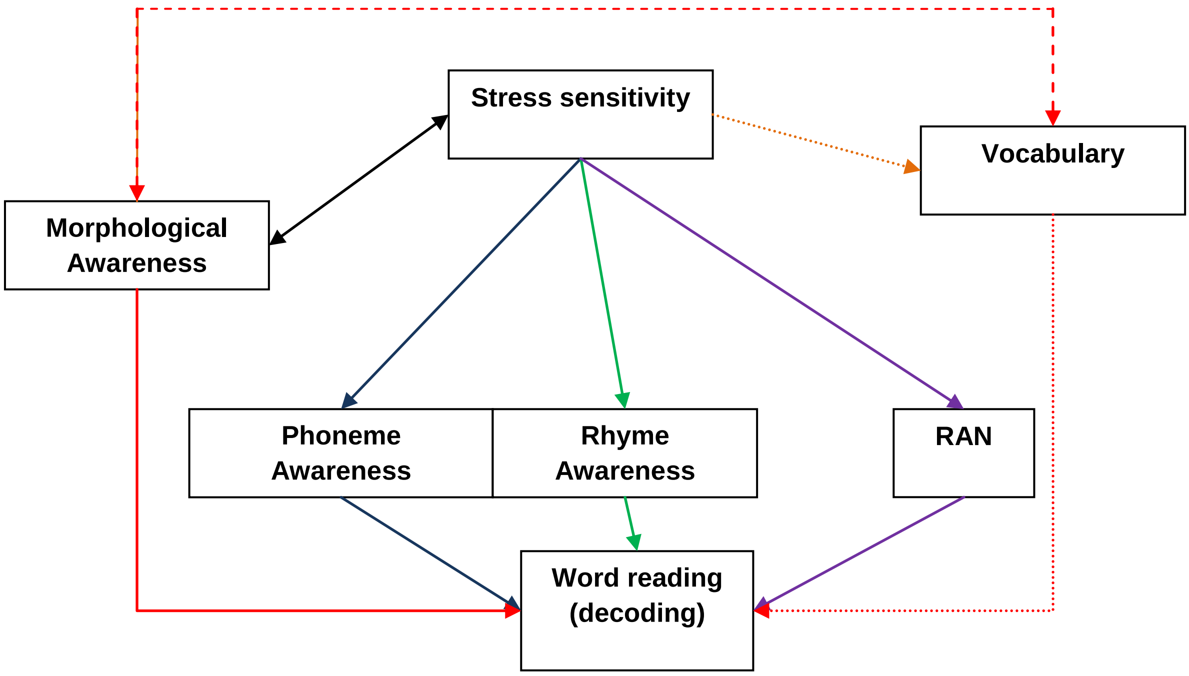

Figure 8.2 Word reading model based on regression analyses outcomes of all studies

No direct contribution of stress sensitivity to reading was found once age, vocabulary, phonological awareness or RAN were controlled for (in the 7;2 to 9;7 year old Study 2 sample), but stress sensitivity was not dependent on vocabulary or IQ (based on children aged between 4;5 and 7;4 years old in Study 4). The blue, green and purple lines in the model depict stress sensitivity's contribution to word reading skills through phonological awareness and RAN.

Since stress sensitivity did appear to be linked to word reading via vocabulary in some samples, the orange, dotted, line was included, indicating a contribution of stress sensitivity to word reading via vocabulary which was not always apparent however. In the 4- to 7-year-olds stress sensitivity could predict nonword reading and rhyme awareness independently from vocabulary, indicating that stress sensitivity directly affects early, segmental phonology components in addition to its association with early vocabulary knowledge. Whereas in the 7- to 9-year-old sample (Study 2) stress sensitivity could not predict word reading beyond vocabulary's contribution to reading, perhaps because stress sensitivity was involved greatly with the children's vocabulary skills. However, in this study no significant correlations between stress sensitivity and vocabulary were obtained.

These findings result in some level of confusion. On the one hand it can be said that stress sensitivity is implicated in early vocabulary knowledge but also offers something unique to nonword reading and early rhyme awareness and subsequently aids decoding, which is in line with Wood's findings (2006b) for instance. However, later in children's development stress sensitivity is not associated with vocabulary knowledge anymore and can also not add unique variance to word reading when vocabulary is controlled, which is contrary to previous relations observed by Holliman *et al.* (2008).

Lindfield *et al.* (1999b) found supporting evidence for the importance of stress in spoken word recognition which subsequently facilitates vocabulary knowledge. It could therefore be hypothesised that early on in children's development stress sensitivity aids vocabulary development, but once this association has been fully utilised, stress sensitivity is no longer directly related to vocabulary; or perhaps the associations are so subtle that the tested samples were not large enough to show underlying relations between vocabulary and stress sensitivity anymore.

Furthermore, although it is not clear yet whether lexical representations are stored with prosodic information, it was observed that 18- to 23-month-olds were able to differentiate between correctly pronounced novel (non) words such as *vaby* and *baby*, showing eye movements directed towards the correctly pronounced words more often than to the mispronounced words (e.g. Swingley and Aslin 2000); in addition these observations were said to be independent from the young children's vocabulary knowledge and ability to produce words, thus indicating that prosodic representations are indeed also stored in the mental lexicon. Although Slowiaczek *et al.* (2006: 507) stated that “(e)vidence does not exist to support a lexical architecture based on stress information.”, it certainly plays a part in early segmentation of words however (Cutler and Mehler 1993). Therefore, it could be that those children whose vocabulary knowledge and mental lexicons are more developed perhaps have stress sensitivity resources left that can be used for with other literacy-related skills (e.g. PA) and consequently aids reading directly.

In addition to this, vocabulary’s contribution to early word reading has been demonstrated previously (e.g. Chiappe, Chiappe and Gottardo 2004) as well as its association with early phoneme awareness (Metsala and Walley 1998), although the literature is mixed with regards to the direct contribution offered by receptive and expressive vocabulary knowledge to word identification skills (e.g. McBride-Chang, Wagner and Chang 1997; Metsala 1997). The Study 4 sample was assessed with a receptive vocabulary measure (which was significantly correlated with stress sensitivity) whereas the Study 2 sample was assessed with an expressive vocabulary measure (which was not significantly correlated with stress sensitivity). Thus, the different findings obtained in the current studies may have been due to the different vocabulary measures that were used (as well as due to the different ages of the samples perhaps). Therefore vocabulary was linked to word reading in the depicted model (dotted red line), indicating that this link may not always be apparent.

Furthermore, stress sensitivity was not significantly correlated with word reading skills in the longitudinal study thus its association to word reading over and above the control variables (including MA) were not assessed and therefore the red lines depicted in the model connecting morphological awareness and vocabulary as well as linking MA directly with word reading are speculative, based on earlier studies (e.g. Carlisle 2007; Clin *et al.* 2009; Nagy, Berninger and Abbott 2006).

When the youngest sample was assessed, which showed significant associations between stress sensitivity and (non) word reading, it was found that stress sensitivity's association with nonword reading was independent from vocabulary knowledge but related to phoneme and rhyme awareness. Since nonword reading abilities are indicative of phonologically based decoding skills, this is not surprising. In line with current views of speech rhythm's association with word reading, the findings obtained from the studies in this thesis provided partial support for the vocabulary pathway and more direct support for the rhyme and phoneme pathways proposed by Wood *et al*. (2009) and also for the association of rhythmic sensitivity with reading via rapid phonological processing speed, proposed by Zang and McBride-Chang (2010). Being sensitive to suprasegmental features may promote speech segmentation skills (e.g. Sawyer 1991), which in turn facilitates segmental awareness. The identification of phonemes in stressed syllables is easier than in unstressed syllables (Wood and Terrell 1998b), therefore aiding children in phoneme identification and manipulation, which promotes phoneme awareness. Likewise, stress sensitivity facilitates identification of vowel occurrences, which aids onset-rime boundary detection in young readers and thus promotes rhyme awareness (Goswami 2003). As shown in the proposed decoding model (Figure 8.2), stress sensitivity could aid decoding skills via rhyme and phoneme awareness in young, beginning readers. In somewhat older (more experienced) readers, the mental lexicon may be more established (including rhythmic aspects of words), thus the contribution of stress sensitivity to decoding occurs via PA as well as vocabulary (as found in Study 2).

Additionally, being able to rapidly access phonological representations could also include suprasegmental aspects, which could explain the observed contribution of stress sensitivity to decoding via RAN, across a larger age range (as observed in Studies 2 and 4). Impairment in RAN (namely slow naming speed) observed in dyslexics for instance could be indicative of underlying neuronal impairments and may be linked to impaired phase locking (as suggested by the temporal sampling framework by Goswami 2011); thus stress sensitivity may be associated with reading via rapid automatised naming processes.

The morphological pathway could not be directly tested on this occasion however a black (solid) line was included in the model indicating a speculative, bidirectional association between stress sensitivity and morphological awareness. Based on the understanding that children are sensitive to rhythmic properties of language very early on (e.g. Cutler and Mehler 1993; Jusczyk, Cutler and Redanz 1993; Mehler *et al.* 1988) and that children learn increasingly more about morphology (e.g. Deacon and Kirby 2004), which comprises stress changing derivations (e.g. Clin *et al.* 2009; Jarmulowicz 2002) it is proposed that the associations between MA and stress sensitivity may change over time and thus perhaps are bidirectional. Early on in children's reading development, being sensitive to different stress patterns could aid the identification of different (stress changing) derivations, and thus promote reading via morphological awareness (Jarmulowicz 2002). Additionally, when children's morphological awareness increases throughout their development, this could aid their ability to identify different stress patterns (and subsequently aid their correct stress placement) when reading of more complex, multisyllabic, words. This clearly requires further research however.

Comparing the results from the 4- to 7-year-olds (Study 4) to that of the older children in Studies 2 and 3, the associations between stress sensitivity and word reading changed; this suggests that at some point in the child's reading skill development stress sensitivity ceases to be implicated directly in word reading. Further analyses are needed to validate this argument however.

Stress sensitivity and reading comprehension

When stress sensitivity's link with reading comprehension skills were examined, the data suggested that stress sensitivity was contributing to comprehension directly, when vocabulary (or IQ), PA, RAN and morphological awareness were controlled concurrently (Time 2 in Study 5), when the children were between 8- and 10-years-old (green solid line in the model in Figure 8.3). Morphology was not able to contribute significant unique variance over and above vocabulary (or IQ), PA and RAN, therefore the red dotted and dashed line was included in the model, showing indirect contributions of MA to comprehension via these skills.

Indirect contributions of stress sensitivity to comprehension were also found, via PA (blue dotted line) or RAN (purple dotted line). In Study 2, stress sensitivity could not account for additional variance once RAN was accounted for, again offering support for Zang and McBride-Chang's (2010) model, whereas in the same study stress sensitivity could predict comprehension in addition to PA's contribution to this skill. Rapid access of phonological representations may also include accessing of stress information (e.g. stress patterns), which could aid the reader in their stress placement and subsequently aid the understanding of sentence structures and meanings (e.g. Schwanenflugel *et al*. 2004).

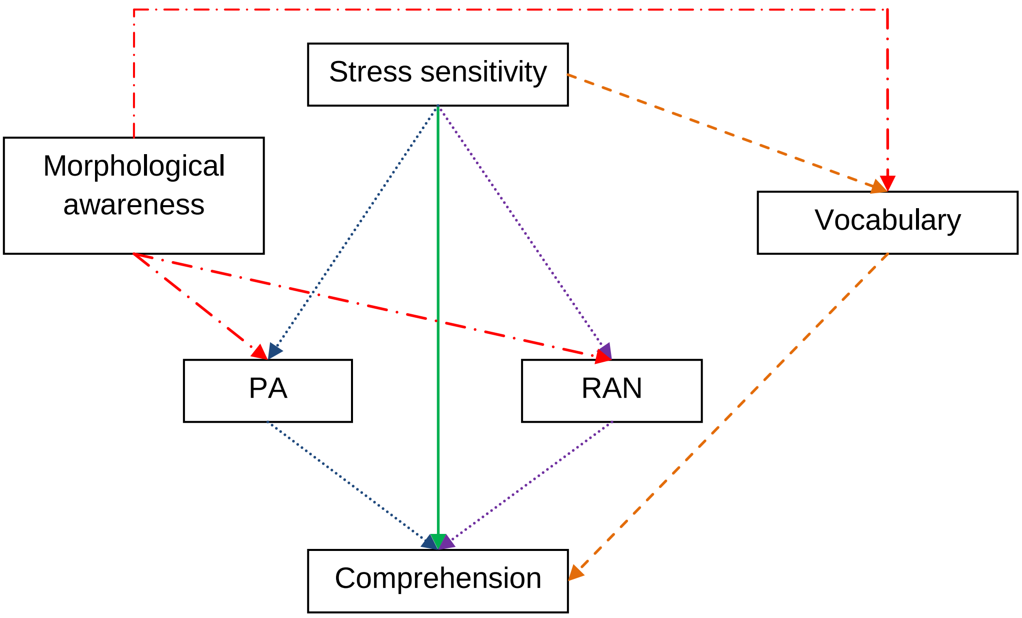

Figure 8.3 Comprehension model based on regression analyses outcomes of all studies

When the longitudinal contribution of stress sensitivity was examined in Study 5, stress sensitivity's association with comprehension was mediated by PA. Stress sensitivity's contribution to PA may be predominantly utilised for the identification of phonemes within the stressed syllables, which could aid the chunking of words into rhythmical utterances that enhance the syntactic and semantic understanding of the texts. This process may become more automatic over time, and thus the contribution of stress sensitivity was not always observed to be via PA (e.g. Study 5 Time 2). Overall, these findings indicated that the associations of stress sensitivity with reading comprehension were dependent on the assessed samples, and perhaps indicative of maturational differences between the children. Furthermore, once vocabulary was controlled, stress sensitivity was also unable to account for unique variance in comprehension skills over time (Study 5), therefore the dashed, orange line was included in the model, to highlight that the direct contribution of stress sensitivity was not always present, and sometimes stress sensitivity's association with comprehension was mediated by vocabulary knowledge. As was proposed for the decoding model, stress information may be stored in the mental lexicon; thus when words are read this information is accessed to extract their meaning. Similarly, the associations of stress sensitivity with vocabulary may have been too subtle (or the sample was too small) to be detected at Time 2 in Study 5, where a direct contribution of stress sensitivity to comprehension was found. Therefore the model also shows stress sensitivity's contribution to reading comprehension via vocabulary. Again, these differences may also be age related, but require further testing.

No line connecting MA and stress sensitivity was included in this model because the data obtained was not sufficient to do so; the findings highlighted a direct association of stress sensitivity to reading comprehension, therefore it was thought that it would be inadequate to propose a link between morphology and stress sensitivity on this occasion. Similarly to the link proposed in the word reading model however it is conceivable that MA and stress sensitivity are associated (e.g. Clin *et al.* 2009) but further investigation of this was beyond the scope of this research.

Stress sensitivity and reading fluency

Lastly, associations between stress sensitivity and fluency were examined; as can be seen in Figure 8.4, the found associations across all studies mirrored those obtained when associations between reading comprehension and stress sensitivity were examined.

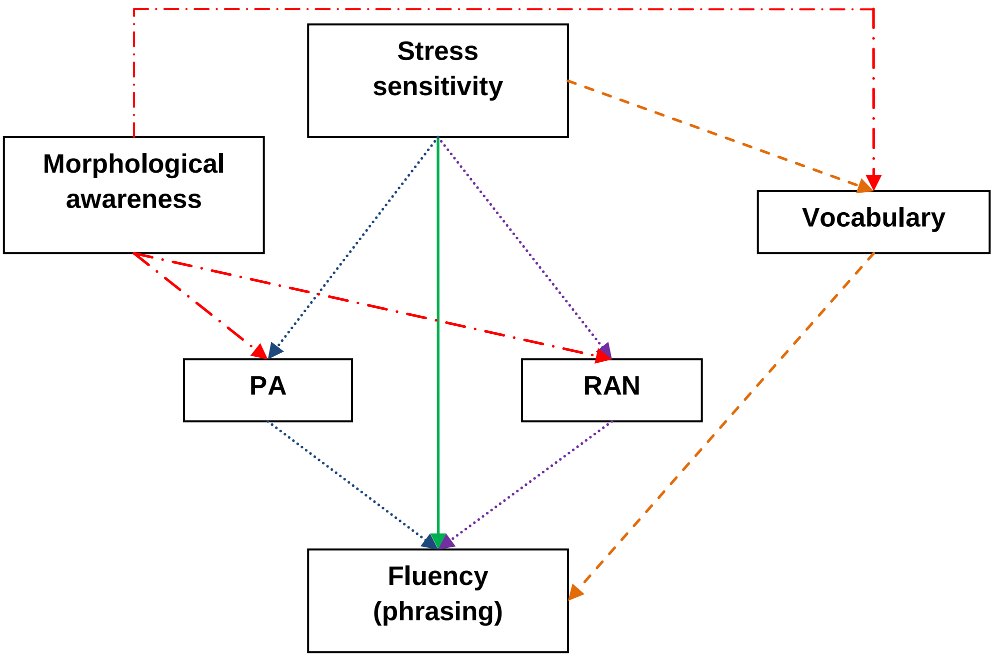

Figure 8.4 Fluency model based on regression analyses outcomes of all studies

Stress sensitivity was significantly correlated with overall fluency ability in Study 2 whereas in Study 4 only the phrasing components were significantly related to rhythm. A direct contribution of stress sensitivity to phrasing ability was observed in the concurrent data (Time 2) from Study 5, whereas in the same study the relationship from Time 1 stress sensitivity with later phrasing ability was mediated by PA (dotted blue line), RAN (dotted purple line) and vocabulary (dashed orange line). In Study 2 stress sensitivity's association with fluency was independent from vocabulary however. Furthermore, as was found with reading comprehension, stress sensitivity was able to account for variance in phrasing ability over and above morphology, which did not add variance once vocabulary (or IQ), PA and RAN were accounted for, thus the red, dotted and dashed, lines were included highlighting morphology's association with phrasing via these skills. In general, these findings were again indicative of varying relationships between stress sensitivity and fluency (components) – dependent on the assessed sample. It is unclear whether these varying observations were due to the different sample sizes or perhaps the children's ages however.

Overall, these findings offer further support for previously found links between speech rhythm sensitivity and decoding (e.g. Wood 2006b), comprehension (Whalley and Hansen 2006) and also with reading fluency (Holliman *et al.* 2010b), and further highlighted that lexical stress is a necessary skill needed for reading development. Nevertheless, its associations with reading development vary depending on the assessed reading skills. This can be seen with word reading especially. In children's early reading development their stress sensitivity seems to be aiding phonological awareness, phonological processing speed and at times vocabulary to help decoding skills. Whereas once children master the ability to decode words, stress sensitivity becomes involved more in comprehension and fluency, independently from its associations with phonological processing skills, vocabulary knowledge and morphology. In line with Kuhn and Stahl's (2003) proposal, once children are able to read accurately and quickly, resources are available to focus on comprehension of texts. Prosody could act as a function to hold auditory sequences in working memory (Frazier, Carlson and Clifton 2006) and thus enable the analyses of text's meanings, which facilitates comprehension (Koriat, Greenberg and Kreiner 2002). Likewise, greater stress sensitivity could enhance phrasing ability (e.g. Miller and Schwanenflugel 2008), perhaps also grounded in children's already established word identification skills (which were promoted by earlier stress sensitivity); analyses controlling for earlier word reading skills were not conducted however when predicting fluency and comprehension and should be included in future analyses.

Although it can be argued that the observed associations do not differ from previously proposed relationships of speech rhythm to reading skills (e.g. Wood *et al.* 2009; Zang and McBride-Chang 2010), they do help to consolidate these earlier findings and also highlight that subtle differences are apparent across stress sensitivity's relationship with specific reading skills. To provide a clearer understanding of stress sensitivity's contribution to reading skills it is necessary to assess the obtained data more specifically by analysing the individual Year or age groups. This would result in even smaller sample sizes in the present studies however and also include issues of varying measures used with children of similar ages, therefore at this point in time it can only be hypothesised that clearer differences between stress sensitivity's relationship with reading (related) skills could be obtained when the data is analysed across particular age groups.

8.4 Methodological Limitations

The studies conducted as part of this thesis aimed to provide a systematic investigation of stress sensitivity's relation with reading skills across different age groups. Several aspects need to be highlighted however that reduced the systematic approach.

Firstly, not all samples were assessed using the same reading tests, despite testing similar age groups. The WRAT 4 was used in Study 2 whereas the YARC was used in Study 3 and subsequently in Study 5. Although standardised scores were used to compare the reading skills this could have introduced problems. For instance, the ability to read a sentence that has one word omitted (as in the WRAT 4 comprehension test) may be assessing reading comprehension slightly differently compared to assessments that require the child to read a passage and then to answer questions about the story (as in the YARC assessments). These slightly different comprehension tasks subsequently could be related to reading comprehension differently. That is, the sentence comprehension measure may not be assessing comprehension skills as complex as the passage reading comprehension measure, which included more words varying in their prosodic richness.

Additionally, the reading fluency measure that was used in Studies 1 and 2 was based on the reading of a short and easy passage, which was then analysed using the Multidimensional Fluency Scale (Rasinski 2003). The children assessed in Study 3 were assessed on fluency based on their reading rate when reading the YARC passages. These passages were longer and more complex, compared to the NEALE passages (Neale 1997), and were not assessed using the MDFS. In Study 5, when the children were re-tested the YARC passage reading was used again but the fluency rate was not included as the fluency measure, instead the recordings were analysed for the phrasing, smoothness and pace components of fluency. To ensure the Time 2 measure was comparable to the Time 1 measure the reading recordings, from those children who were previously assessed as part of the Study 3 sample, were re-analysed using MDFS. Although this did not show that fluency or any components were significantly correlated with stress sensitivity, it could have been that the larger sample in Study 3 would have shown significant associations with fluency (or components of it).

Using this scale was beneficial since it was found in the Cohort A of Study 5 that fluency overall was not significantly associated with stress sensitivity but that the phrasing component was. Thus individual aspects of fluent rendering may be more closely associated with stress sensitivity; this also indicates that merely measuring the rate at which children are able to read a passage may not be the most insightful way of assessing fluency skills, and may not necessarily be associated with speech rhythm. Therefore, ensuring that the same assessments are used across all sub-samples and studies is essential and was unfortunately not as systematic as it should have been across the current studies.

Furthermore, as Schwanenflugel *et al*. (2006) proposed, using more complex passages appears to yield more prosodic renderings of text, which would potentially be more closely related to stress sensitivity measures. However, the decision was made to use a very easy passage in order to also include those children who have limited decoding abilities. Whereas the YARC passages are selected on the basis of the children's decoding skills, so should be suitable for each individual child's reading level and therefore adequately assess fluency.

The children in Study 4 were not assessed on reading comprehension and reading fluency due to their young age. However, some children could have been assessed on these measures; this further highlights the difficulty when assessing a large age range of children in one study. The decision was made to assess all children on the same measures, and in order to keep the testing time to a minimum it was deemed inappropriate to assess some children on additional (comprehension and fluency) measures. Furthermore, a listening comprehension task could have been used with all children to assess whether their oral language comprehension skills were associated with their early reading skills and also with stress sensitivity. This assessment could have been completed with all participants and used as an early comprehension measure, as research has shown that listening comprehension is predictive of later reading comprehension (e.g. Hoover and Gough 1990; Kendeou, White, van den Broek and Lynch 2009) and prosody plays a role in spoken word recognition and also in comprehension (e.g. Cutler, Dahan and van Donselaar 1997).

Another limitation that was present across these studies was that morphological awareness was only assessed in the final study, when some children were re-tested. Due to the focus of this thesis being on speech rhythm sensitivity, morphological awareness was not considered as a potentially important factor throughout. Because morphological awareness increases with age and its importance to reading skills also develops over time (e.g. Deacon and Kirby 2004; Singson, Mahony and Mann 2000) it was seen as sufficient to assess this skill at a later stage. However, given that children are aware of morphological components and utilise these fairly early on, this skill should have been measured more consistently (Carlisle 1995). Similarly, vocabulary, IQ, PA and RAN could have been assessed during the second testing phase in Study 5 in order to draw clearer conclusions of the relationships between stress sensitivity and these skills longitudinally and concurrently.

Furthermore, bearing in mind that sensitivity to stress may only be a residual ability from infancy which fairly quickly progresses to awareness of prosodic features, it could have been that the oldest children (in Years 5 and 6) would have benefitted from different instructions compared to younger children. These instructions could have directed the children specifically to pay attention to the varying rhythm contours of the heard utterance and therefore directly assessed their awareness of stress. In addition, to further investigate the notion of speech rhythm being an implicit rather than an explicit ability in primary school (especially during the first few years of schooling) the children could have been asked how they decided upon the word stimuli being similar or the same after they completed the LJT. This may have further aided the interpretation of the task and helped shed light onto the matter when LJT may become an awareness tasks, rather than a task measuring stress sensitivity.

Lastly, although it can be said that the Lexical Judgement Task is a good measure to indicate children's stress sensitivity, the task requires further development, especially for the use with young children. As Table 8.3 indicated, about half of the whole Study 4 sample performed at chance level, which raises the question whether the task is suitable to be used with children aged between four and seven years. The task may require additional instructions to ensure that the children understand what is being asked from them (see next section), or the computer-based format may not be as suitable to be used with the youngest children and requires replacing. To further assess this and to refine the LJT it would be essential to conduct assessments with samples of 4-, 5-, 6- and 7-year olds separately to identify at which point children are able to complete the task above chance level. Once this has been established, the task could be adapted (or refined) so that the youngest, school-aged, children could be assessed for their stress sensitivity.

8.5 Future research

In terms of the age-related trajectory of speech rhythm sensitivity it is essential to further assess more children, especially much younger ones that have not been exposed to literacy tuition yet. These children should then be followed longitudinally to assess how stress sensitivity changes once these children are exposed to formal literacy tuition and throughout the primary school years. The Lexical Judgement Task may not be suitable for children younger than four-years-old but this would require further testing. In order to complete such studies, initially, the Lexical Judgement Task requires redevelopment in order to be a successful measure for the use with very young populations.

Firstly, a systematic corpus analysis is proposed that examines the printed words that young children are exposed to in terms of their stress pattern properties. Examining the ‘Children’s Printed Word Database’ (Masterson, Stuart and Dixon 2002) for instance could highlight which words and stress patterns children are exposed to the most in early literacy and these words could be used, as well as those stress patterns represented the least, to create a data base for words to be used as stimuli for the LJT. These words would initially be predominantly monosyllabic words, which in the English language are mostly strong syllables (although function words for example are weak). When multisyllabic words are examined a greater range of stress patterns will be present and it would be of interest to further examine if these stress patterns present regularities based on different phonemes, rimes or morphemes presented within these words for example, which would add to the understanding of rhythm across words.

Vousden, Ellefson, Solity and Chater (2011) for example examined a word frequency list of children's texts which included children's early reading vocabulary (Stuart, Dixon, Masterson and Gray 2003) and also examined the CELEX database (Baayen, Piepenbrock and Gulikers 1995) for texts that adults are exposed to and analysed which types of representational units (e.g. whole-word, head-coda, onset-body or graphemes) within monosyllabic words facilitate reading acquisition best. Their analysis showed that whole-word representations are most useful when a small amount of words are being read, whereas graphemic representations are most useful when many words are being read. It is clear that phonological awareness is an essential part of the learning to decode process but less focus has been placed on identifying which mappings from orthography to phonology are the most useful. Vousden *et al.*'s research proposes that "teaching mainly grapheme-sized letter-sound correspondences should be more beneficial than teaching other sized correspondences […] Therefore, it would seem wise to introduce grapheme-phoneme correspondences from the outset of reading instruction, starting with the most useful correspondences first. " (p. 64). It may be the case that certain stress patterns (other than the predominant strong-weak rhythm found in the English language) are also represented frequently in children's vocabularies; these perhaps link to certain grapheme-phoneme units. Highlighting these different stress patterns to children and including the teaching of different rhythms would perhaps aid young readers' stress sensitivity and subsequently enhance their phonological awareness and reading development. Thus, the importance of this proposed corpus analysis is twofold; it could yield important insights into the regularities or frequencies of stress patterns that children are mostly exposed to and it could inform better stimuli choices for assessments.

After the identification of words for a stress pattern database the words should then be recorded and analysed using spectrographs, to assess the recordings in terms of their spectral features (intensity, duration, and stress), which would enable a more systematic selection of words to be used as stimuli for the LJT for instance. This would ensure that words are being selected that are similar in their physical properties as well as follow the same stress patterns, which would ensure that better filtering procedures can be used. As was already stated in section 8.1 some words may have filtered better than others, so it is essential to analyse the recorded words systematically prior to applying filtering procedures to ensure all words are filtered to the same degree, even if this means that some words are filtered at a different Hz level.

Secondly, presentation of the LJT to younger populations may require restructuring in order to be used as an effective measure of speech rhythm sensitivity. Instructing pre-school children to clap to the syllables of words could be used as a training/test phase prior to completing the LJT. This way the children would be asked to focus on the rhythmic properties of the words before completing the LJT, which requires the children to decide whether a filtered word followed the same (or different) stress patterns as a clear spoken word. This initial training phase could be used to assess if the children understood if words followed a rhythmic pattern and would also indicate if the children understood that words differed in rhythmic patterns. Additionally, rather than using the computer to provide the answers for the LJT stimuli, children could be asked to report whether they thought two words had the same or different rhythm to minimise potential errors when pressing the answer buttons. Although the children complete the clear spoken baseline LJT condition as a means to familiarise them with the answering principle to ensure they are able to use the computer buttons to give their answers, there is still potential for errors.

Using a between groups design, one group could be presented with the additional "clapping" prior to completing the LJT whereas another group would receive the "normal" LJT with its brief test trials (four trials with feedback prior to experimental main part of the task). A third group would receive the "clapping" instructions in addition to completing the LJT but with added verbal responses for their answers, rather than mere pressing of the computer buttons. A fourth group would be presented with the LJT that requires a verbal response. These four groups could then be compared to assess which method a) works best for the young participants, and b) to assess whether differences could be observed in terms of their stress sensitivity. It would also be of interest to see whether individual children respond differently to each of these conditions (within-participants design); they could be exposed to each condition on different testing occasions. To minimise practice effects, different stimuli sourced from the stress pattern word data base should be used for the LJT on each occasion. This would show if young children are able to complete the LJT or whether other methods to assess their stress sensitivity are needed. It may be the case that adding a "clapping" instruction would cue the children to pay attention to the rhythmical properties of the words and they would therefore be able to complete the LJT successfully.

Furthermore, children in the secondary school years also require additional testing. It was observed that the oldest children tested rarely reached ceiling level performance on the LJT. If stress sensitivity increases similarly to the ability to utilise prosody in spoken language, then it would be expected that children should get better on the LJT over time (Wells, Peppé and Goulandris 2004). Such an increase was observed, so perhaps towards the end of secondary education adolescences reach proficiency with prosodic skills that are comparable to adults and thus would we able to perform even higher on the LJT. Conversely it could also be that the performance on this task gets worse, as this task was designed to measure sensitivity to stress and it appeared that towards the end of the primary school years children transitioned from an implicit knowledge to a more explicit awareness of stress.

To assess this notion further it would be interesting to assess several groups of children at different ages on a revised LJT, adopting a microgenetic approach utilising self-reports. Microgentic methods aid the understanding of changes in children's development and learning (e.g. see Flynn, Pine and Lewis 2007, for an overview; Kuhn 1995) and would be useful to further understand stress sensitivity's development over a shorter period of time; this has the potential to add to the understanding of the developmental trajectory of speech rhythm and when a shift from sensitivity to awareness of rhythm might occur. The latter would be aided by using self-reports to assess how children made decisions to match word stimuli to be similar or different based on their stress patterns. For instance reporting "I don't know" when asked how the children made a decision to class words as similar or different could be indicative of an implicit knowledge of stress patterns (when the decision was correct), therefore indicating stress sensitivity. Whereas stating that the words followed a similar rhythm for instance would indicate a level of understanding of the words' rhythmical properties and therefore be indicative of stress awareness (explicit knowledge). Critten, Pine and Messer (2012) and Critten, Pine and Steffler (2007) conducted studies investigating children's understanding of spelling representations and whether 5- to 7-year-olds (Critten *et al.* 2007) and 4- to 6-year-olds (Critten *et al.* 2012) showed evidence of implicit or explicit spelling representations, that could be conceptualised within the Representational Redescription (RR) model (Karmiloff-Smith 1992).

Similar studies focussing on speech rhythm and children's reading development would be important. Assessing groups of children aged between 4- and 12-year-olds, weekly, over a period of a few weeks, using the LJT (with self-reports) and age appropriate reading as well as phonological tests would be an important next step. Especially examining children aged between 7-and 9-years in comparison to 9- 11-year-olds would be important, as it was found in the present studies that speech rhythm sensitivity was no longer clearly associated with reading skills in the older samples. Thus, to understand the underlying mechanisms of the observed changes in relationships it is essential to assess these age groups again, with specific focus on a speech rhythm assessment that is followed by a self-report of the children, so that it can be identified whether children are sensitivity to or aware of different stress patterns. Implicit and explicit speech rhythm knowledge may be at the root of these observed changes in relationship between reading and speech rhythm.

Drawing stimuli from the proposed word stress pattern database to create several different LJT versions could be useful to reduce practice effects when the task is used on a weekly basis; and this would aid the understanding of strategies used by children to correctly distinguish between words that match or do not match based on stress patterns, which is not based on the same words and would therefore be indicative of general rules (and strategies) used. Additionally, the use of self-reports could aid the children in their learning, or refinement, of speech rhythm (see Rittle-Johnson 2006 for effect of self-explanation) and the use of microgenetic methods could aid the understanding of how these self-explanations affected the children's learning (e.g. Siegler and Crowley 1991).

In addition to this, the Lexical Judgement Task needs to be assessed further to determine whether the obtained findings were artefacts of the task or the specific samples assessed. Moreover, perhaps re-developing the LJT would yield better alpha reliability coefficients when additional items would be included (for example 18-items to increase power). Using spectrographs to determine the similarity of words in terms of their stress contour could also be carried out to provide additional checks and to assess subtle differences between the words once they have been low-band pass filtered. The suitability of the stimuli in terms of their difficulty and ability to discriminate between poor and good performers could further be explored applying Item-Response-Theory (IRT, Hambleton, Swaminathan, and Rogers1991). This would allow for a more comprehensive assessment and better understanding of the performance, since the "IRT is a theory of measurement that assumes that the performance on a given item can be explained by the latent ability or abilities of a given examinee" (Schatschneider *et al.* 1999: 441).

Overall, the systematic analysis and redevelopment of the Lexical Judgement Task appears to be the most important area for future studies, followed by further assessment of children with this task to aid the understanding of speech rhythm's involvement in children's reading development. Another suggestion for a specific future research study moves away from the use of the LJT and centres on stress sensitivity's role in children's reading comprehension using eye-tracking techniques. This would be a good method to assess how children adopt prosodic contours to written texts when reading silently, and how this relates to their understanding of the read texts. As readers project prosodic contours onto texts and use prosodic boundaries as cues for sentence chunking (Fodor 1998) it would be of interest to assess this with children.

Studies, e.g. by Ashby (2006a) and Ashby and Clifton (2005) in English; Kreiner (2003) in Hebrew and Luo, Yan and Zhou (2012) in Chinese, have examined the role of prosody in reading comprehension using eye-tracking techniques in adult participants. Overall it was found that prosody played a main part in the rendering of the texts when read silently and aided comprehension; but few such studies to date have been conducted to test this with children. Luo *et al.* (2012) also presented low-pass filtered speech prior to presenting visual sentences to their participants and found that Chinese readers are able to project just heard melodies onto the reading material; the prosodic boundary information aided to disambiguate syntactic parsing and therefore helped to integrate disambiguated words into the sentence context. Eye-tracking studies with children have also been conducted but did not focus on reading abilities but the use of prosodic cues to solve speech ambiguities, e.g. Zhou, Su, Crain *et al.* (2011) assessed 4-and 5-year-old Mandarin speaking children and Höhle, Berger, Müller *et al.* (2009) assessed 1- to 4-year-old German children and found that the children were able to make use of prosodic cues to solve ambiguous speech. These findings further support the current understanding of prosody's role in language development, however further research is needed to transfer this knowledge to reading development. Conducting eye-tracking studies with English speaking children, using different conditions of sentence presentation (with and without the prior exposure to filtered sentences) followed by comprehension assessments would be highly interesting and further the current views of speech rhythm's role in literacy development.

Furthermore, the current studies explored whether differences between poor readers and typical readers could be observed in terms of their LJT performance. It was not assessed however whether some children that were classed as poor readers were in fact dyslexic. Future studies could further explore this by examining dyslexic children and normally developing readers on the LJT. No significant differences between poor and typical readers were found in the current studies; however, such differences could be observed when children with specific reading deficits are examined.

A final suggestion for future studies includes the assessment of children with different language backgrounds on the LJT to test if similar results could be obtained, as were found in the current studies. The stress sensitivity task paradigm could easily be adapted for the use in any given language, so has the potential to be utilised as a cross-linguistic tool, which would enable more specific comparisons. For example, in Dutch, which is similar in many rhythmic ways to English, similar patterns of associations between stress sensitivity and reading skills would be expected to be found. Whereas Spanish, which differs to English in it stress placement would potentially indicate different relationships of rhythmic sensitivity with reading skills. A pilot study has been conducted, using a Spanish version of the LJT with 7- to 8-year-old children, which indicated that sensitivity to stress is related to Spanish speaking children's reading comprehension, similarly as was found in the present studies (Tarczynski-Bowles and Calet, in preparation). The study indicated that although the Spanish stress placement is different to English, rhythm is still associated with reading skills, which further highlights and offers support for the importance of this skill.

8.6 Concluding remarks

This thesis demonstrated that the Lexical Judgment Task is a promising new assessment tool that, although it will require further development, could be used with a range of different children to examine their speech rhythm sensitivity. This measure was able to highlight associations between stress sensitivity and reading skills, which aid the conceptualisation of current theoretical models and generally supported previous research findings. Stress sensitivity was linked to vocabulary and phonological processing skills but could also contribute something unique to reading skills, especially to reading comprehension and fluency. Furthermore, assessments of word reading, reading comprehension and fluency skills separately have shown that stress sensitivity may be related to these skills differently across varying age groups, which should be considered when examining the theories and also encourages future studies to assess more specific age groups. These studies require large scale, cross-lagged longitudinal designs in order to systematically explore speech rhythm sensitivity's role in children's reading development. In conclusion, this thesis has demonstrated with a consistent measure that speech rhythm sensitivity, and in particular lexical stress sensitivity, is an important skill in children's early reading development (word reading, reading comprehension and fluency), which should be incorporated in theoretical models of reading development.

Chapter 9 – References

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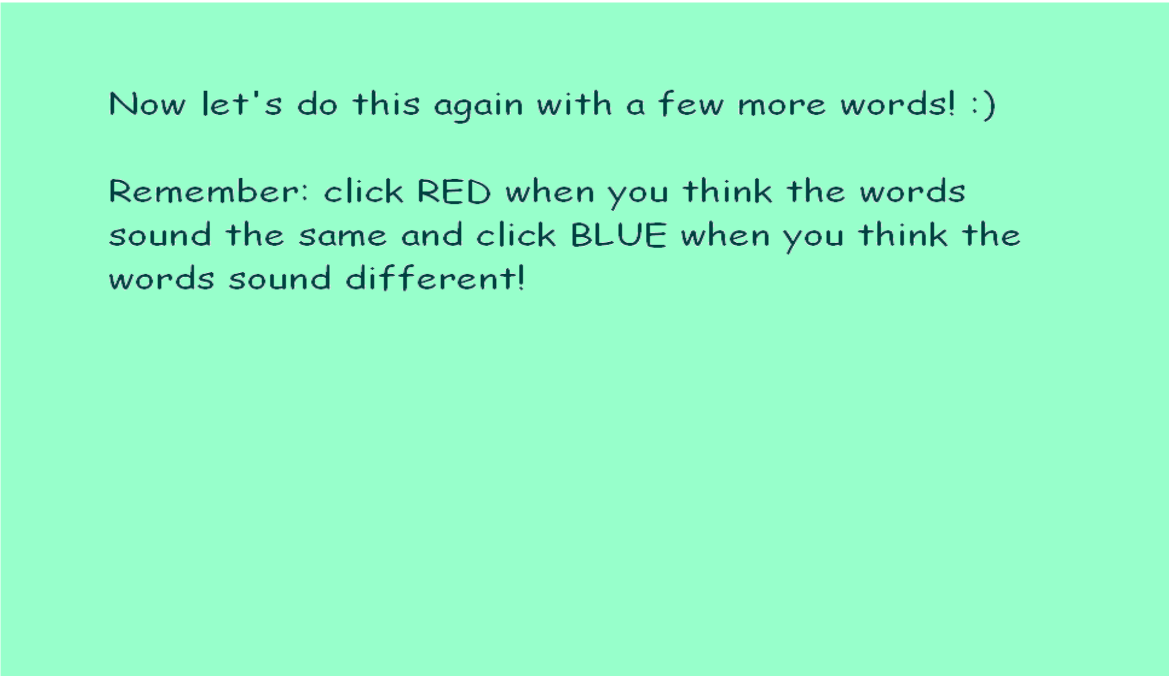
Appendices

Appendix 1 – LJT Task Screenshots

Introductory Screen for LJT Baseline Task

Screen following practice trials, introducing main LJT baseline

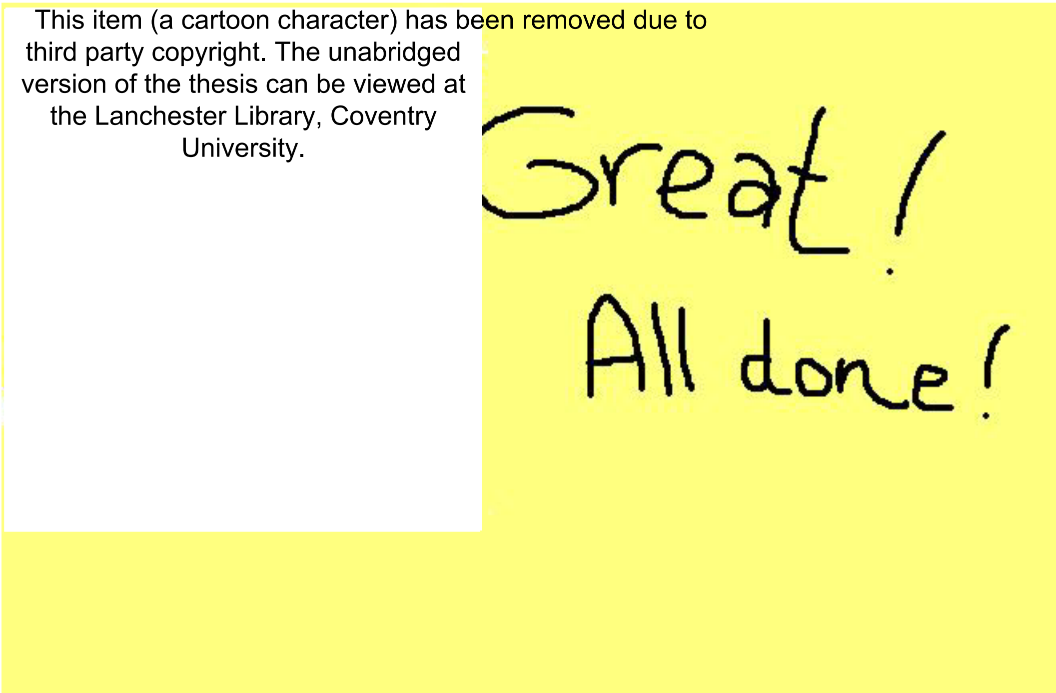


Cartoon character picture in between aural stimuli pairs (to cue children of upcoming sounds)

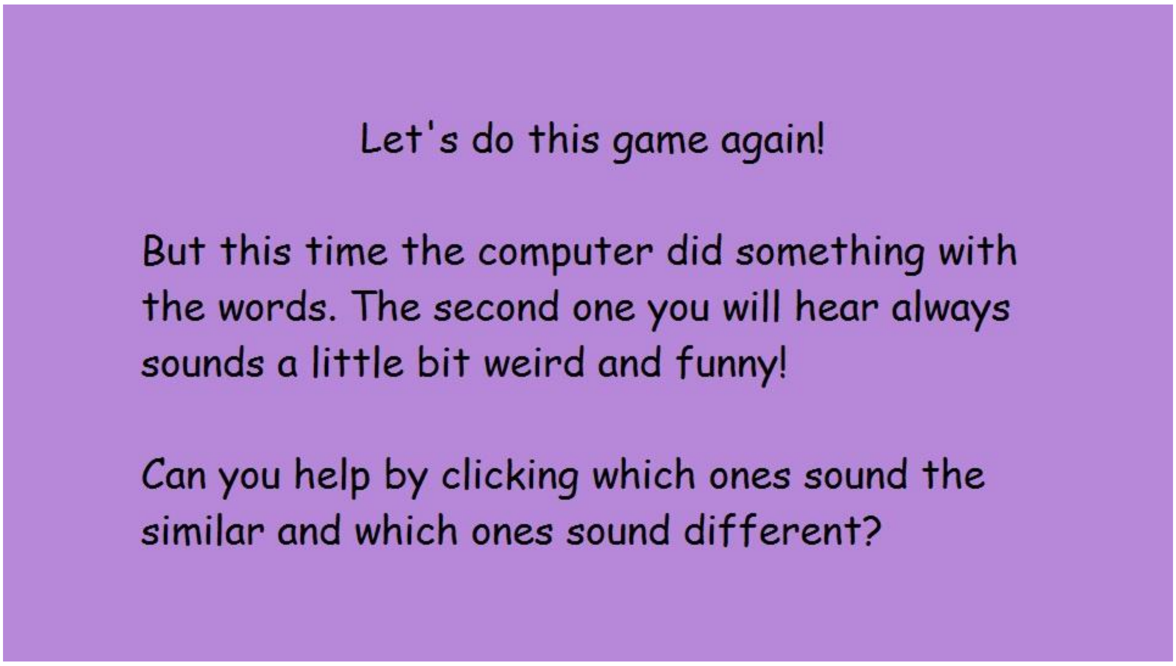
This item (a cartoon character) has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University.

Picture when task completed

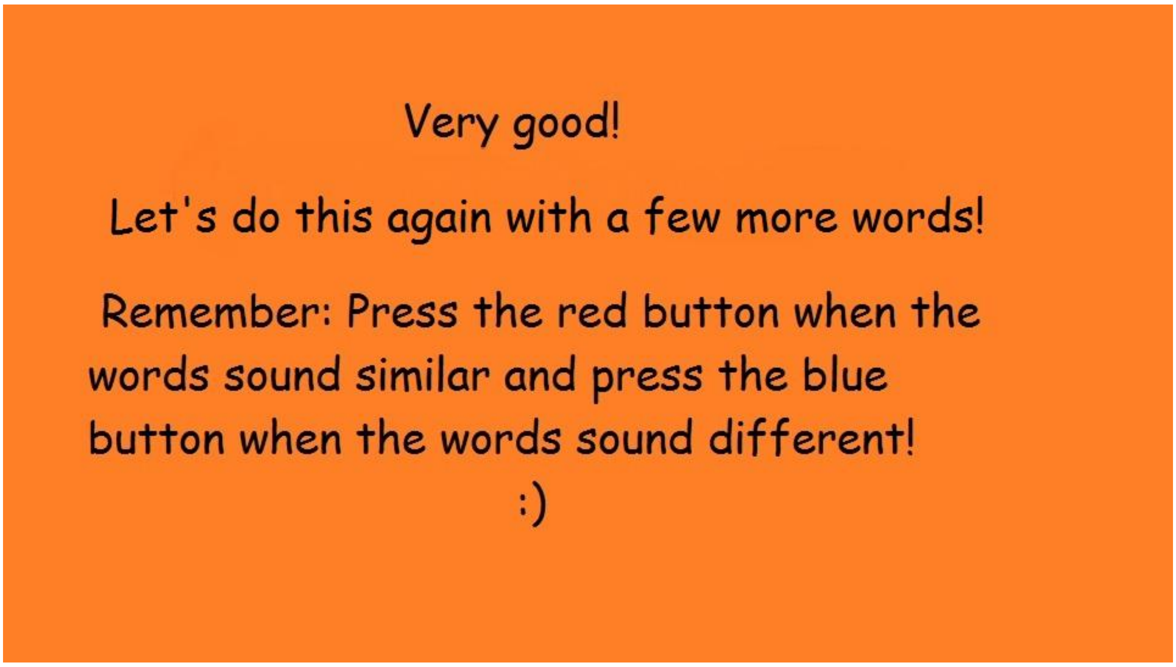
This item (a cartoon character) has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University.



Introductory Screen for LJT Experimental task

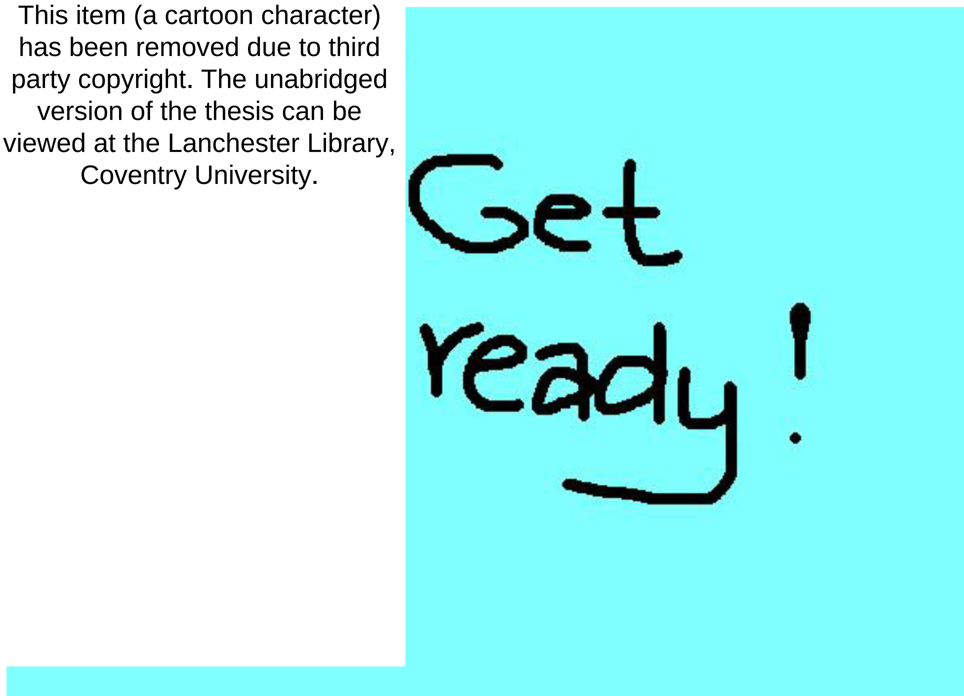


Screen following practice trials, introducing main LJT experiment

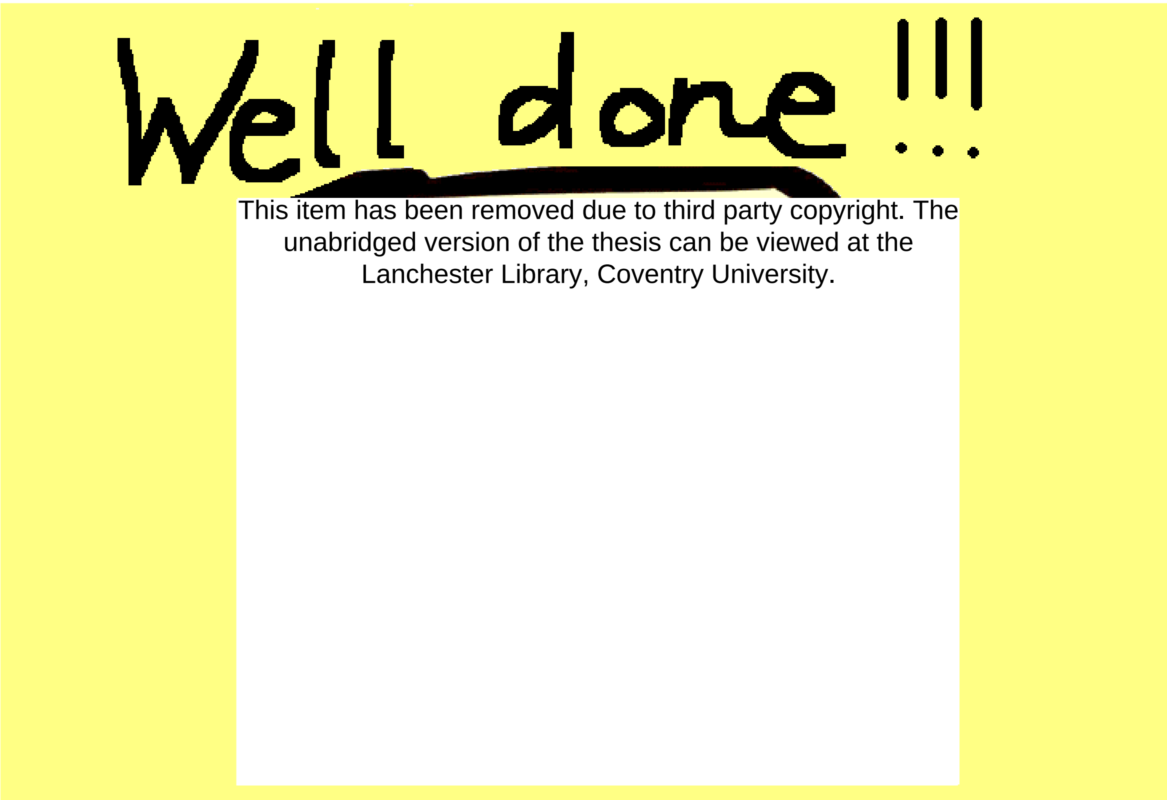


Cartoon character picture in between aural stimuli pairs (to cue children of upcoming sounds)

This item (a cartoon character) has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University.



Picture when task completed



Appendix 2 – LJT 40-item baseline stimuli list

Lexical Judgment Task (40 items) Baseline word pairs with stress patterns (SP)

SP	Word pairs
200	Alphabet - Honeycomb
200	Astronauts - Astronauts
200	Suddenly - Alphabet
200	Suddenly - Burglary
200	Vitamin - Vitamin
200	Burglary - Factory
200	Honeycomb - Factory
200	Jellyfish - Jellyfish
200	Officer - Officer
200	Pantomime - Pantomime
102	Afternoon - Afternoon
102	Disappear - Disappear
102	Kangaroo - Overhead
102	Lemonade - Lemonade
102	Magazine - Mandolin
102	Anymore - Mandolin
102	Introduce - Introduce
102	Magazine - Kangaroo
102	Overhead - Anymore
102	Siamese - Siamese
210	Caretaker - Bonfire
210	Grasshopper - Grasshopper
210	Newspaper - Kingfisher
210	Shopkeeper - Shopkeeper
210	Bonfire - Newspaper
210	Sunglasses - Sunglasses
210	Bricklayer - Bricklayer
210	Kingfisher - Grandmother
210	Timetable - Timetable
020	Computer - Computer
020	Remembered - Commotion
020	Umbrella - Bananas
020	Amazing - Amazing
020	Allotments - Allotments
020	Umbrella - Performance
020	Forever - Forever
020	Inspector - Inspector
020	Performance - Remembered

Appendix 3 – Ethics approvals

Appendix 3A Ethics feedback sheet for Pilot, Study 2 and Study 3

REGISTRY RESEARCH UNIT

ETHICS REVIEW FEEDBACK FORM

(Review feedback should be completed within 10 working days)

Name of applicant: Luisa Tarczynski-Bowles...................... **Faculty/School/Department:** HLS, Psychology …

Research project title: A task validation study investigating monolingual and bilingual school aged children's speech rhythm sensitivity and its relation to reading ability

Comments by the reviewer

1. Evaluation of the ethics of the proposal: Sound ethics proposal with full attention to detail.
2. Evaluation of the participant information sheet and consent form: Clear and appropriate for intended audiences. Check through for some minor typos.
3. Recommendation: (Please indicate as appropriate and advise on any conditions. If there any conditions, the applicant will be required to resubmit his/her application and this will be sent to the same reviewer). [X] Approved - no conditions attached [ ] Approved with minor conditions (no need to resubmit) [ ] Conditional upon the following – please use additional sheets if necessary (please re-submit application) [ ] Rejected for the following reason(s) – please use other side if necessary [ ] Further advice/notes - please use other side if necessary

Name of reviewer: Dr. Rebecca Jenks ....

Signature: RAJenks ....

Date: 15th July 2010 ....

Appendix 3B Ethics Feedback sheet for Study 4

REGISTRY RESEARCH UNIT

ETHICS REVIEW FEEDBACK FORM

(Review feedback should be completed within 10 working days)

Name of applicant: Luisa Tarczynski-Bowles .... **Faculty/School/Department:** ……HLS/ PBS……………………

Research project title:

Comments by the reviewer

1. Evaluation of the ethics of the proposal:

This ethics proposal relates to on-going research towards the award of a PhD. The student is now entering the final stages of data gathering and has been engaging with this school for some time. The project involves a vulnerable group, researching children between the ages of 4 and 6 years. However, it seems that all reasonable measures to protect confidentiality and reduce any risks of harm have been addressed, and the nature of the research involves activities that are within the normal remit of what would happen during a typical school day. Children and parents are also aware that they are able to withdraw from the study. The methodology seems appropriate to the aims of the project.

2. Evaluation of the participant information sheet and consent form:

The method of consent is unusual because it involves an 'opt-out' methodology. However, I am aware that this is now quite common practice in research in schools where the research activities do not significantly deviate from the usual school activities, and therefore this would seem to be an appropriate mechanism for this study and will presumably increase participation. The only suggestions I would make are as follows:

1. The school should be asked to publicise the research through displaying posters and discussing the research with parents for example, to ensure that all parents are aware of it and have the best opportunity to opt-out should they have any reservations.
2. The researcher should consider what provisions there are in place to ensure that parents for whom English is not their first language or parents who may have low levels of literacy are appropriately informed.

3. Recommendation:

(Please indicate as appropriate and advise on any conditions. If there any conditions, the applicant will be required to resubmit his/her application and this will be sent to the same reviewer).

☐ **Approved - no conditions attached**

☐ Approved with minor conditions (no need to resubmit)

☐ Conditional upon the following – please use additional sheets if necessary (please re- submit application)

☐ Rejected for the following reason(s) – please use other side if necessary

☐ Further advice/notes - please use other side if necessary

Please see notes above.

Name of reviewer: Helen Poole ....

Signature: *Helen Poole* ....

Date: 14.11.11 ....

Appendix 3C Ethics Feedback sheet for Study 4

REGISTRY RESEARCH UNIT

ETHICS REVIEW FEEDBACK FORM

(Review feedback should be completed within 10 working days)

Name of applicant: Maria Luisa Tarczynski-Bowles....... **Faculty/School/Department:** HLS/ Psychology and Behavioural Sciences...

Research project title: Can stress rhythm sensitivity predict reading: a longitudinal assessment

Comments by the reviewer

1. Evaluation of the ethics of the proposal:

The project is ethically sound.

2. Evaluation of the participant information sheet and consent form:

The required forms are included.
It may be worthwhile to include some form of debriefing for both the parents, and children. They have given up some time so perhaps give something back to these individuals.

3. Recommendation:

(Please indicate as appropriate and advise on any conditions. If there any conditions, the applicant will be required to resubmit his/her application and this will be sent to the same reviewer).

[ ] Approved - no conditions attached

[X] Approved with minor conditions (no need to resubmit)

Consider debriefing information, including useful weblinks/references etc

[ ] Conditional upon the following – please use additional sheets if necessary (please re-submit application)

[ ] Rejected for the following reason(s) – please use other side if necessary

[ ] Further advice/notes - please use other side if necessary

Name of reviewer: Andy Johnson...

Signature: ....

Date: 04/10/11..

Appendix 4 – Participant Information Sheets (PIS)

Appendix 4A – PIS for Studies 1 to 3

Participant Information Sheet

Study Title:

A task validation study investigating school aged children's speech rhythm awareness and its relation to reading

Your child is being invited to take part in a research study. Before you agree for them to participate, it is important that you understand the purpose and nature of the study.

What is the purpose of this study?

I am interested in finding out whether or not pure speech rhythm can be assessed and subsequently linked to reading ability in children.

Why have I been approached?

I am looking to recruit children who are aged between 5 and 11 years old. I am writing to all the parents at the school whose children are in this age group to see if they are willing for their son/daughter to take part in this study.

Do we have to take part?

No. You, or your child, are under no obligation to take part. If you decide your child can participate, then you may keep this information and you would need to fill out a consent form stating that it is alright with you to approach your child as a participant in this study. You are free to withdraw your consent for your child at any time, without any consequences, should you change your mind.

What will happen to my child if s/he takes part?

S/he will be asked to complete a short IQ assessment, a simple reading task (which will be audio recorded) and some tasks that assess how sensitive to sounds in speech s/he is. This sensitivity is known as phonological awareness and is linked to reading and spelling ability. These assessments will be completed on one occasion. On a second occasion s/he will be asked to complete tasks that measure prosodic sensitivity. This is the awareness of rhythm in speech.

What are the possible disadvantages and risks of taking part?

There are few disadvantages and risks for the children who take part in this study. However, the children will be assessed during school hours, at a time arranged and agreed with their class teacher. I am asking the children to complete the assessments on two to three occasions to keep the time that they are out of the classroom to a minimum. Each session will last up to 30 minutes.

What are the possible benefits of taking part?

Based on work so far, I expect to find that sensitivity to speech rhythm is linked to reading ability and that good speech rhythm sensitivity can predict reading development. If this is the case, further work can be promoted in establishing contemporary reading theories including speech rhythm sensitivity. Also, comparing this sensitivity across children from different age groups will aid in establishing the nature of its development and consequently aid in establishing ways to promote it in children with speech rhythm deficits.

What if something goes wrong?

The research will be conducted at school, in close proximity to staff members who will be able to monitor the activities. The children are able to indicate if they do not wish to take part any longer and will return to the classroom without question. If you are unhappy with the conduct of the study please do not hesitate to contact me directly in the first instance using the number at the end of the sheet.

What will happen if I don't want to continue with the study?

You, or your child, are free to withdraw at any point during the study, and up to four weeks after participation. You or your child will not be penalised in any way for doing so. Your child will be allocated a unique participant number in order for the data to be identified. Please contact me to request that your data be withdrawn quoting your participant number at the time. Any information collected about your child will then be destroyed.

Will our taking part in the study be kept confidential?

Yes. Each child taking parting in this study will be allocated a unique participant number (which will be given to the child and you as a parent on the debrief form after participation). This number will be used to identify your child's data, as no names will be noted on the assessments. This way they cannot be identified from any data collected. The school will not be given any of the test scores without your written consent. If the school asks for the data, I will contact you to ask if you are willing for the scores to be given to them. Otherwise I will retain it. All data and data results will be stored in a locked filing cabinet and destroyed as soon as the scores have been inputted into a computer file. The children's consent forms will be stored in a separate, locked cabinet and destroyed after completion of the project.

What will happen to the results of the research study?

The results will be written up as part of my doctoral thesis and may also be presented at academic conferences.

Who is organising and funding the research?

The research is organised by Luisa Tarczynski-Bowles, who is a postgraduate PhD students at Coventry University, under supervision of Dr Clare Wood, CPsychol. AFBPsS FHEA, who is a member of the Applied Research Group in Reading Development. The project is funded by the PhD Studentship.

Who has reviewed the study?

The Coventry University Ethics Committee has reviewed and approved this study.

Contact details:

Mrs Luisa Tarczynski-Bowles BSc

Psychology Department

Coventry University

Priory Street

Coventry

CV1 5FB

Tel: 024 76 88 7023

Email: tarczynm@uni.coventry.ac.uk

Appendix 4B – PIS for Study 4

Participant Information Sheet

Study Title:

Do pre-readers show sensitivity to stress?

Your child is being invited to take part in a research study. Before you agree for them to participate, it is important that you understand the purpose and nature of the study.

What is the purpose of this study?

I am interested in finding out whether stress rhythm sensitivity is a skill present in young pre-readers or whether this skill is only present after children have been exposed to reading tuition. Additionally, a new stress rhythm sensitivity measure for the use with young children is being validated.

Why have I been approached?

I am looking to recruit children who are between 4 and 7 years old and are either pre-readers or beginning readers. I am writing to all the parents at the school whose children are in this age group to see if they are willing for their son/daughter to take part in this study.

Do we have to take part?

No. You, or your child, are under no obligation to take part. If you decide your child can participate, then you may keep this information and you do not need to do anything further. You are free to withdraw your consent for your child at any time, without any consequences, should you change your mind.

If however you <u>do not want</u> your child to take part, then you would need to fill out the attached form and return it to the reception of your school.

What will happen to my child if s/he takes part?

S/he will be asked to complete a short word reading task to determine whether s/he is a pre-reader or beginning reader. Additionally, to measure stress rhythm sensitivity, the sensitivity to beats and rhythms in words, s/he will be asked to complete a short, computer-based test which involves listening to audio recordings of words. A brief rhyme detection task and a colour/object naming task will also be administered. Lastly, the children are asked to point to pictures of words, as a means to determine their vocabulary knowledge.

What are the possible disadvantages and risks of taking part?

There are few disadvantages and risks for the children who take part in this study. However, the children will be assessed during school hours, at a time arranged and agreed with their class teacher. I am asking the children to complete the assessments in one session, which will last up to 30 minutes.

What are the possible benefits of taking part?

The findings from this study will add to the growing research in the area of stress rhythm sensitivity. One important aspect which requires further research evidence is that of pre-readers' stress sensitivity and the direction of the relationship between this skill and reading development. The current study will be able to draw conclusions on these aspects and provide clearer theoretical understanding.

What if something goes wrong?

The research will be conducted at school, in close proximity to staff members who will be able to monitor the activities. The children are able to indicate if they do not wish to take part any longer and will return to the classroom without question. If you are unhappy with the conduct of the study please do not hesitate to contact me directly in the first instance using the number at the end of the sheet.

What will happen if I don't want to continue with the study?

You, or your child, are free to withdraw at any point during the study, and up to four weeks after participation. You or your child will not be penalised in any way for doing so. Your child will be allocated a unique participant number in order for the data to be identified. Please contact me to request that your data be withdrawn quoting your participant number at the time. Any information collected about your child will then be destroyed.

Will our taking part in the study be kept confidential?

Yes. Each child taking parting in this study will be allocated a unique participant number (which will be given to the child and you as a parent on the debrief form after participation). This number will be used to identify your child's data, as no names will be noted on the assessments. This way they cannot be identified from any data collected. The school will not be given any of the test scores without your written consent. If the school asks for the data, I will contact you to ask if you are willing for the scores to be given to them. Otherwise I will retain it. All data and data results will be stored in a locked filing cabinet and destroyed as soon as the scores have been inputted into a computer file. The children's consent forms will be stored in a separate, locked cabinet and destroyed after completion of the project.

What will happen to the results of the research study?

The results will be written up as part of my doctoral thesis and may also be presented at academic conferences.

Who is organising and funding the research?

The research is organised by Luisa Tarczynski-Bowles, who is a postgraduate PhD students at Coventry University, under supervision of Professor Clare Wood, CPsychol. AFBPsS FHEA, who is a member of the Applied Research Group in Reading Development. The project is funded by the PhD Studentship.

Who has reviewed the study?

The Coventry University Ethics Committee has reviewed and approved this study.

Appendix 4C – PIS for Study 5

Participant Information Sheet

Study Title:

Can speech rhythm sensitivity predict reading: a longitudinal assessment

Your child is being invited to take part in a research study. Before you agree for them to participate, it is important that you understand the purpose and nature of the study.

What is the purpose of this study?

I am interested in finding out whether stress rhythm sensitivity can predict reading ability one year after initial assessment and how stress rhythm sensitivity changes over time.

Why have I been approached?

Your child has taken part in a research study during the last school year, where we were interested in finding out if there is a link between sensitivity to stress and reading ability. To assess how this skill changes over time and if reading is closely linked to this skill a follow-up study is now being conducted. For this all the children who took part in the initial study are invited to be re-assessed on a reading and speech rhythm measure.

Do we have to take part?

No. You, or your child, are under no obligation to take part. If you decide your child can participate, then you may keep this information and you do not need to do anything further. You are free to withdraw your consent for your child at any time, without any consequences, should you change your mind.

If however you do not want your child to take part, then you would need to fill out the attached form and return it to the reception of your school.

What will happen to my child if s/he takes part?

S/he will be asked to complete a word reading task and a reading comprehension task (which will be audio recorded). To measure stress rhythm sensitivity, the sensitivity to beats and rhythms in words, s/he will be asked to complete a short, computer-based test which involves listening to audio recordings of words.

What are the possible disadvantages and risks of taking part?

There are few disadvantages and risks for the children who take part in this study. However, the children will be assessed during school hours, at a time arranged and agreed with their class teacher. I am asking the children to complete the assessments in one session, which will last up to 30 minutes.

What are the possible benefits of taking part?

Based on work so far, I expect to find that sensitivity to speech rhythm (measured during the last study) can predict reading ability (measured during the current study). If this is the case, further work can be promoted in establishing contemporary reading theories including speech rhythm sensitivity and potential interventions can be informed through these findings. Furthermore, the children can benefit from the added reading practice they receive during testing.

What if something goes wrong?

The research will be conducted at school, in close proximity to staff members who will be able to monitor the activities. The children are able to indicate if they do not wish to take part any longer and will return to the classroom without question. If you are unhappy with the conduct of the study please do not hesitate to contact me directly in the first instance using the number at the end of the sheet.

What will happen if I don't want to continue with the study?

You, or your child, are free to withdraw at any point during the study, and up to four weeks after participation. You or your child will not be penalised in any way for doing so. Your child will be allocated a unique participant number in order for the data to be identified. Please contact me to request that your data be withdrawn quoting your participant number at the time. Any information collected about your child will then be destroyed.

Will our taking part in the study be kept confidential?

Yes. Each child taking parting in this study will be allocated a unique participant number (which will be given to the child and you as a parent on the debrief form after participation). This number will be used to identify your child's data, as no names will be noted on the assessments. This way they cannot be identified from any data collected. The school will not be given any of the test scores without your written consent. If the school asks for the data, I will contact you to ask if you are willing for the scores to be given to them. Otherwise I will retain it. All data and data results will be stored in a locked filing cabinet and destroyed as soon as the scores have been inputted into a computer file. The children's consent forms will be stored in a separate, locked cabinet and destroyed after completion of the project.

What will happen to the results of the research study?

The results will be written up as part of my doctoral thesis and may also be presented at academic conferences.

Who is organising and funding the research?

The research is organised by Luisa Tarczynski-Bowles, who is a postgraduate PhD students at Coventry University, under supervision of Professor Clare Wood, CPsychol. AFBPsS FHEA, who is a member of the Applied Research Group in Reading Development. The project is funded by the PhD Studentship.

Who has reviewed the study?

The Coventry University Ethics Committee has reviewed and approved this study.

Appendix 5 – Certificate

Certificate for children as reward for participation.

Appendix 6 – “Consent” form

Project Agreement

Unique Reference Number:_____________

☐ Luisa has told me about her work and I understand what I will be asked to do if I work with her.

☐ My reading will be recorded so Luisa can listen to it again after I worked with her and that is fine by me.

☐ I would like to take part in this speech rhythm study with Luisa.

☐ I know that I can change my mind about working with her whenever I want to and this will be ok.

My name is: ____

My signature: ____

Date: _____________

Researcher’s signature:

Unique Reference Number:_____________

You will need to tell me this code if you do not want me to use your test results in my study!

Appendix 7 – LJT 12-item baseline stimuli list

Lexical Judgement Task Baseline word pairs with stress patterns (SP) for 12-item version

SP	Word pairs
102	Kangaroo - Overhead
102	Magazine - Mandolin
102	Introduce - Introduce
102	Siamese - Siamese
210	Caretaker - Bonfire
210	Newspaper - Kingfisher
210	Shopkeeper - Shopkeeper
210	Bricklayer - Bricklayer
020	Bananas - Commotion
020	Computer - Computer
020	Allotments - Allotments
020	Umbrella - Performance

Appendix 8 – Correlation matrix (Study 5)

Correlation matrix between Time 1 variables, Time 2 reading skills, MA and stress sensitivity across the whole sample (*N* = 77)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Age	-												
2. Vocabulary	.499***												
3. IQ	-.213	.521***	-										
4. PA	.318**	.564***	.430***	-									
5. RAN	-.378**	-.494***	-.218	-.608***	-								
6. LJT	.304**	.329**	-.041	.288*	-.309**	-							
7. Word reading	-.095	.332**	.463***	.587***	-.564***	.137	-						
8. Comprehension	.281*	.593***	.434***	.669***	-.568***	.329**	.604***	-					
9. Fluency	.341**	.561***	.293**	.695***	-.732***	.273*	.661***	.731***	-				
10. Phrasing	.369**	.590***	.280*	.702***	-.684***	.288*	.636***	.754***	.938***	-			
11. Smoothness	.260*	.510***	.343**	.687***	-.691***	.230*	.594***	.669***	.902***	.785***	-		
12. Pace	.288*	.408***	.166	.479***	-.590***	.215†	.558***	.543***	.873***	.735***	.662***	-	
13. MA	.436***	.614***	.259*	.547***	-.345**	.448***	.275*	.510***	.372**	.448***	.317**	.223††	-
14. LJT	.085	.234*	.210	.168	-.130	.400***	.183	.258*	.195	.267*	.107	.140	.288*

Note. Time 2 variables are shaded in grey. PA = phonological awareness; RAN = phonological processing speed; Phrasing, Smoothness and Pace = components of fluency; MA = morphological awareness; LJT = stress sensitivity.
**p* < .05, ***p* < .01; ****p* < .001; † = .06, †† = .051.